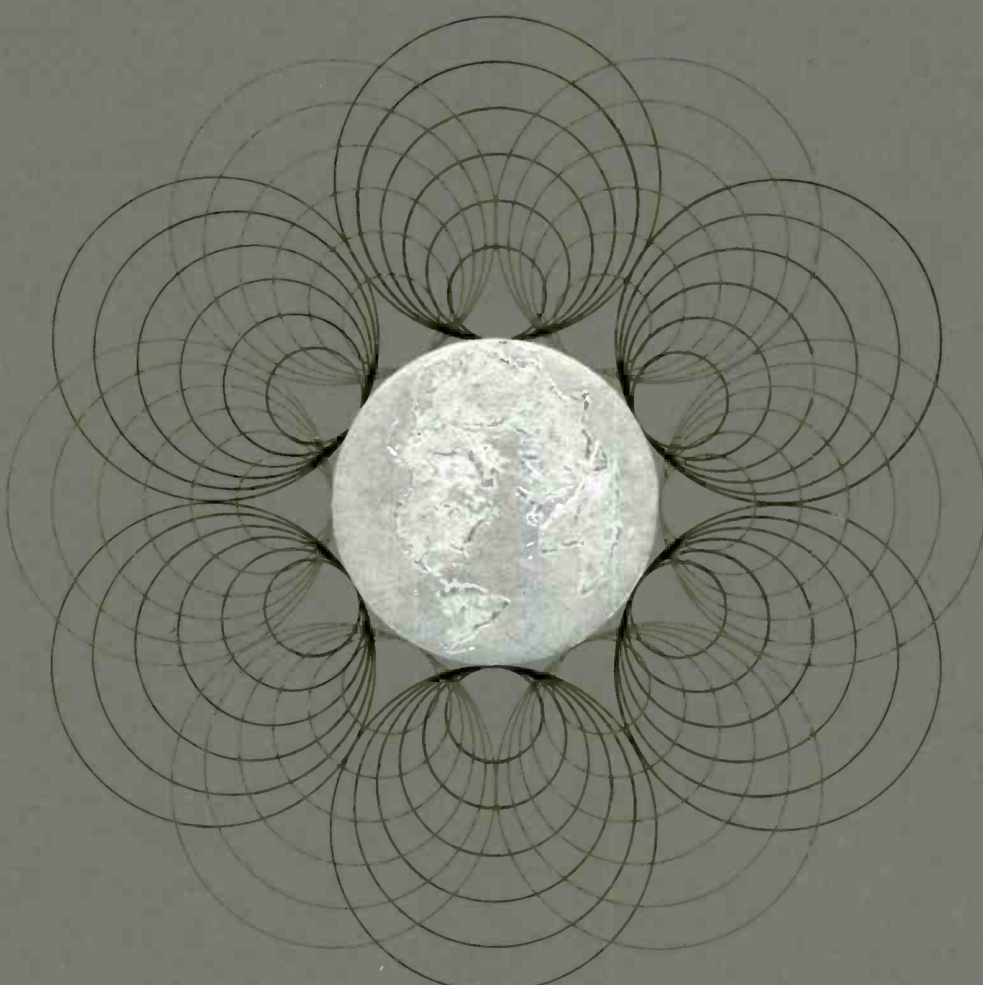
RCA Engineer

Vol 23 | No 4
Dec 1977
Jan 1978

Circular polarization



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

Professional satisfaction

Although my viewpoint may be biased by my own experience as a design engineer, I believe that every engineer, in every field, has chosen and practices daily a highly creative profession.

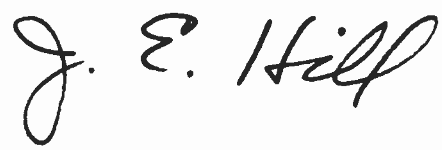
As individuals, our approaches to daily work are influenced by many complex factors, but one of the most important job-related motivations for engineers is the satisfaction they derive from seeing the results of what they have done put to useful and successful purpose. I believe that the responsibility for achieving this creative satisfaction lies in at least three areas:

Engineers must first know and then continually develop their own unique talents, and understand and grow in their own disciplines. They must involve themselves in developing something new, something better, something useful.

Engineering managers, for their part, must understand the capabilities of their engineers, and give them the tools, experience, and resources necessary to truly succeed and to make genuine contributions. Engineers' creative instincts must be nourished through challenging assignments.

Those of us in business and product management must select, for the engineering team, those viable projects that will result in successful, salable products. In this way, the engineers will be able to see, in actual constructive use, the end result of their labor and creativity.

When all three groups fulfill their responsibilities in these areas, we all benefit. Engineers enjoy the rewards of creative satisfaction; management can measure the positive tangible results of their own skills; and the company succeeds in the marketplace.



J. E. Hill
Division Vice President
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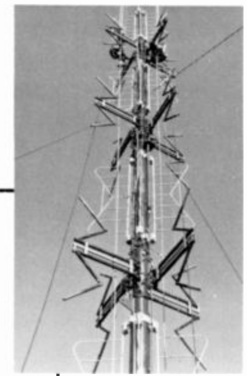
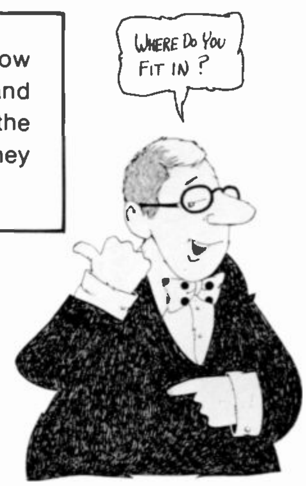
advanced communications for the 1980s





coming up

Our next issue (Feb/Mar) looks at radar. See what the new developments are for radar in military systems, weather radar, and even radar for blast furnaces.

Later issues will have software, space technology, and manufacturing themes.

RCA Engineer

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Life in the communication factory

It's been a long summer. Thirty-five years ago, on June 18, 1943, when I was still in the school-teaching business, RCA gave me a July-August summer job at the Industry Service Laboratory in New York. Now that long summer is about to end, ironically in cold January rather than in August. Makes me want to sneak off to Florida for a couple of months.

Anyway, my thirty-five year stint with RCA in the technical communication field has given me many a window to look in through and out of—and the scenes in either direction have been interesting, stimulating, and, on occasion, fascinating. Admittedly, most of the windows through which I have viewed the emanations of the paper age have been in the electronics research sector, but in traveling around a bit I've also peered into quite a few product-division windows here and there. Now, as I come to the end of the line, let me share with you some of the sights and insights stemming from my journey.

Have you ever seen a young father gazing in rapture at his first offspring through the window of the newborn-baby nursery? His look of pride and joy is akin to the expression I've often observed on a young engineer's face as he views his first technical article in print. It is a sight to behold, and it runs counter to the moth-eaten notion that scientists and engineers dislike to write or speak. It has been my experience that given the proper vehicle or forum from which to address their peers in the technical world, engineers are usually cooperative and willing to participate. Naturally, oral or written expression comes easier to some than to others, but with a bit of coaxing, encouragement, and incentive, even the shy engineer will try his hand at preparing an article for a journal or a conference (particularly if the conference is in Miami, San Francisco, or Europe). Once he's fallen in love with that first baby, he's ready to repeat the performance, and a seasoned writer is often in the making. One of my great joys has been to witness this metamorphosis from neophyte to pro by many members of our staff, often getting their start in the pages of the *RCA Engineer*. This same experience must also have been shared by my colleague TPAs and Editorial Representatives throughout RCA.

In similar vein, I have also seen the more prolific writer-engineers climb the ladder of success to sometimes spectacular heights. How about these RCA engineers as examples: Zworykin, Engstrom, Brown, Donahue, Hillier, Herold, Williams, Webster, Schade, Goldsmith, Luther, Rose, Rajchman, Sonnenfeldt, Olson, Vollmer, Vonderschmitt, Heilmeier, Powers, and Tietjen! These men not only had something to say, but more important, they said it. And from their saying it, they, and the world, benefited beyond measure.

In the earlier years of my time with RCA, the exciting subjects were transistors, television from black-and-white to full color, 33- and 45-rpm phonograph records, electronic computers, and radar. Now that those areas have become an accepted part of the social scene, new and even more exciting items are emerging—lasers, microprocessors, integrated circuits, fiber optics, CCDs, satellite communications, home video-tape recording, automotive electronics, medical electronics—and still more. What splendid opportunities lie ahead for aspiring engineer authors!

Luckily, this business of technical communications is a two-way deal, looking in and looking out. On looking in, we observe the pulse of our own operations; on looking out, we see what others are doing. There we become part of the IEEE, the AIP, the ACS, the ECS, and the several other science-oriented organizations that look to us for support even as we share in their offerings. By such association, whether through their literature or via the personal relationships that stem from membership and participation, the mutual rewards are great. From my window I've seen much proof of this.

My personal reward over the past third of a century has been the pleasure of my association with so many of RCA's dedicated scientists and engineers, and as TPA, of having had some small part in helping to get their fruits of tongue and pen distributed to a waiting society. Corollary to this activity has been a most rewarding association with the professional communications people of RCA who, for the past 20-odd years, have met regularly six or more times each year to review and plan, and often to meditate on, the outpourings that will bring yet new scientific information to man, and possible fame to the authors.

Yes, indeed, it's been a long, great summer!

—Chet Sall

Ed note: Chet Sall is retiring after thirty-five years with RCA. Most of that time he's been helping engineers get their names in print. He's done it well, but he's had to wear several hats to do it—planner, psychologist, editor, ghost-writer, mediator, wet nurse, administrator, whipping boy, and confidant. This experience has given Chet some unique insights on professional technical communication that we've asked him to share in this guest editorial.

Broadcast communications— review and survey

A.C. Luther

Broadcasting is a mature industry, but technological advances and new operational needs keep it changing.

Television and radio broadcasting is so much a part of the present-day scene in the United States that one could easily overlook that it is still developing and growing. Yet, in the last five years, major changes in techniques and services provided have occurred, and still more changes are visible in the near future. Several of the articles that follow in this issue of the *RCA Engineer* go into detail about specific present and near-future technological advances. This paper gives an overview of broadcasting and its equipment needs to help put those technological subjects into perspective.

Arch Luther has been Chief Engineer of Broadcast Systems since 1973. In his 27 years with RCA, he has worked on color-tv studio equipment, many video tape recorders (including the Emmy-winning TCR-100 video cartridge recorder), and other studio and transmitting equipment for radio and television.

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Broadcasting worldwide

By visiting various places around the world today, one can see radio and television broadcasting systems at various stages of evolution. In the United States, Western Europe, and Japan, for example, complete broadcasting systems are fully in place and developed to an advanced level of technological sophistication. However, these countries have different system standards (NTSC-PAL-SECAM-AM-FM, etc.) that affect equipment considerations. Also, broadcasting facilities have wide differences in the ways they serve the public—education, entertainment, promotion, sports, politics, advertising, news, and so on. These various uses, which are differently distributed around the world, place a differing emphasis on certain equipment characteristics.

Lesser-developed areas of the world are still building their initial broadcasting systems. These countries may not need the same technological sophistication of service that industrialized nations require; instead, advanced technology should be applied to make it easy for them to acquire, install, and operate their broadcasting systems. Since a major problem in less-developed areas is the availability of trained technical workers, these countries should have great interest in automated equipment that can simplify skilled manpower requirements.

Broadcast equipment

The broadcasting-equipment industry today is quite mature.

Numerous suppliers around the world compete in most of the world markets. Systems standards are published on a worldwide basis by the CCIR (Consultative Committee on International Radio).* Most equipment designs are second- or third-generation solid state, and most basic market needs can be fulfilled at a price. Present equipment-design effort is strongly directed to improving the cost of ownership of future broadcast installations and to advanced features for certain special applications. New broadcast products feature all of the state-of-the-art technologies—microprocessors, LSI, CCDs, etc.

Broadcasting equipment must be designed to deliver high-quality service over an operating life of at least ten years.

In many cases, broadcast installations run 24 hours a day, seven days a week, so reliability and maintainability are paramount considerations. The basic structure of broadcasting (one transmitter and many receivers) means that receivers should cost as little as possible. Therefore, the transmission performance should substantially *exceed* overall system performance needs so that the performance requirements on the receivers can be minimized. All of this means that broadcasting equipment becomes expensive

*The CCIR gives technical advice on radio matters to the International Telecommunications Union, which acts, in a sense, like an international FCC.

Reprint RE-23-4-15| Final manuscript received December 2, 1977.

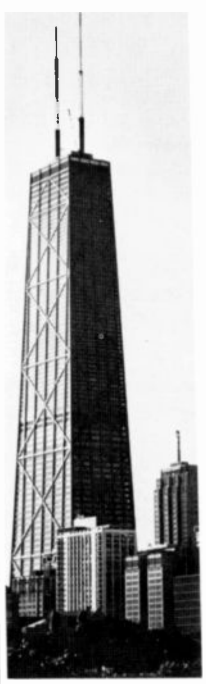
when compared to similar functions in mass-produced receivers; costs one or two orders of magnitude higher than mass-produced items are not unusual. One of the broadcast engineer's greatest challenges is to keep equipment cost under control.

Broadcasting operations

The functions of a broadcaster can be divided into two parts—origination and continuity.

Using cameras, recorders, and switching or mixing equipment, programs are put together from live input material. In most cases today, this process is done ahead of time and the total program is *recorded* on tape or film. The process of preparing recorded program material is called *production* or *teleproduction* (for television). Most broadcasters do some of this, but many organizations do *only* teleproduction—they are not broadcasters. Teleproduction operations may be in business to produce total program packages, or they may just offer technical services to others who provide the program content material.

Every broadcaster performs the second function of broadcasting. Called a *continuity* operation, it is the process of assembling program material from various sources into a continuous stream that feeds a transmitter. Fig. 1 shows how these two functions combine in a typical United States television broadcasting environment, including our network system. Notice that news is shown as a completely separate operation at both the network and local levels. News is a specialized teleproduction and continuity operation that should be explained further.



Recent developments at RCA

The need for immediacy in news programming is overwhelming.

Broadcasters compete actively to be first with a news break, and so want to minimize the time delay from shooting pictures at a news scene until finished material is available for airing. Much news programming is done with 16mm movie film, and most broadcast stations have sophisticated film operations for this purpose. Recently, however, there has been a trend to doing news "electronically," using television cameras and video tape recorders. Called "electronic news gathering" or "electronic journalism," it is growing because it provides greater immediacy, better quality on-air, and lower cost of operation than film systems. Electronic journalism is leading to a special category of equipment optimized for portability, flexibility, ease of operation, and reasonable performance. RCA's electronic journalism camera, the TK-76, has been very successful, with over 700 units sold by the end of 1977. Sid Bendell's article in this issue describes the camera and its crash design program.

Video recording is the essential technology in the process of teleproduction today.

Live program material from either studio or location shooting is recorded on video tape. Then the material goes through the "post-production" processes, where it is corrected, adjusted, mixed, and assembled into the finished program sequence. In these processes, where artistic factors dominate, it is essential to have the greatest possible flexibility for manipulating the recorded materials. This has led to extremely sophisticated systems for controlling the video recorders and special peripheral equipment for editing the recorded material. RCA's microprocessor-based AE-600 time-code editing system is the subject of a paper in this issue by Jukka Hamalainen.

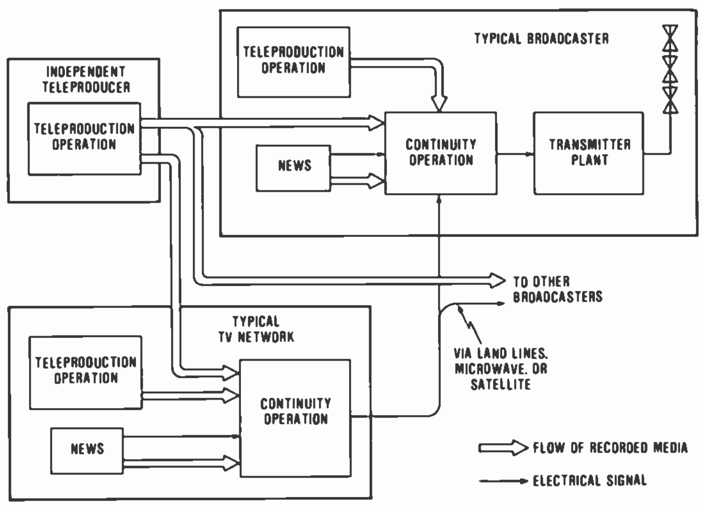


Fig. 1
Broadcasting structure for U.S. television. Note division into teleproduction and continuity operations at both the station and network levels. News requires special treatment.

Digital techniques are becoming more important.

Although the signals for radio or television broadcasting are basically analog, the use of digital technology has increased significantly for certain signal-handling or signal-processing functions. This is occurring because the low-cost digital circuit techniques that have been developed for computers can provide some features that are extremely difficult for analog techniques to achieve. Probably the most significant one of these features is the memory function. With digital LSI memory devices, even a complete television frame of information can be stored at reasonable cost. This makes possible numerous signal-processing functions for synchronization, noise reduction, or picture enhancement. Bob Hurst will describe how far digital television has progressed in an article to be published in the *RCA Engineer* in the near future.

All-solid-state transmitters are replacing tube types.

Broadcast equipment today is all solid-state except for pickup devices, display tubes, and the higher-power stages of transmitters. However, solid-state devices are becoming more capable and even the high-power circuits are going to solid state. RCA's new all solid-state 5-kW and 10-kW a.m. radio transmitters, described by Len Oursler and Dave Sauer in this issue, are a good example. Here the solid-state approach is providing higher power efficiency, better on-air reliability, and better performance than previous tube-type transmitters.

Another new development that has received a go-ahead in the United States is circularly polarized broadcasting for television.

Circular polarization promises improved reception and reduced "ghosting" in areas with difficult multi-path problems and where portable antennas such as "rabbit ears" are used. The FCC authorized circular polarization for tv broadcasting in the late spring of 1977, and four stations had ordered the new type of antenna by the fall. Circular polarization is the subject of Matti Siukola's article in this issue.

Conclusion

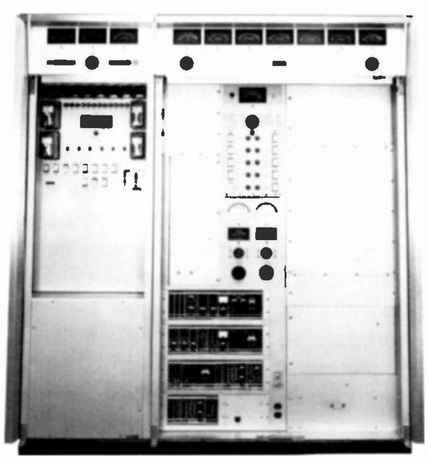
Broadcasting today is very much a worldwide industry. It is growing dynamically, with new features and services being developed and offered. Likewise, broadcast equipment has embraced the latest technological developments to provide more and more capability at lower cost to the broadcaster. With this kind of environment, we can expect the broadcast industry to continue its growth and success pattern for the foreseeable future.

What equipment does RCA make for the broadcasting industry?

Just about everything, to put it briefly. This abbreviated list and the photos on these two pages show the breadth and completeness of RCA's broadcast line.

Video tape recorders
TV cameras
Telecine cameras, projectors and multiplexers
TV slide projectors
Terminal and switching equipment
Radio and tv antennas
Radio and tv transmitters
Transmission lines and related equipment
Outside broadcast vans
Sound-on-film recording equipment
Broadcast audio equipment

1 TK-760 studio camera. **2** TP-55 telecine multiplexer. **3** Antenna installation at Chicago's John Hancock building. **4** TT-25FL transmitter. **5** TR-600 video tape recorder with AE-600 time-code editing system and monitor bridge. **6** Mobile broadcast van. **7** TCR-100 video casette recorder. **8** Traveling-wave antenna for high-band uhf stations.



Electronic journalism with the TK-76 camera

The TK-76 camera started a revolution in tv newsgathering.

S.L. Bendell

"Electronic journalism" has become, during the past few years, the most powerful way to cover news and live general-interest events for television. In large part, this revolutionary newsgathering technique has been closely keyed to technological advances in the field of television pickup and recording equipment.

Forces behind "the revolution"

Up to perhaps five years ago, news pickups were done almost entirely on 16mm motion-picture film.

The film, following coverage of the event, would have to be developed, edited, and then converted to the required electronic format by a special "telecine" tv camera.

The number of steps in this total analog process and the opportunity for cumulative picture degradations to occur was great indeed. Only a small part of the original film (estimates are from 5% to 10%) was ever useful for final airing, for reasons of technical quality as well as content. Although stations would have liked routine direct pickup of unprogrammed news events on live color-tv cameras, it was only a theoretical possibility prior to 1975 because of the large size, complication, and logistics of tv-camera equipment. Fast-breaking news required the mobility of small man-carried 16mm movie cameras, but the development and editing time lag of the film process prevented news teams from filming events occurring later than about two hours before air time.

What broadcasters wanted

Steadily, as the importance of tv news coverage grew, a real need also grew for a better system which would have the following features:

1) The immediacy of live tv pickup with the opportunity of real-time news coverage.

2) Lightweight, easy-to-operate equipment to achieve mobility with minimum on-site crew size.

3) A correspondingly small recording/storage system with the flexibility of immediate playback and reusable storage medium.

In short, the broadcasting industry needed small color-tv cameras and video tape recorders capable of being mancarried.

Fortunately, fast-paced developments in both tv camera sensors (a dominant component determining camera size) and small helical-scan video tape recorders were being refined rapidly. Specifically, the sensor activity was being directed toward both solid-state charge-coupled devices (CCD) and 2/3" photoconductor tubes. These two approaches were highly competitive by mid-1975, and RCA carried out considerable testing and system evaluation to determine the best sensor to use in a small color camera weighing less than 20 pounds.

As it turned out, solid-state sensors were then not yet sufficiently developed to meet tv broadcast performance requirements. For example, an experimental 3-sensor CCD camera developed by RCA was demonstrated at the NAB Convention in April 1975 in Las Vegas. While this experimental camera generated considerable interest among the broadcasters, it had some limitations that made it, at that time, noncompetitive with the photoconductor-tube types. Its major limitation was sensitivity; when it was compared with a small tube-type camera, it fell short by a factor of about 50X. The CCD camera's cosmetic defects and limited resolution also favored the tube approach.

Considerations and tradeoffs

RCA demonstrated an advanced development model of an electronic journalism camera (Fig. 1) at the 1975 NAB Convention in April and at the Montreux TV Symposium in June. This camera was a first pass at designing a system that would best fit the needs of electronic newsgathering. Many factors were considered in making this preliminary design, which formed the basis for the eventual product version, named the TK-76. A partial listing of some of these considerations follows:

Sensitivity. The tv camera would have to compete with 16mm news cameras, which usually use high-speed film having an ASA rating of 125. Such cameras were capable of taking pictures at light levels down to 40 foot-candles with lenses having maximum apertures of *f*:2.0. Under pushed film development, the 16mm cameras could operate down to 12 to 15 foot-candles, but with noticeable picture degradation. Films introduced more recently are rated at ASA 400 and can be pushed to over ASA 1000. (At ASA 1000, a film camera can operate at about 5 foot-candles.)

Fig. 1
Advanced development model of the TK-76 showed it could be done, but still needed refinements (see Fig. 2 for comparison with finished product).

Light weight. By observing closely the form that most of the successful 16mm cameras had taken relative to weight, size, shape, and man-machine interface, the physical characteristics of the TK-76 became conceptualized. Many mockups were assembled for critiques by broadcasters, 16mm news camermen, and many others, including our very enthusiastic top management who took an intense interest in the TK-76 program. A weight of 15 to 20 pounds seemed most desirable. Lighter weight would adversely affect camera holding stability; more weight would be too burdensome for the cameraman. The camera should be a single package with a separate lightweight battery belt.

Low power. Most broadcasters indicated the need for a minimum battery-operating time of 90 minutes. By limiting the battery-belt weight to 4 to 5 pounds and using NiCad batteries (the most practical type), camera power requirements should be something less than 35 watts. The power source should be a single-voltage 12-V supply, the most universally available source.

Stable, reliable, and rugged. These three requirements are all important, but the last one has become far more important than we ever could have imagined; several TK-76s delivered since the first product shipment in April 1976 have suffered such fates as being dropped out of helicopters and flung from speeding motorcycles. Operation over a large range of environmental conditions should be expected in newsgathering.

Simple no-hands operation. Traditionally, tv color cameras have contained a very large number of controls requiring skilled attention over a wide range of intervals. However, operating personnel for the tv news camera would quite often be film cameramen or other non-electronic types having little or no experience in tv-camera setup. Therefore, a primary concern for the news camera was that it would require *no* technical attention for extended periods up to several months; the rationale for much of the mechanical and electronic design followed from this very rigorous requirement. Downtime for broadcast equipment means lost dollars for the broadcaster. Therefore, equipment packaging would need to favor quick checkout and repair when necessary.

Performance. At the very beginning of the electronic-journalism development, equipment makers and users generally assumed and accepted that small cameras would necessarily produce a compromised level of performance relative to a top-line studio camera. This view was very short-lived, however, and soon gave way to the more realistic conclusion that picture quality from tv news cameras would have to be practically indistinguishable from their big brothers in the studios. Manufacturers who initially offered limited-performance cameras for electronic journalism eventually fell by the wayside. Performance parameters of major importance are colorimetry, resolution, signal-to-noise ratio, and registration.

International markets. A growing segment of the tv broadcast business is in countries that have different television standards than the American NTSC standard. Packaging and partitioning of the new camera's electronic circuitry should facilitate cost-effective conversion.

Fig. 2
Production version of TK-76 was coming off the assembly line only twelve months after the advanced development model was shown.

Fig. 3
TK-76 system consists of the camera and video tape recorder, which are tied together with an "umbilical" cord. Battery belt weighs only five pounds.

Acceptable initial equipment cost/operating cost. The 16mm film cameras most commonly used for tv news are relatively inexpensive ($5,000 to $15,000) compared with high-quality color-tv cameras. This difference is partially offset by the added cost of film development and the recurrent high cost of the film itself. To the user, the cost equation is obviously very complicated. However, for tv news cameras to be a viable business for RCA, it became painfully apparent that keeping the product cost to an acceptable low value would be an extremely challenging assignment for all elements of the program, including marketing, manufacturing, and design.

The camera sensor choice

The advanced development version of the TK-76 alluded to earlier answered some of the questions posed by the above list of requirements and paved the way for the product version of the TK-76 (Figs. 2 and 3). Our evaluation of many types of camera sensors showed that the 2/3" lead-oxide tube (the Plumbicon, manufactured by Matsushita and Philips) was best suited for this application. The sensor parameters influencing this decision were:

Sensitivity. Using the 2/3" PbO, the camera can operate at excellent *S/N* (51 dB) at an incident light level of 125 foot-candles (3200°K) with an aperture of *f*:2.8. A camera equipped with such tubes and zoom lenses (available with apertures to *f*:1.6) can operate at light levels down to 40 foot-candles. The *S/N* margin is so great that a high-sensitivity mode (increased video gain) is possible, which further increases camera sensitivity by a factor of 3X and still maintains a very acceptable *S/N*.

Resolution. At 400 tv lines, the 2/3" PbO has an aperture response of approximately 20% to 25%. This is about half that obtained with the larger 30mm lead-oxide tubes used in the top-grade studio cameras. However, the low external circuit capacity associated with the smaller tube (2 to 3 pF) permits such a high *S/N* at these frequencies (5 MHz) that the loss in response at the high line numbers can be corrected by linear phase aperture compensation with minimal *S/N* degradation. The 2/3" Saticon tubes, which have recently been introduced for use in the TK-76 as an alternative to 2/3" lead oxide, give a response at 400 tv lines of 40% to 45%, thus making it even easier to match the resolution performance of the large studio cameras. (The Saticon is manufactured by Hitachi and is currently being sold by RCA Electro-Optics and Devices in Lancaster).

Lag. The image smear that occurs with picking up moving objects is a type of fundamental picture impairment that has high visibility in the final display. Lag performance in the small-area 2/3" tube is significantly improved over that of the larger tubes because of the formulation of the photo layer, which provides lower storage capacitance in conjunction with the reduced scan area. Lag grows worse if the tube is forced to run at smaller signal currents (*i.e.*, higher sensitivity). However, using bias light can minimize lag. With the 5.0-nA bias light supplied in the prism optics of the TK-76, lag is held to quite acceptable values even when operating at high sensitivity.

Many other characteristics must be considered in making a choice of sensor, such as highlight handling, temperature stability, color response, transfer characteristic, geometry, and cosmetic defects.

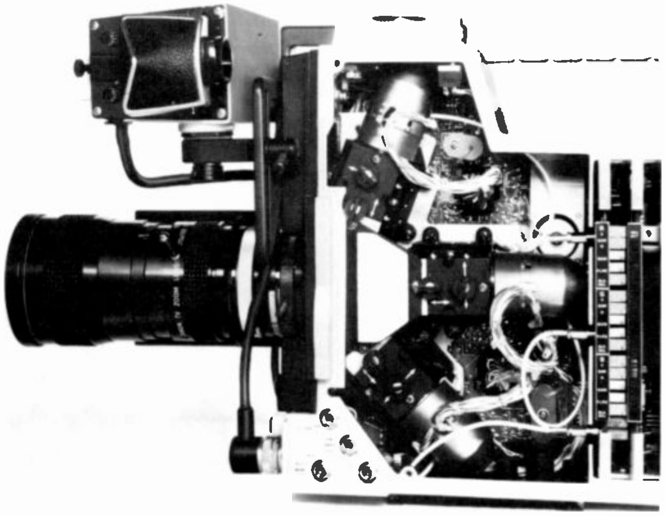


Fig. 4
Optical system—lens, prism, yokes, tubes, and preamps—is mounted as a single unit and isolated from the rest of camera by three-point shock-mount system. Method keeps system in precise registration during rugged use.

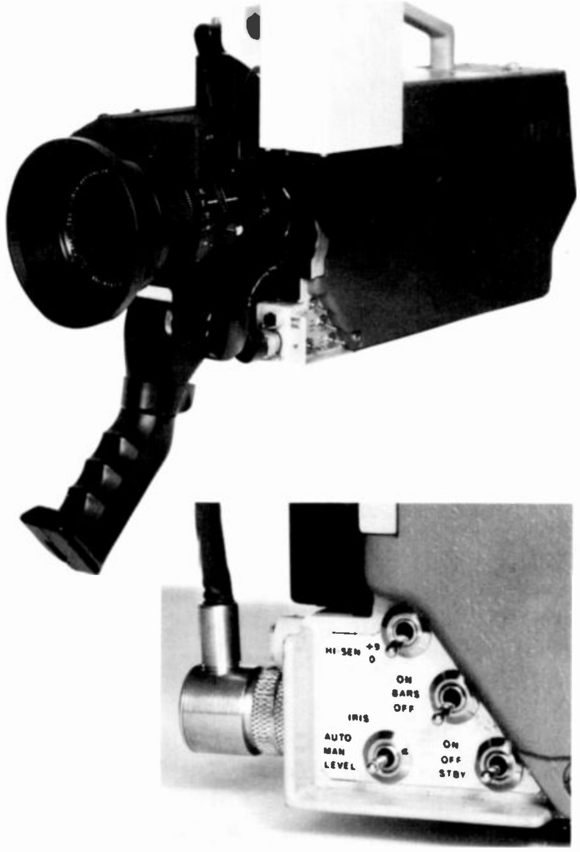


Fig. 5
Human factors were important in TK-76 design. Photos show how camera is designed for easy balancing on cameraman's shoulder. On/off/standby switch and other operator controls (kept to a bare minimum) are all located conveniently in one spot.

Optics and registration

Prism optics are now the most widely accepted color-separation method.

Prism optics provide, at highest efficiency, the proper bandwidth color to each of the three (red, green, blue) pickup tubes. Very-high-index glass ($n = 1.76$), first used in the TK-76, makes possible a very small prism having a high numerical aperture and a relatively short total light path. This short light path is important because it lets the camera use small lightweight zoom lenses having high optical speed. A unique optical/mechanical system, used in the first developmental model and carried over to the product design, has simplified the manufacturing of the camera and provided stability in operation.

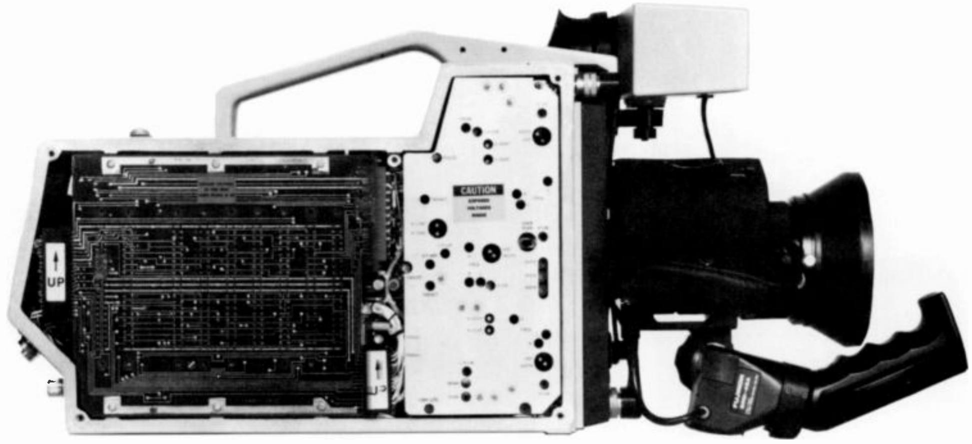
The optical system must remain stable within one micron of translation.

In this system, the three tube/yoke assemblies are hard mounted to an optical bed plate that also rigidly supports the main picture-taking lens and the beam-splitting prism. The entire system (Fig. 4) is mechanically isolated from the main camera frame via a three-point shock-mount arrangement. This scheme protects the delicate and precise alignment of the various optical/mechanical elements necessary for preserving registration. To maintain 0.02% registration, the translational positional stability of the listed components must be kept on the order of one micron. (Registration error between any two color-channel signals is expressed as a percentage of picture height; 0.02% is measurable and 0.1% is quite useable.) The front surface of the optical plate is brought out to the front of the camera and terminates in radiator fins, so the assembly effectively sinks heat generated by the yoke assemblies and preamplifiers.

Human-factors considerations

Camera technology means nothing if the operator has trouble using the camera.

As noted, equipment packaging and human engineering played a vital part in shaping the mechanics of the camera. The eventual product version weighed 20 pounds, not including battery pack. (See Fig. 5.) The camera profile is low; and the electronic viewfinder (a 1¼" kinescope viewed via a low-power magnifier and mirror system) position is adjustable. These two features allow the cameraman to seat the camera directly on his shoulder in a balanced stance, which provides excellent camera stability, causes minimum fatigue, and permits comfortable viewing of the finder. The system's center of gravity is approximately 5" above the cameraman's shoulder, with the camera lens axis at approximately eye level. In normal picture-taking, the cameraman has an almost completely unobstructed view of the region to his left and right front sectors. Such an unobstructed view is very important to the safety of the cameraman, who very often faces hazardous walking conditions and even finds himself at times in hostile crowds. Normal operating controls are easily positioned so they can be operated by "feel" with minimum chance of error.



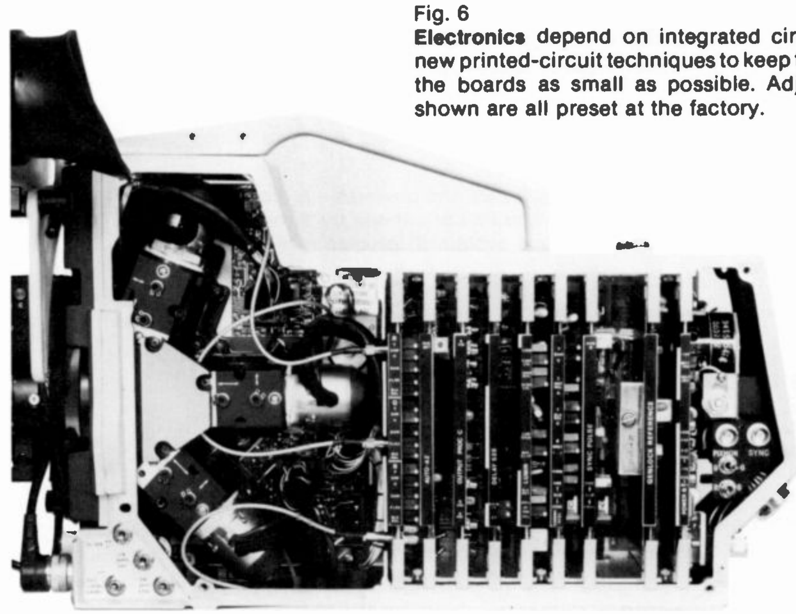


Fig. 6
Electronics depend on integrated circuits and new printed-circuit techniques to keep the size of the boards as small as possible. Adjustments shown are all preset at the factory.

Electronics

New integrated circuits, printed-circuit techniques, and circuit designs substantially reduced the physical size of the circuit boards.

Fig. 6 shows the camera's circuitry and Fig. 7 is a simplified block diagram. Here are some brief highlights:

A miniaturized video preamplifier housed within the yoke/tube assembly provides a 51-dB signal-to-noise ratio at normal operating current levels. This is within 1.0 dB of the theoretical limit.

An integrated-circuit sync generator has a genlock capability so that two or more cameras can be readily locked together for multi-camera operation.

The novel pulse-type power supply has a constant conversion efficiency greater than 75%, even as the battery supply ranges from 10.5 to 15.0 volts. Pulsewidth control during the horizontal blanking period enables the necessary regulation mechanism to operate in a timely fashion that avoids power-switching transients during active picture time.

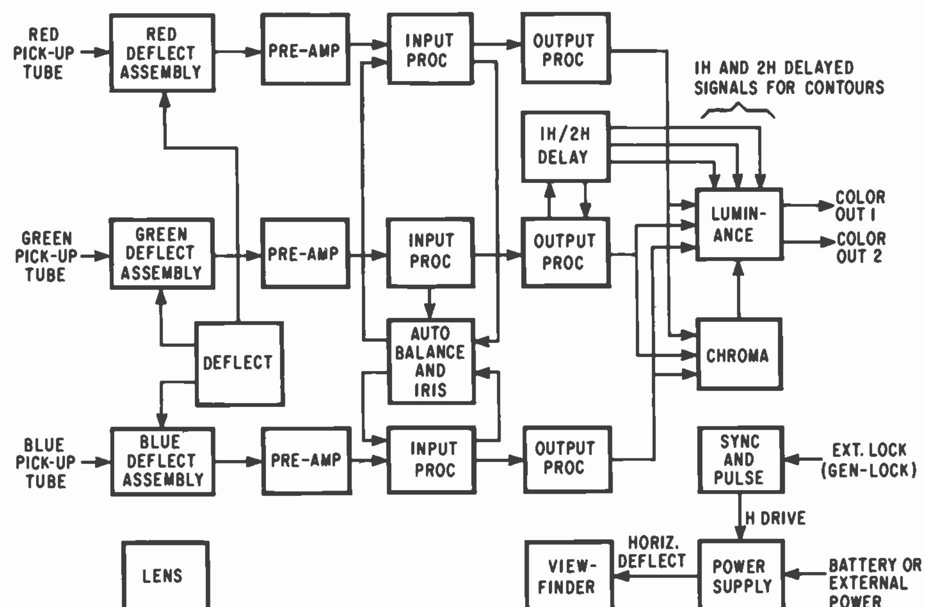


Fig. 7
Electronic system depends on pulsed power supply to keep high efficiency over a wide range of battery voltages.

Automated control system

To simplify camera operation, it is necessary to automate as much control as possible without unduly constraining the cameraman's esthetic expression.

For example, white balance is automated on an "on demand" basis; the cameraman points the camera at any "white" object (as small as 5% of picture width and one line high) and actuates the white-balance button. A cursor line then shows up in the viewfinder display to guide him in accurately placing the white object within the cursor-indicated sampling interval. Within a few milliseconds, the white-balance circuits electronically control (and store) the video gain of the red and blue channels and equalize them to the green signal level.

The automatic-iris mode is another control at the cameraman's option. It controls exposures by sensing peak video level and giving special weighting to the central picture area. For special lighting conditions, such as heavy backlighting, two other non-automatic exposure controls are available. These operate by providing point-enhanced visual indication of exposure in the viewfinder display.

A "zero-based" control philosophy made operation by technically unskilled people possible.

Traditionally, color cameras have required a very large number of operating and setup controls. This could not be tolerated in a small hand-carried camera operated under rugged field conditions by technically unskilled persons. A "zero-based" control philosophy was adopted early in the program—the system started with zero controls and needed ones were provided only when they could be justified on a rational basis.

Concept to production in thirty months

Choosing the sensor came first.

The quest for a suitable sensor started in early 1973, during which time a number of different types, including silicon vidicons and CCDs, were tested. Developmental samples of the first 2/3" Plumbicons were supplied to RCA by Philips during the 4th quarter of 1973. Analysis of these tubes and preliminary evaluation of their performance in a color system was carried out during the first quarter of 1974. For this purpose, a breadboard test camera was jerry-rigged, using an ancient developmental large-studio camera. By the spring of 1974 results using the Plumbicons looked encouraging enough to warrant going ahead on the design of a developmental electronic journalism camera.

At this point, Mr. Joe Bulinkis, the RCA industrial designer, was called in, and a lively period of human engineering activity followed. Some five camera versions employing various packaging concepts were built in mock-up form and critiqued by marketing, management, and some select broadcasters. By late spring 1974, the decision to go with a single-package concept was made, and from then to February 1975 the Advanced Development Camera Group engaged in a frantic effort to design, fabricate, and test a developmental 20-pound electronic journalism camera.

Everything going into the design literally had to start from scratch, including optics, yokes, circuits, power supply, and battery pack.

A successful landmark demonstration was given to RCA top management in February 1975. The first advanced-development model worked well, but would have won no prizes for styling. This, coupled with management's decision to show the unit in April at the 1975 NAB Convention in Las Vegas, created a minor styling crisis. Again Mr. Bulinkis came to the rescue and, with some artful cosmetic work, gave the camera a look of respectability for its debut in Las Vegas.

As this effort continued, the Camera Product Design group began work on the TK-76 in the second quarter of 1975. Their schedule for the production version of the TK-76 seemed well beyond reach at that time. The dedication and skill that the members of this group displayed in carrying out this seemingly impossible assignment won the entire team a David Sarnoff Achievement Award. Enthusiasm on the TK-76 program was contagious; all elements of the production team were caught up in the excitement of this new and promising product. In April 1976, the first production camera came off the line, passed all tests, and was shipped to the first customer. The TK-76 program seems destined, for some years to come, to be used as a standard of comparison for judging other difficult program schedules and successes.

Subsystem inspection required special test equipment.

Many of the major components of the TK-76 were subsystems that were purchased outside the company under close purchasing specifications and then went through rigorous incoming inspection and testing. Yoke assemblies, optics, and tubes are examples of such items. In some cases, special test equipment had to be developed to verify subsystem performance and assure that the total system would meet its performance requirements.

For example, registration is a particularly difficult aspect of color-camera performance. It was anticipated at the start of the program that it would be an even more severe requirement for the TK-76 than for other cameras, because of the small scan size (0.26" X 0.35") of the 2/3" pickup tubes and their tiny associated deflection assemblies. RCA therefore had to develop a geometry-testing apparatus for measuring yoke and tube geometry errors to a precision that had never been attempted before. This equipment, including a computerized matching capability, became part of a rather elaborate component acceptance process; RCA manufactured and supplied similar units to specific vendors. Computerized/automated testing of module boards has been widely used throughout the program and is one reason we have met our production commitment of more than 50 cameras per month.

Start of a new generation

By the end of 1977, RCA had delivered approximately 700 TK-76 cameras.

Repeat orders by enthusiastic TK-76 customers, as well as new sales, attest that all or most of the original goals for this camera have been met. Field experience has been very gratifying, especially in the area of stability, operational simplicity, and reliability, which depended so crucially on many new design concepts. The cameras are shipped to the customers fully operational and are often taken directly from the packing crate and put into service. Many of the units delivered at the very start of the program have, to this date, never required servicing or re-adjustment.

Picture quality from the TK-76 is subjectively equivalent to that of the top-line studio cameras, especially when the newer Saticon tubes are used.

Broadcasters are finding that the camera performs quite well for many types of field production—that is, pickup of a scheduled event, like a baseball game, opera, or commercial, that may be presented in real time or rebroadcast later. This application is quite far afield from the original intent of a limited-use news camera. However, camera systems for production must include many specialized operational features not required for news work (e.g., chroma key special effects, color matching, large viewfinder, and large lenses).

To fill this need, RCA has designed the TK-760 camera; deliveries will start in early 1978. Essentially a TK-76 repackaged into a studio/production configuration, it has a remote operating panel, larger viewfinder, and the ability to operate on long cables. The TK-76 contained within the TK-760 can be readily reconfigured back to a normal TK-76 shoulder-carried version in a matter of a few minutes. It is becoming clearer that the small-format (2/3" pickup tube) camera is having a revolutionary impact on the way broadcasters are perceiving the trends in camera design. Many observers hold the view that introduction of the TK-76 marked a dramatic turning point in camera design.

Electronic journalism will continue to demand improved equipment, particularly video tape recorders.

Small (28 to 30 pounds) U-matic-type helical-scan recorders, most commonly used for news, pose a definite performance limitation. The majority of the tv news cameras presently available produce pictures that are significantly better than those the portable recorders can produce. The major degradations that occur are in resolution, signal-to-noise ratio, and time-base stability. Unfortunately, these impairments become compounded as a result of multi-generation recording, a necessary step in the editing process.

The typical small U-matic video tape recorder is designed to operate in a very restricted environmental window, which precludes operation, for example, on damp or very cold days. In addition to their limited performance and lack of extended environmental ruggedness, the present recorders are too heavy and must be carried by a second person. The umbilical relationship between the camera and recorder seriously limits the camerman's ability to react in fast-moving news situations. Wireless links between the camera and a distant receiving point, through the use of either a microwave or optical transmission system, have proven practical only for specialized and limited applications where the characteristics of the path are controllable. Ideally, the tape recorder and camera should be capable of being readily carried by one person, which means a maximum weight of 20 pounds. The technology for merging the tape recorder and camera into the present weight limit for the camera alone is not yet at hand. Accomplishing this, and at the same time satisfying all of the other performance needs, stands out as the challenge for the next generation of electronic-journalism cameras.

Acknowledgment

The TK-76 camera was, above all, a team effort. The team of Broadcast Systems engineers that worked on the project and won the David Sarnoff Award for Outstanding Technical Achievement included Lucas J. Bazin, John J. Clarke, Donald C. Herrmann, Cydney A. Johnson, Anthony H. Lind, Mark R. Nelson, Dennis M. Schneider, Alexis G. Shukalski, Harry G. Wright, and the author.

Reprint RE-23-4-7
Final manuscript received November 18, 1977.

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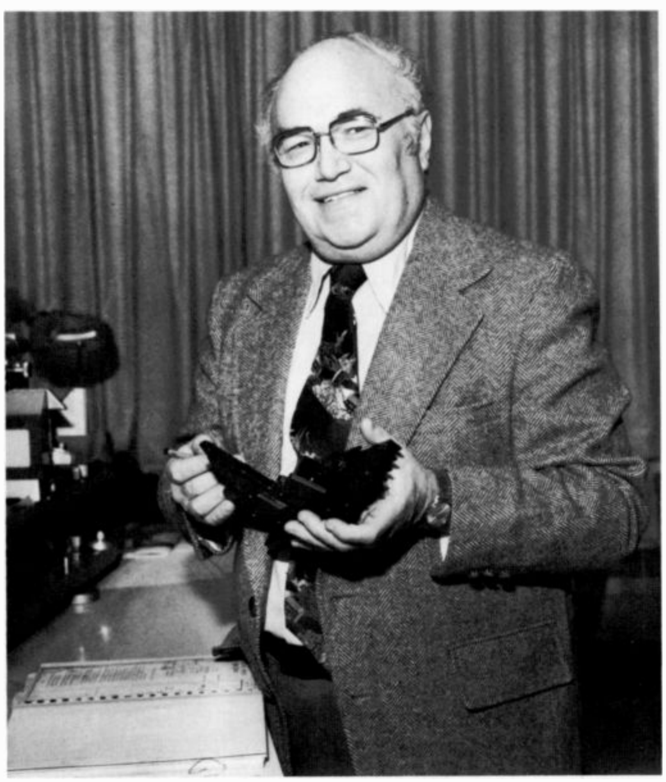

Video tape editing systems using microprocessors

Modern video tape editing systems demonstrate the degree of sophistication the broadcast industry has reached during the last five years.

K.J. Hamalainen

Early video tape editing was quite crude by today's standards—in the early sixties the tape was cut with a razor blade. But as the recorders improved, especially in the area of servo stability, electronic editing equipment was developed. Basically, these early electronic devices converted the physical distances between the erase and record heads (Fig. 1) to time differences and energized the correct functions at the right times and in the correct sequence. For example, for the recording to coincide with the erased portion of the tape, the video record head had to be turned on approximately 0.7 s after the master erase head was energized; only in this manner could a disturbance-free edit be made.

Reprint RE-23-4-5
Final manuscript received October 17, 1977.

The editing evolution

Timing and sequencing the recording functions were only the first steps in the evolution of electronic editing.

The next requirement was to identify the edit point and to preview it before executing the final edit. Initially, this was done by recording a bench mark (cue tone) on one of the two audio tracks on the video tape. By using this tone for initiating the edit, the edit could be simulated, previewed, and modified several times before the actual recording was made. The latest improvement and basis for the modern editing systems was the introduction of the time-code signal, a digital signal that is usually recorded on the cue (second audio) track of the video tape. This signal identifies every tv picture by hours, minutes, seconds, and picture-frame number (Fig. 2). By using the time-code signal as reference, the edit points for both audio and video can be selected while viewing the recorded material.

The first editing controllers were built with hardwired logic, but microprocessors soon became the key building block of modern video tape editing systems.

Since most of the functions required are, as already indicated, direct control functions or mathematical calculations, editing is ideally suited for computer-type control operations and decision making.

A good editing controller should be directly interfaced with the individual editing machine. It must "know" all the special features and characteristics of the machine

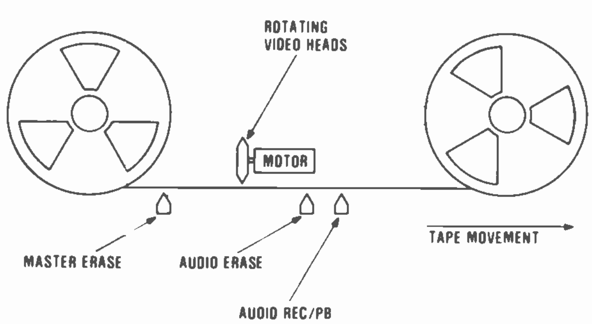

Fig. 1
Editing system must keep track of the video tape recorder's characteristics: the location of and separation between the audio and video heads; separation between the erase and record heads; and system acceleration and deceleration.

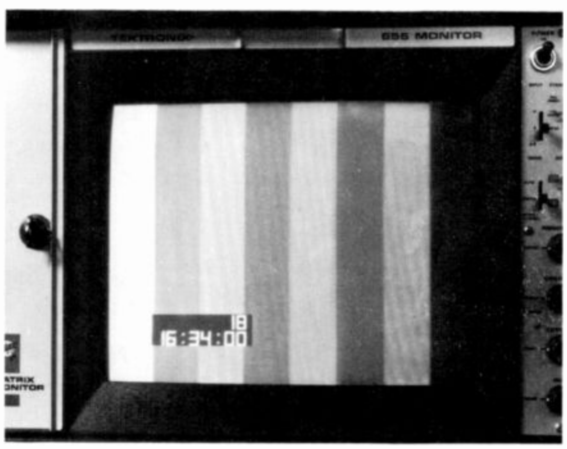

Fig. 2
Time-code signal improved editing systems significantly when it was added. It identifies each picture by hours, minutes, seconds, and frame number (1-30).

to be able to perform the control functions correctly. At the same time, the controller must provide the operator with a clear picture of the status of the editing process with easily understandable displays and have a simple and functional control panel.

RCA's two microprocessor-based editing systems

During the last three years, RCA has developed two different microprocessor-controlled editing systems to operate with our TR-600 video tape recorder: the AE-600, a sophisticated time-code editing system using the Intel 8080 microprocessor with 15-kilobyte memory; and the SE-1 "simple editing system" using the RCA CDP1802 microprocessor with 2-kilobyte memory.

Jukka Hamalainen is a Unit Manager with the Electronic Recording Engineering Dept. at Broadcast Systems. During the last two years, he has mostly been working with the design of microprocessor-controlled video tape recorder accessories. He has been associated with video tape recorders since 1961, when he was a member of the TR-22 development team. Between engineering assignments, he has held sales and management positions in Europe. For two years, he was manager of RCA's project management team for the state broadcast complex in Vienna, Austria.

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Editing video tape for broadcast—what's involved

Editing is the process of assembling a number of individually recorded segments together in the proper sequence and time relationship to produce a desired total program effect. Regardless of the recording medium used (photographic film or magnetic tape), editing requires two functions:

1) decision making (where to cut one recorded segment off and begin another, including the choice of the type of transition to use in the cut point); and

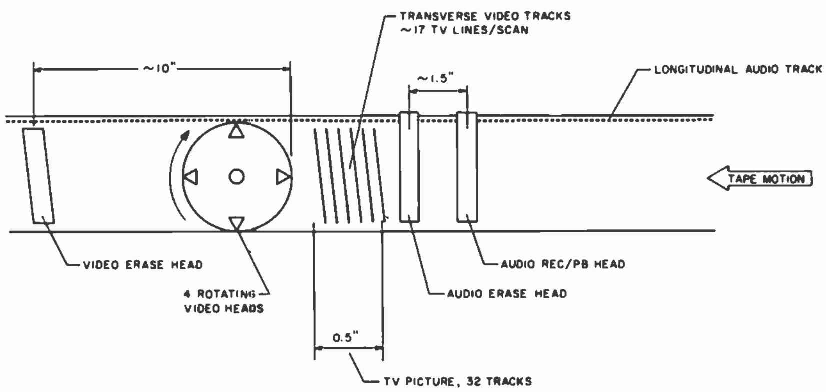
2) the final editing (actually assembling the master recorded material into a continuous program).

Decision making requires very versatile capabilities for viewing the recorded material (searching the edit points, simulating the final transitions, etc.) The final edits require sophisticated means of cutting and joining the actual recordings. With magnetic-tape systems, we refer to all this as "electronic editing," since the entire process is accomplished electronically.

An editing device must recognize the technical features of the video tape recorder it works with (in this case, the TR-600 quadruplex machine). The editing device must know the sequencing and timing of the VTR's record and erase functions for both the video and audio channels. (See figure below.) It must also synchronize both the record and playback machines so that a new section can be added (recorded) precisely at the correct predetermined location on the master tape. (See figure next page.)

All technical functions (searching, sequencing, simulating the editor, synchronizing the machines, and performing the final edits) must be done as fast as possible to reduce editing time, and personnel must be able to make their editing decisions as easily as possible. The total emphasis must be given to artistic creativity. The complex technical system behind a simple, easily understandable control panel should be inconspicuous and hidden.

The mechanics of videotape editing



The typical video tape recorder shown above has audio and video heads that operate independently. When a recording or "edit" is made, the following steps take place:

First, the machine goes into the playback mode.

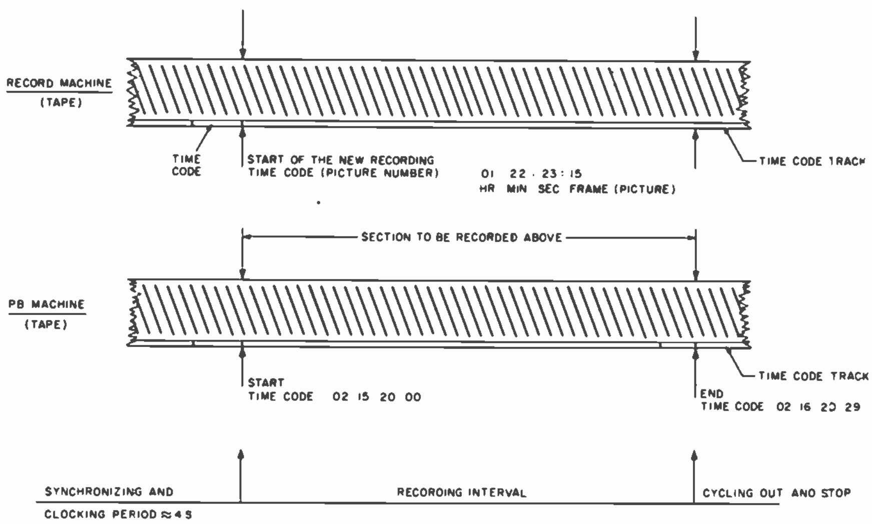
Then the master erase head turns on.

After the tape has traveled 10 inches (approximately 0.7 seconds later), the erased portion of the tape reaches the rotating video heads and these heads are switched from playback to record. The accuracy required for this switch is approximately 0.007 inch along the direction of tape travel, or approximately one microsecond in rotational timing.

The audio erase head turns on approximately 1.5 inch or 0.1 second before the video record head starts so the audio and video record heads are energized simultaneously.

All early editing devices could do these functions and simple calculations; the microprocessor-based AE-600 editing controller does them with software and memory rather than hardwired logic. The major advantage of the AE-600 is, however, its use as a controller—the operator uses it to select (mark) the portions of the tape that are going to be edited together. The AE-600 "marks" tape with the time code, an electronic signal that is recorded on the tape with the picture (on a special audio track). This signal gives every picture on the tape an identification number—hours, minutes, seconds, and frame number (30 pictures per second).

When the edit points (start and end) are being selected during the preview sessions, their identification numbers are stored in the AE-600's memory. These edit points can be reviewed and modified several times during the editing process. In the final edit session, one machine (the record machine) records the finished version from several playback machines.



In the typical edit shown above, the operator has already previewed the tape and has decided to take roughly one minute of material from the playback tape (bottom) and put it at a specific location on the record tape (top). To perform the editing the operator puts the following identification times into the AE-600 memory:

- the location where the new material is to be added to the record tape (01:22:23:15);
- the beginning of the new material (02:15:20:00); and
- the end of the new material (02:16:20:29).

The AE-600 controls both the record and playback machines. Upon an "edit" command, it has them go through the procedure below.

- First, it cues both machines to a starting point approximately 5 seconds before the start of the edit.
- The AE-600 then starts both machines and synchronizes them so that when the record machine reaches picture 01:22:23:15, the playback machine is playing back picture 02:15:20:00. At this moment the record machine starts recording. (Actually, the AE-600 had given the record signal 0.7 second earlier so that the video heads would start recording the new material on an erased portion of tape.)
- Recording stops when the end code (02:16:20:29) is reached.

The systems were designed with flexibility, time-saving, and simplified computer control in mind.

The primary objective in designing these editing systems was to give the operator flexibility for expanding artistic creativity. A second important objective was to enhance productivity by minimizing the technical noncreative delays associated with editing systems. The final objective for the AE-600 was to develop a system so that both the basic video recorder and the editing sysem could be directly controlled by a central computer without complicated machine-oriented interface devices.

The AE-600— for sophisticated editing

The AE-600 editing controller, which is discussed here in more detail, is a good example of how these guidelines were applied.

Typical functions of a video tape editing device such as the AE-600 are:

- store edit-in and edit-out points, using the time code.
- Provide simple ways to modify these points (keyboard);
- search and cue the tape to a selected and stored point;
- preview or rehearse an edit;
- perform the final edit;
- animate (automatically record one picture at a time); and
- synchronize the machines (more than one recorder can be handled by one editing system).

In addition to performing these functions, the editing system must recognize and keep track of many special characteristics of the video tape recorder. These include:

- location of and separation between the audio and video heads (Fig. 1);
- separation between the erase and record heads;
- acceleration and deceleration characteristics of the tape-transport system;
- color framing, etc.

The AE-600 system allows editing machines to interact with each other without an expensive external computer.

All these features are available in most editing systems. What makes the AE-600 system unique is that each machine has its own integrated editor, which can communicate with the editors in other similarly equipped TR-600 machines. This system (Fig. 3) has two distinct advantages. First, it increases versatility and shortens the time required for individual edits. Second, it eliminates the expense of the time-shared computer sysem that is otherwise necessary for machine interaction.

The editing system can control one record TR-600 and up to eight playback TR-600s simultaneously. A thin cable of three twisted-pair wires is looped through all the machines in the system for transferring the required edit and transport control functions. Any one of the TR-600s can be designated as the "edit" or the "record" machine by selecting the edit mode on the control panel (Fig. 4). (Electronic interlocks insure that only one machine can be the edit machine at any one time.) Playback machines are selected on the edit machine's control-panel keyboard. Machines connected in the system but not required by the edit VTR are available for other use.

Each machine has its own control panel, but the system can be expanded into a centrally controlled editing system using a remote-control panel.

A standard remote-control panel includes two playback-machine control panels and a master record panel with associated keyboards and displays. Communication between each machine and its remote-control panel is through individual four-wire connections, but the main editing commands between the machines are still distributed through the three twisted pairs previously described. In other words, the playback and source machines are still delegated to and controlled by the "record" machine.

The control panels have been designed to maximize user effectiveness and minimize operator error. Several keys have upper-case functions very similar to those on scientific pocket calculators. Using these multiplexing techniques, the forty-six switches on the control panel provide sixty-four separate functions.

The microprocessor can directly interface with the machine functions as well as control functions.

In the example shown in Fig. 5, the microprocessor synchronizes the machine after the "play" command and maintains direct control until lock-up by means of a data bus between the microprocessor and the capstan servo. Within the microprocessor, one register is preset with

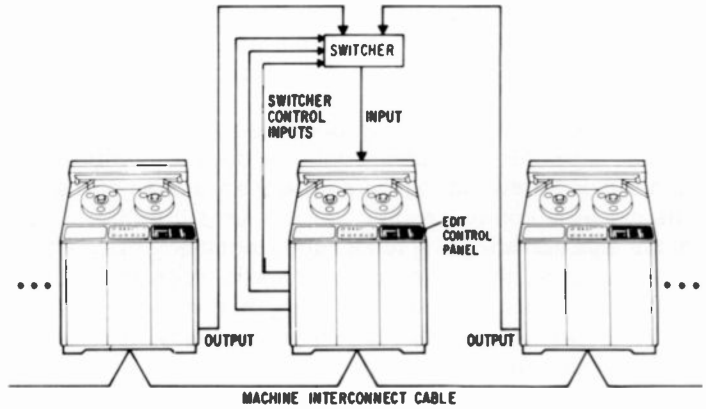


Fig. 3
Multi-machine operation is possible with the AE-600 system. One "edit" machine can control up to eight playback machines.

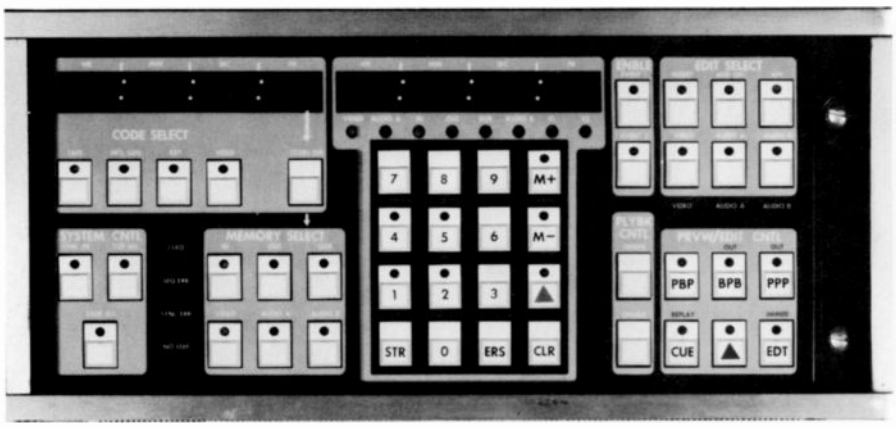


Fig. 4
Each machine has its own control panel and may act as the "edit" machine. Interlock system assures that only one machine can be the edit machine at any one time.

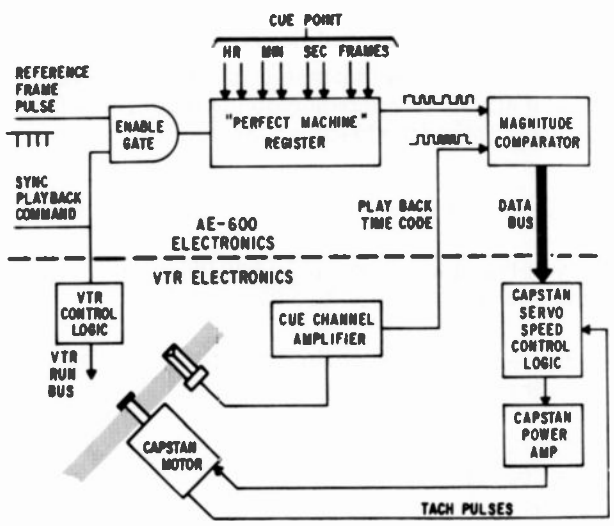


Fig. 5
Microprocessor synchronizes editing by working with AE-600 control electronics (top of diagram) and by direct interface with tape-recorder electronics (bottom). Microprocessor has built-in no-inertia "perfect machine" register that starts instantaneously on edit cue point. VTR starts rolling at the same time, but has inertia and so takes time to catch up. Microprocessor compares "perfect" register with signal from VTR, then uses the resulting error signal to drive the VTR until the two signals are locked together.

the cue point. This register is a model of a "perfect machine." It parks right on the cue point and has no inertia so that it can start instantaneously. When a sync playback command is received, this register is incremented with tv reference-frame pulses. At the same time, the VTR starts to roll from this one point. By comparing the VTR's playback time code with the incrementing "perfect machine" register, an error signal is produced and used to bring the real machine in step with its perfect model. This error signal is in the form of a digital word that programs the capstan speed in fractions of frame increments until the servo has properly locked.

This direct machine-microprocessor interaction is a good example of the advantages of the integrated approach. The built-in microprocessor system handles the special interface problems and individual machine characteristics. The communications to the outside world can now be made on the "computer level" using standard codes.

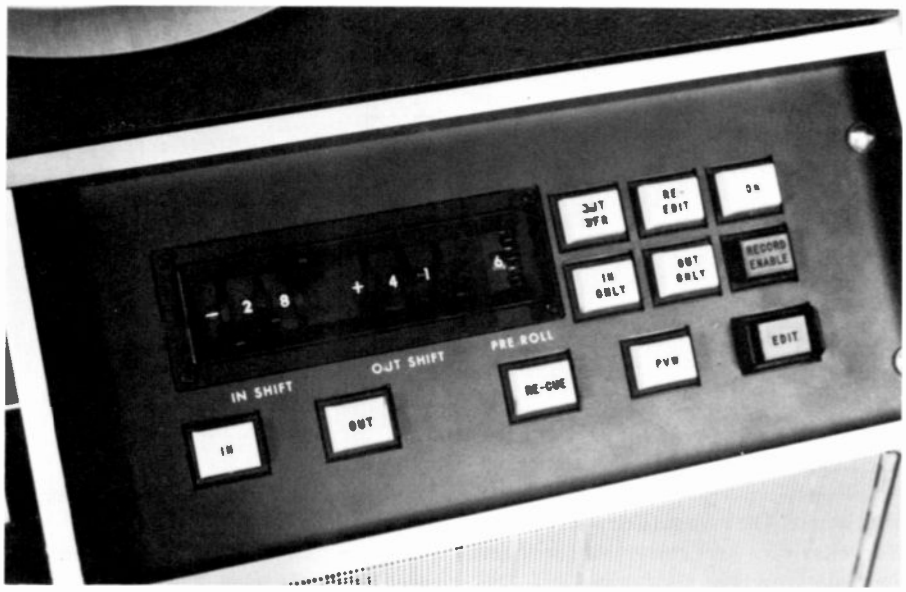


Fig. 6
SE-1 system (control panel shown here) is simpler than AE-600 system. It uses control-track signal on video tape, rather than a time-code signal.

To complement this advanced editing system, several other features were designed into the TR-600 video tape recorder. These features include:

- A video character generator, which inserts and displays the time code;
- A time-code reader, also using a microprocessor, which can read time at tape speeds from 1/10 to 100 times normal;
- An edit servo, which automatically makes sure that the new signal will be recorded in correct phase on the tape; and
- A CRT/TTY interface module, which provides video display or printout of the editing log.

To achieve optimum video performance, the super high band deviation standard and a continuous pilot-tone error-correction technique were added to the video and fm subsystems.

The SE-1— for simplified editing

The AE-600 system is one of the most advanced editing systems available and is an ideal base for interfacing with large computer-controlled editors or station automation. However, for everyday routine operation, a much less sophisticated system is appropriate. For this reason, RCA designed another microprocessor-controlled editing accessory, the SE-1 "simple editor."

The SE-I system is built around the RCA CDP1802 microprocessor.

This simplified system (Fig. 7) performs most of the typical edit control functions listed previously; however, its cueing or timing reference is the control-track signal that is always recorded on the video tape. Therefore, the time-code signal is not required.

In our estimation, even in this noticably less sophisticated application, the microprocessor had several advantages over hardwired logic. These advantages include less drafting work, fewer modules, a faster design cycle, and lower manufacturing cost.

The best proof of successful designs and concepts is customer acceptance. Approximately 50% of the TR-600 machines sold now include the AE-600 editing accessory, and a noticeable portion of the remaining 50% are delivered with the SE-1 editor.

Future editing systems

The AE-600 can be called a third-generation editing controller.

When the AE-600 is interfaced with a central automation computer, it can perform hundreds of successive edits. What does the fourth generation hold? The future of editing systems is closely linked with the development of video tape recorders and other associated video and audio equipment. The computer technology that controls these devices is already available. The present trend is in the Moviola (film-type) editing of video tape with slow, fast, and stop motion. Equipment that includes these features is available, although it must be refined to achieve totally reliable high-quality results.

The video recorder is probably the weakest link in the total editing chain.

Considerable time and effort is spent in adjusting and aligning machines for optimum performance. One possibility for improving video recorders, although it is a long-range one, may be digital recording. It could provide us with multiple copies, tapes that have minimum degradation of picture quality, and machines that could be easy to align and maintain.

Whatever the future holds, a microprocessor-controlled editor, like the AE-600, directly interfaced with the video tape recorder, will be a natural building block for the future editing systems.

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Automatic transmission systems for television

R.W. Zborowski

Automatic systems may be able to monitor and control tv broadcasting parameters better than manual operators can. The technology is available and waiting an FCC decision for the go-ahead.

Automatic television transmission is almost here. The Federal Communications Commission recently authorized automatic operation of a.m. and f.m. broadcast transmitters and stated that it will authorize similar operation for tv transmitters in the immediate future. Contemporary broadcast transmitters have achieved such high levels of stability that operators, who normally monitor their performance at the required intervals, make significant operational adjustments infrequently. Many transmitters are already remotely located (on mountaintops, for instance) and controlled from production studios. These existing remote-control provisions make the transition to automatic transmission systems (ATS) that much easier.

R.W. "Sam" Zborowski joined Broadcast Systems in 1976 as a member of the Broadcast Transmitter Design Group. He is active in Automatic Transmission System (ATS) design and has made contributions in the interfacing of television transmitters for remote control. Sam in currently engaged in the TTUE-44 uhf exciter program.

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Aside from the obvious benefit of freeing the operator to perform more productive tasks, a properly designed ATS can provide more consistent broadcast quality. Automatic transmission is an extension of the trend that many broadcasters are following—using a computer to select program segments and commercial spots in the correct sequence. In a few of these systems, the computer even keeps track of the billing for each commercial as it is aired!

An examination of the FCC's notice of proposed rulemaking, along with the actual ruling on ATS for a.m. and f.m. broadcast services, leads to a more detailed prediction of the coming ATS regulations for tv broadcasting. Specifics are in the box at the right; the major items expected are:

1) Automatic monitoring and control of aural and visual rf output power, aural modulation level, and several visual modulation parameters.

2) Automatic shutdown in the event of equipment failure (failsafe).

3) Absolute executive on/off control from an attended monitoring/alarm site.

ATS system description

A microprocessor-based Automatic Transmitter Controller (ATC) unit is the heart of the system.

Fig. 1 shows a system configured to satisfy the FCC's anticipated ATS regulations. The ATC unit monitors transmitter operation and makes supervisory decisions to maintain optimum performance consistent with the anticipated rules. It includes an analog multiplexer that sequentially delivers a number of voltage samples to an A/D converter for data acquistion, a bank of relay drivers for output commands, and a modem for communications with the studio unit over a two-way audio link. Since the transmitter must have a blanking-level visual-power control loop, the ATC unit only monitors visual output power (via a detector in the rf output line) to verify that it remains within prescribed limits.

The remaining visual parameters are controlled by a separate, dedicated instrument that automatically corrects the video and shows how much correction is required.

A visual demodulator delivers a video sample representing the actual rf output signal to the automatic video corrector. The program video must include a vertical interval reference (VIR) or vertical interval test (VIT) waveform. The automatic video corrector takes either of these output waveforms, compares it against reference values, and pre-distorts the transmitter's video input to minimize the difference.

The video corrector scales all video sample levels relative to blanking and zero-carrier levels; blanking level is measured from the "back porch" of the video waveform. A carrier blanking signal is sent to the demodulator, which chops the rf input signal during zero-carrier-level measurement. The combination of automatic blanking-level control and the video corrector's ability to adjust sync amplitude (as well as other parameters) relative to blanking and zero-carrier levels will hold peak of sync power essentially constant.

Reprint RE-23-4-16
Final manuscript received December 5, 1977.

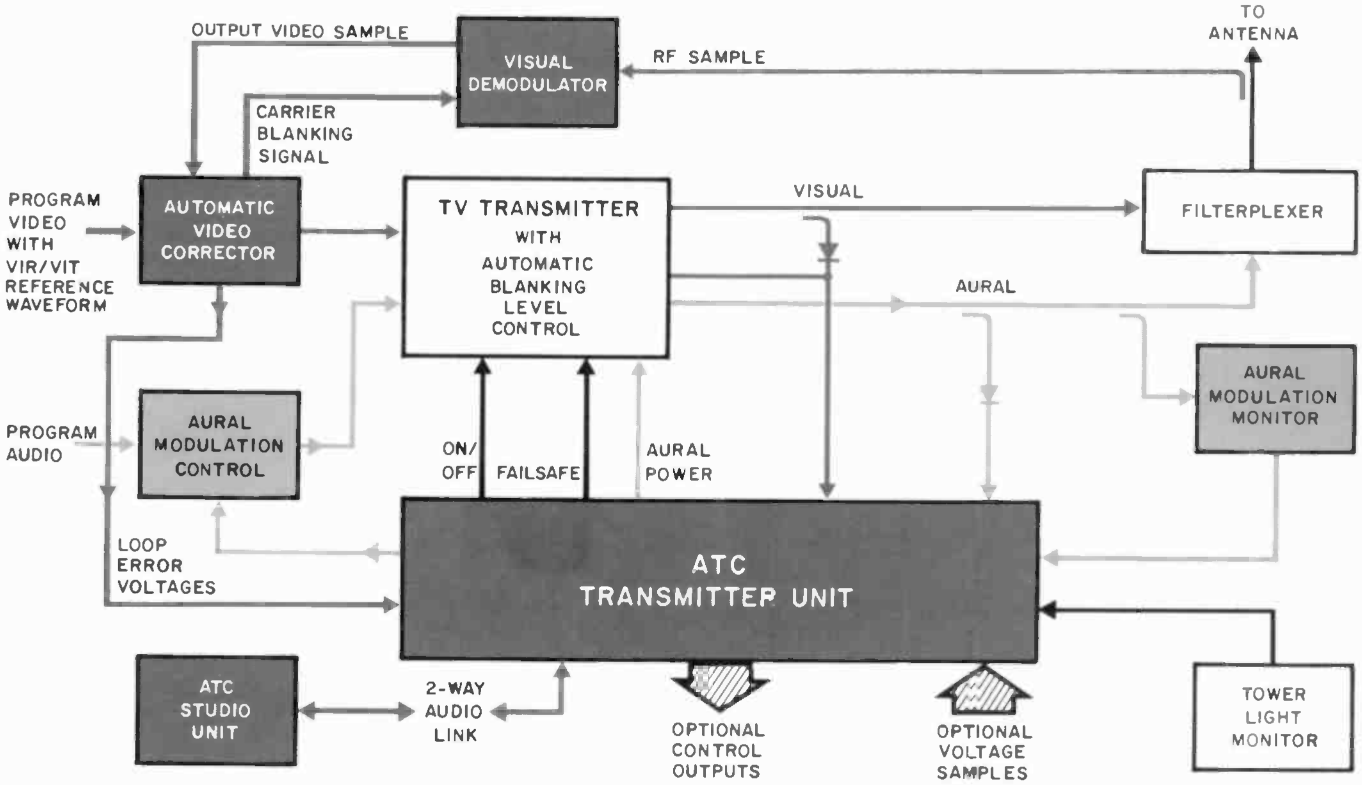


Fig. 1
Automatic transmitter system centers around the microprocessor-based automatic transmitter control (ATC) unit, which monitors output power levels and controls the transmitter for optimum performance. Separate instruments (presently commercially available) monitor and control program audio and visual parameters.

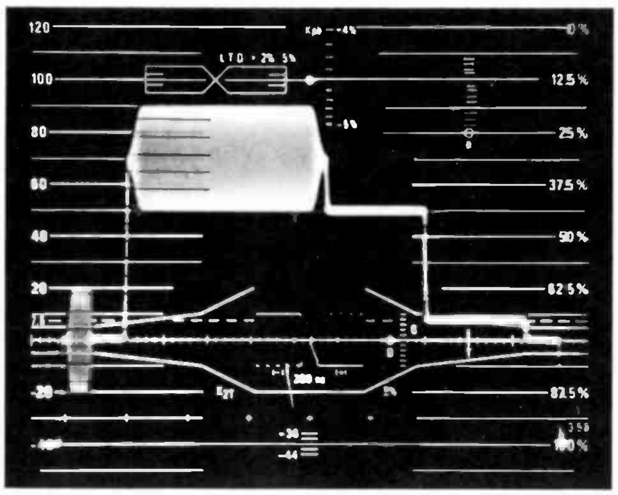


Fig. 2
VIR waveform is frequently used in commercially available automatic video correctors. It facilitates reference measurements of overall video gain, chroma gain and phase, burst amplitude and phase, sync amplitude, and black-level setup. For example, envelope at top of waveform provides chroma gain and phase information.

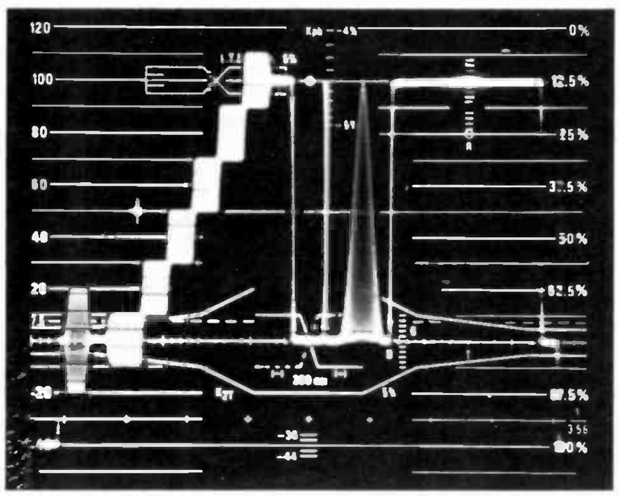


Fig. 3
VIT waveform may be a better approach. It facilitates reference measurements of all the VIR parameters (except black-level setup), then adds new ones: white-level reference, chrominance/luminance delay indication, low-frequency distortion indication, and differential phase and gain indication. For example, staircase waveform provides differential phase and gain information.

Commercially available automatic video correctors can be improved.

Commonly available automatic video correctors use the VIR waveform (Fig. 2), which includes no reference white level; the modulation depth must be extrapolated from the 50 IRE level of the waveform. With this method, the transmitter could develop a white-compression problem that would continue only partially corrected as a result. A more suitable approach would be to use a video corrector based on the VIT signal (Fig. 3), which does include a reference white level.

In either case, the automatic video corrector provides analog voltages representing the amount of correction required for each of the important visual parameters listed earlier. The ATC samples each parameter (voltage) periodically to check if it is within prescribed limits. Narrow limits on each parameter would activate warning indicators at the ATC studio unit before the wider automatic shutdown limits are reached. This early "call for help" should help correct problems before shutdown in many cases.

Audio measurement and control is done with another piece of dedicated hardware.

The ATC similarly measures aural rf output power via a detector in the rf output line and controls power by the usual remote-control interface (contact closure driving a motorized pot or attenuator). Aural modulation levels must be monitored continuously, indicating a requirement for a dedicated piece of hardware for this function alone. As a result of the adoption of ATS for f.m. broadcasting, dedicated modulation monitoring/control equipment is commercially available. In ATS for television broadcasting, such a controller would monitor and adjust aural modulation levels consistent with the ATS rules and provide alarm signals to the ATC unit in case of out-of-tolerance operation.

With parallel-transmitter operation, the visual demodulator must include an automatic gain control to permit continuing video correction during failure of one transmitter. For a station having motorized output switching, the output combiner could be switched out automatically for single-transmitter operation. The ATC could additionally monitor the outputs of the operational exciter to select the alternate one in case of failure. During normal operation, the ATC unit could adjust the relative phasing of the two transmitters to minimize the power dissipated in the combiner loads.

With suitable current-monitoring devices, intruder detectors, and smoke/fire detectors added, the ATC unit could even monitor the antenna tower lights and building security.

The separate ATC studio unit would also be implemented in microprocessor form, primarily to simplify the communication format of the transmitter unit. The operator interface at the studio would consist of a transmitter on/off switch, a bank of visible status indicators, and an audible alarm.

Anticipated ATS provisions

This listing, an educated guess at the forthcoming ATS regulations, was used in preliminary system design.

1) Aural and visual rf output power must be monitored and controlled.

The transmitter must shut down automatically if output exceeds 110% of licensed power for three consecutive minutes.

An alarm must sound if output power falls below 80% of licensed power for three consecutive minutes.

An additional alarm must sound after carrier loss for over three minutes.

2) Aural modulation level must be monitored and controlled.

Modulation depth must be reduced if 10 bursts (a burst is understood to be a sequence of over-modulation instances within a 5-ms interval) of over 100% aural modulation occur within any one-minute period.

The transmitter must shut down automatically if overmodulation is not corrected within three minutes.

An audible alarm must be sounded following three minutes of no modulation.

All SCA (Subsidiary communications authorization) subcarrier generators must have a deviation-limiting device.

3) Visual modulation levels must be monitored and controlled.

The following parameters must be monitored:

Color-burst amplitude

Color-burst phase relative to active video

Black-level set-up

Sync amplitude to pix ratio

Chrominance-to-luminance ratio

Depth of modulation

If any of the above parameters are out of tolerance for a specified time limit (tolerance and time not yet defined) an alarm shall sound.

A depth of modulation exceeding limits for three minutes must produce automatic shutdown.

An alarm must sound following three minutes of no video modulation.

Note: The above video levels are measured relative to blanking and zero-carrier levels.

Failsafe and reliability features

The system must be failsafe against communication-circuit failure that could cause loss of control, and against failure of the supervisory/monitoring equipment. To satisfy the first requirement, the studio unit would continually send a command to energize a relay connected to the transmitter's interlock circuits. If a communication-circuit failure or ATC unit failure occurred, the relay would drop out and shut off the transmitter; a three-minute delay would preclude shutdown during momentary communication interruptions. The monitoring equipment depends primarily on the functioning of the analog multiplexer and A/D converter. Consequently, the second failsafe requirement can be addressed by providing two reference voltages within the ATC unit. These voltages would be periodically scanned and compared against prescribed limits to check the measurement accuracy.

4) The ATS monitoring/alarm location must include:

Transmitter on/off control.

Off-air program and SCA receivers and monitors.

Automatic tower-light alarm indicator (unless visual observation is used).

All of the required alarms defined above must be both audible and visible. Once an alarm is triggered, the audible indicator may be shut off by the attendant, provided the visible indicator remains active until the fault is corrected.

Any optional status/alarm indicators must be easily distinguishable from the FCC required alarms.

The monitoring/alarm location(s) must be reasonably secure from unauthorized access.

5) Miscellaneous ATS Provisions:

Automatic switching to an alternate main or auxiliary transmitter is permitted, provided that such transmitters are fully equipped for ATS operation.

Modulation must be monitored continuously.

All other required sampling of transmitting system parameters must be at intervals not exceeding one minute.

The ATS system must include a provision to test all automatic control and alarm devices.

More than one monitor/alarm location is permitted, provided each is under control of the licensee.

6) Failsafe requirements:

The transmitter must shut down automatically after:

Loss of ATS sampling for three minutes.

Failure of the communications circuit between the transmitter site and the monitor/alarm location causing loss of manual on/off control for over three minutes.

Failure of any required alarm system for over three minutes.

Overall ATS reliability can be enhanced by providing alternate program audio/video feeds and an alternate communication link with the ATC studio unit. Uncorrectable output audio or video response could be programmed to have the alternate feed selected as a last resort before shutdown. The three-minute failsafe delay suggests the possibility of using an automatic dialing telephone accessory so that ordinary (as opposed to dedicated) phone lines could become the secondary ATC communication path. Relay switching can be provided to switch all transmitter control lines to an existing remote-control system. This can provide an additional measure of redundancy by enabling ordinary remote operation in case of ATS failure.

What has RCA done?

RCA has participated in long-term tests of the video correction scheme described earlier at KDKA, Pittsburgh, Pa. (TT-30FL transmitter) and at WNJT, Trenton, N.J. (TTU-60B transmitter) in their actual operating environments. The results of these tests were reported in Refs. 1 and 2.

The aural modulation control and automatic transmitter controller equipment is currently being supplied by several vendors for a.m. and f.m. ATS installations. Although a complete system for tv transmitters has not yet been assembled and tested, the previous work indicates no serious difficulty in combining the existing portions of the system when the actual ATS rules are defined. Future designs may incorporate part or all of the ancillary equipment within the transmitter itself.

Future developments

So far, we have seen ATS implementations using equipment that is available today. There seem to be two different schools of thought regarding future ATS directions. One group believes that the transmitter stability is such that normal operating drifts produce no perceptable picture impairments. Indeed, as technology evolves, the transmitter stability should improve, so the control interface with the rest of the ATS system need not be further complicated. The other school of thought believes that more controls should be provided to allow automatic correction of such parameters as low-frequency linearity, subcarrier linearity, subcarrier differential phase, envelope delay, etc. Each of these parameters must be addressed in terms of system reliability tradeoffs for improved performance.

In any case, nearly everyone seems to agree that ATS will *monitor* more functions to predict long-term drift-type failures. It will monitor overall dc-to-rf efficiency along with a multitude of visual parameters obtainable from VIT signals. With uhf transmitters, because of the severe nonlinearity of the klystron transfer characteristic, automatic linearity correction is likely to be added to compensate for primary power line fluctuations. As transmitters become more modular with greater standardization, ATS may be used to identify failed modules and so speed up repair by module replacement. No doubt, ATS will improve overall transmission quality as these systems evolve.

References

1. Gluyas, T.M.; "TV transmitting systems for unattended operation," *Broadcast News*, Vol. 154 (Oct 1974) p. 40. Also presented at the March 1974 NAB Engineering Conf.
2. Gluyas, T.M., "Simulation of unattended operation of uhf-tv transmitters." *Broadcast News*, Vol. 158 (Jun 1976) pp. 40-47.

The BTA-5SS—
RCA's all-solid-state 5-kW a.m. broadcast transmitter

L.L. Oursler| D.A. Sauer

RCA's first all-solid-state transmitter will save broadcasters hundreds of dollars a year in electric bills alone.

The history of amplitude-modulated broadcast transmitters with electronic amplification began almost immediately following the invention of the triode vacuum tube around 1906. A.M. broadcast stations progressed from operating powers of a few watts to fifty thousand watts and higher within a few years as high power tubes were developed. Higher transmitter output power could be achieved by paralleling several power tubes. One example of this was an early RCA one-kilowatt transmitter which utilized four tubes, each rated at two hundred and fifty watts, in a push-pull parallel circuit. Today, single tubes are capable of producing several million watts of radio-frequency output.

The design technology necessary for producing an all-solid-state broadcast transmitter has been available since the early 60s, but the required higher-powered transistors became available only recently. Now, large amounts of rf power can be produced by combining these solid-state devices into transistor arrays.

Solid state vs. tube transmitters

Much can be said about the differences between all-solid-state broadcast transmitters and vacuum tube transmitters. In general terms, the solid-state transmitters are smaller, more reliable, and less costly to operate and maintain. In addition, the first-generation "all-silicon" transmitters have achieved signal quality standards comparable to the state-of-the-art tube designs.

Possibly, the best way to illustrate these differences is in a side-by-side look at an all-solid-state broadcast transmitter and a vacuum-tube-powered transmitter. The RCA BTA-5L2 is RCA's latest 5-kW tube-type a.m. broadcast transmitter; this unit is completely solid-state at power levels below the intermediate power amplifier and thus uses only four tubes. The RCA BTA-5SS is RCA's new 5-kW all-solid-state broadcast transmitter. These two transmitters are shown in Fig. 1 and compared in Table I.

Note that the signal quality of this first-generation all-solid-state transmitter matches that of the tube design. The performance may be improved further as solid-state design techniques mature. This is especially important now that more emphasis is being placed on hi-fidelity a.m. broadcasting as a prelude to stereophonic broadcasts by a.m. stations.

Table I
Comparison of the 5-kW all-solid-state transmitter, BTA-5SS, and its predecessor, the tube-type BTA-5L2.

Specifications	BTA-5L2 Ampliphase	BTA-5SS all-solid-state
Size: an all-solid-state transmitter approaches one-half the size of a tube transmitter of the same power level of recent design. (See Fig. 1.)		
Height	77 in.	77 in.
Width	70 in.	38 in.
Depth	32 in.	36 in.
Weight	2500 lbs.	1000 lbs.
Reliability: Tubes become gassy, suffer from decreasing filament emission with age, and have lower overall power conversion efficiency. Transistor arrays can provide a planned margin of power output capability in the event that a few transistors become inoperative. If the tube transmitter has but one final rf tube, the transmitter has no output when the final tube fails, but the solid state transmitter can maintain full or reduced output if some of the active output devices fail.		
Efficiency:		
Nominal power out	5000 W	5000 W
Approx. power consumption		
@ 0% modulation	10,000 W	6920 W
@ 100% modulation	17,000 W	10,500 W
Power factor	90 %	95 %
Signal quality: The solid-state transmitter meets the quality criteria of the tube design.		
AF response @ 30 to 15,000 Hz	±1.5 dB	±1.5 dB
AF distortion @ 95 % mod; 30-10,000 Hz	2% max	2% max
Noise below 100% mod	−60 dB	−60 dB

Reprint RE-23-4-6
Final manuscript received June 15, 1977.

The solid-state transmitters will cost less to operate and maintain.

The economy of a solid-state transmitter is achieved through higher efficiency, longer-life active elements, and smaller space requirements. Based on such operating economies, a customer should pay for the increased cost of the BTA-5SS in about four years.

The solid-state-transmitter design can easily implement power reduction without the complexity of high-power contactors and power-wasting dropping resistors; a vernier power output control can provide an infinite number of reduced power output levels. By means of this feature, non-standard operating power levels can be easily achieved, and instant on-the-air switching with no program interruption is possible.

perspective

RCA in the broadcast radio transmitter marketplace

RCA has elected to concentrate its radio broadcast equipment sales effort in stations from 5 kW to the maximum size permitted by the FCC, 50 kW.

We have long been a leading supplier of broadcast transmitters, though we formerly included 250-W and 1-kW transmitters in our line. The history of our innovation includes the introduction of high-level modulation in 1-kW transmitters in 1933, in 5/10-kW transmitters in 1936, and in 50-kW transmitters in 1939. Simultaneous with the introduction of high-level modulation, RCA introduced air cooling in place of water cooling. In 1955, RCA introduced Ampliphase as a modulation system at the 50-kW level. Ampliphase provides the advantages of high-level modulation without the disadvantages of the high peak voltages and large modulation components formerly required.

The broadcast transmitter business is highly competitive, including such competitors as Harris, Collins, CSI, and Sparta. While some of these companies have introduced solid-state 1-kW transmitters, none so far has tackled the 5-kW and larger field.

Within the US, approximately 1400 5/10 kW transmitters are in operation; many are quite *old* and a large replacement market exists. The BTA-5/10 SS with its ease of installation, built-in high reliability, and minimum power consumption should have a large appeal to this market. Export sales tend more to the new station business; and while the trend to build transmitters of this size locally inhibits our sales opportunity, still there are areas where the inherent advantages of this transmitter make it an appealing product for new station sales.

—D.S. Newborg

Dave Newborg is Manager of Radio Station Equipment Product Management. Contact him at: **Broadcast Systems; Camden, N.J.; Ext. PC-2146.**

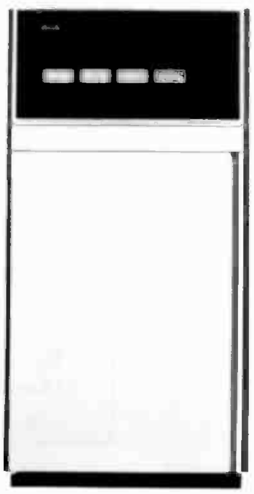


Fig. 1
The RCA BTA-5SS 5-kW all-solid-state a.m. broadcast transmitter (top) is about half the size of its predecessor, the tube-type **BTA-5L2** 5-kW Ampliphase transmitter.

The transmitter's push-pull bridge, saturated amplifier, commonly called a class-D amplifier, has excellent efficiency and provides a sink to either the power supply or ground for any induced or transient energy. Lightning and static discharge can be problems to any transmitter, but careful design can help to minimize possible damage and/or annoying program interruptions. Effective lightning and static protection can take the form of shunt static drain chokes, spark gaps, and reflectometer circuits. In a solid-state transmitter, the type of rf amplifier used can also enhance the protection of the overall system.

The basic class-D rf bridge amplifier is shown in Fig. 2. Each arm of the bridge contains a transistor; the rf input transformer has a single primary winding and four independent secondary windings. The polarity of each secondary winding is such that transistors Q1 and Q2 are on and completely saturated for a given half cycle of rf, while transistors Q3 and Q4 are turned completely off during the same half

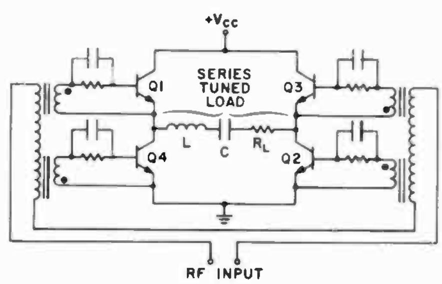


Fig. 2
This class-D rf bridge amplifier circuit protects the system from lightning and static discharge; it ranges in efficiency from 90 to 95%.

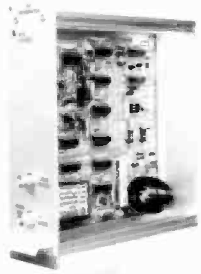
Fig. 3

BTA-5SS—5-kW all-solid-state a.m. broadcast transmitter.

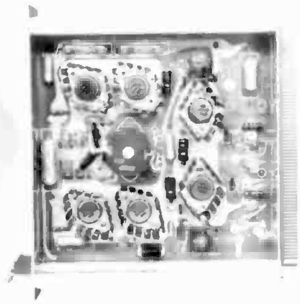
3∅ AC INPUT

Low Voltage Supplies

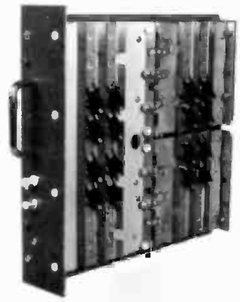
High Voltage Supply



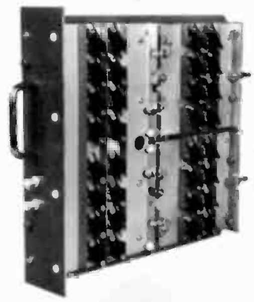
The rf generator module contains a high-stability frequency synthesizer that allows the output frequency to be programmed in 1-kHz steps to satisfy both domestic and foreign frequency assignments. The heart of the synthesizer is a precise 5-MHz temperature-controlled crystal oscillator. The rf generator also has provisions for using an external frequency reference for synchronous stations and for frequency modulating the carrier for a.m.-stereo applications.



The rf pre-driver module is a buffer power amplifier between the rf generator and the rf driver tray and is comprised of saturated class-D rf amplifiers.

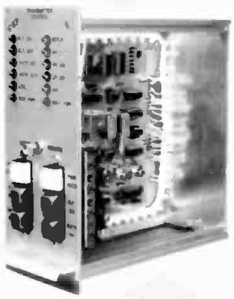


The rf driver tray is a plug-in array of transistors acting as a class-D bridge amplifier.



The final rf power amplifier stage consists of six class-D bridge power amplifier trays whose outputs are summed by means of a combining transformer. This method of combining allows the transmitter to maintain its full power output even in the event of an ocassional loss of an rf output transistor. The combining transformer also provides a static drain to ground and a twenty-to-one step down of induced voltage such as lightning.

Subcarrier Filter



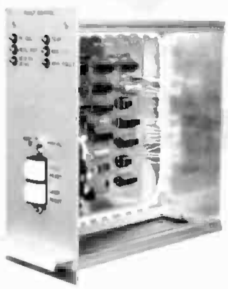
POWER SUPPLY MONITORS

VSWR

TEMPERATURE

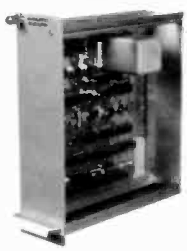
PA BALANCE

PA DRIVE

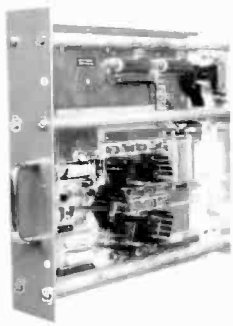


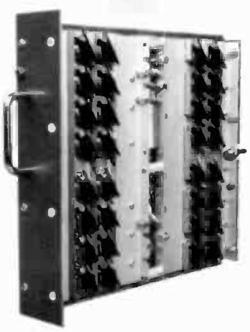
The transmitter control module (top) and the **fault control module** (bottom) provide complete control and protection for the transmitter. The modules have remote control capability, and a remote/local switch is provided for the safety of operating personnel. The main controls are: transmitter on, transmitter off, rf on, and rf off. Two pushbuttons provide a digital power increase/decrease control, which gives eight steps of power increase to 10% above nominal and eight steps of power decrease to 10% below nominal.

AUDIO INPUT

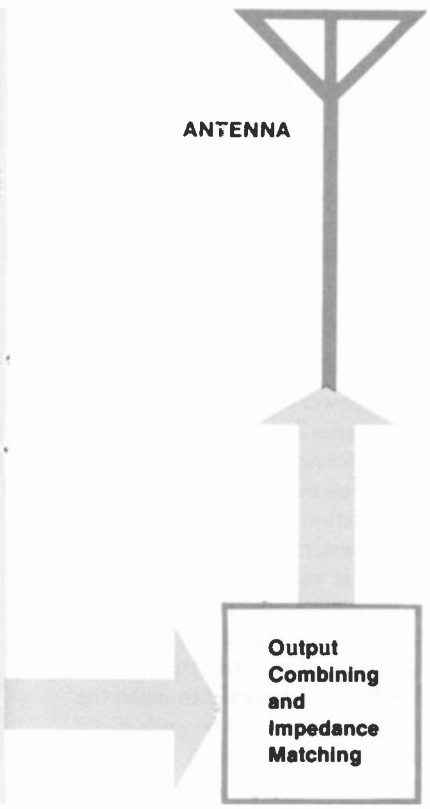


The modulation generator module produces a pulse train output with frequency equal to the subcarrier frequency and pulse width variations proportional to the modulating audio signal amplitude and frequency. In the absence of an audio input signal, the unmodulated duty cycle of the entire modulation section of the transmitter generates the required voltage across the final rf stage to produce the unmodulated carrier power output.





The modulation driver and the **modulator power amplifier** consist of transistor arrays which turn on and off at the subcarrier frequency and in accordance with the modulated duty cycle. The subcarrier filter removes the subcarrier frequency and applies a voltage, which varies at an audio rate, to the final rf amplifier.



rf cycle. When the rf input reverses polarity during the next half cycle, transistors Q3 and Q4 are turned on and transistors Q1 and Q2 are turned off. The time required to turn one set of transistors on and the other set off is extremely short—on the order of a few nanoseconds. During most of the rf cycle, the transistors are either turned completely on in a saturated mode or completely cut off, and the only time a small amount of power is lost in the transistors is during the nanosecond transition period and the saturation period.

The net result of the minimal power loss is excellent rf power amplifier efficiency, in the range of 90 to 95%. If transistors which produced zero transition time and zero saturation voltage were available, the circuit conversion efficiency would be 100%, but the above-mentioned circuit losses are ever present in the real world and limit the obtainable efficiency. The RC network in the base circuit of each of the transistors produces a small amount of bias to help minimize the storage-time effect of the transistors. The voltage produced across the series-tuned-load network is a square wave and the current through the load resistor, R_L, is sinusoidal due to the filtering effect of the series network. The load resistor, therefore, has a sinewave of voltage across it and a sinewave of current through it.

The BTA-5SS—RCA's first

The RCA BTA-5SS is (Fig. 3) the first model in the RCA line of all-solid-state a.m. broadcast transmitters. This transmitter is completely self-contained, produces 5 kW of carrier power, and features low power consumption, high performance, and high reliability.

The rf section of the BTA-5SS consists of the following plug-in modules: rf generator, rf pre-driver, rf driver, and rf power amplifier.

Each power amplifier tray acts as a constant voltage source to its rf load, and all of the transistors on the tray share the output current demand. The trays are designed so that at least 25% of the transistors would have to fail before the tray could not maintain its full current output. An inoperative transistor is automatically removed from the circuit, and the remaining transistors continue to provide the full output current.

The final link between the combining transformer and the output to the antenna is the impedance matching and harmonic filter rf network. A reflectometer is also included to monitor forward power and vswr and to provide protection by instantly quenching the rf output when transmission-line disturbances occur.

The modulator section consists of the modulation generator, modulation driver, modulator power amplifier, and subcarrier filter.

The modulation section, including the subcarrier filter, functions as a variable power supply, and the transmitter's unmodulated carrier level can be adjusted by changing the duty cycle of the modulator pulse train. After the required carrier level has been set, audio can be applied to the modulation generator to modulate the duty cycle at the audio rate, resulting in a varying voltage across the rf final.

In this highly refined pulsewidth modulator, the subcarrier is derived directly from the frequency synthesizer in the rf generator module, and the resulting precise control of subcarrier frequency allows stable system performance.

In general terms, the modulation system provides low distortion, wide frequency response, fast transient response, high modulation levels, high efficiency, and a convenient method of adjusting and regulating carrier output power.

This new transmitter reduces operating controls to a minimum, and has several self-monitoring and correcting features.

The basic transmitter operating controls are on-and-off and power-level select. An eight-step digital power control increases or decreases the voltage on the transmitter's automatic power control comparator, which then adjusts the amplitude of the subcarrier triangle wave. The resultant change of the triangle amplitude changes the duty cycle of the pulsewidth modulator. As described previously, the transmitter's output power is adjusted by this change in duty cycle. A switch gives the operator the option of either automatic or manual overload recycle control, and a digital counter sets the number of overload steps allowed in the automatic mode before the transmitter is shut down. The high-voltage supply is protected from overcurrent and undervoltage conditions, such as the loss of a single phase, and either condition shuts the transmitter down. The front panel indicators show the reason for shutdown.

The low-voltage supplies are undervoltage protected and current-limited. A reflectometer circuit sends a fault pulse to the control logic when a high vswr condition exists, and the transmitter's rf output is instantly cut off. The drive level to the rf power amplifier trays is monitored, and if inadequate drive is present, the transmitter protects itself by turning off. The rf output level of each of the rf power-amplifier trays is detected by the tray balance circuit, and if the trays are not properly balanced in output, the transmitter does not allow operation until the tuning on the trays is set properly or the defective tray is repaired. Under normal operation, the tray balance circuit provides a convenient check on tray performance.

The temperature of each of the rf power-amplifier trays and the modulator power-amplifier trays is monitored, and if a tray

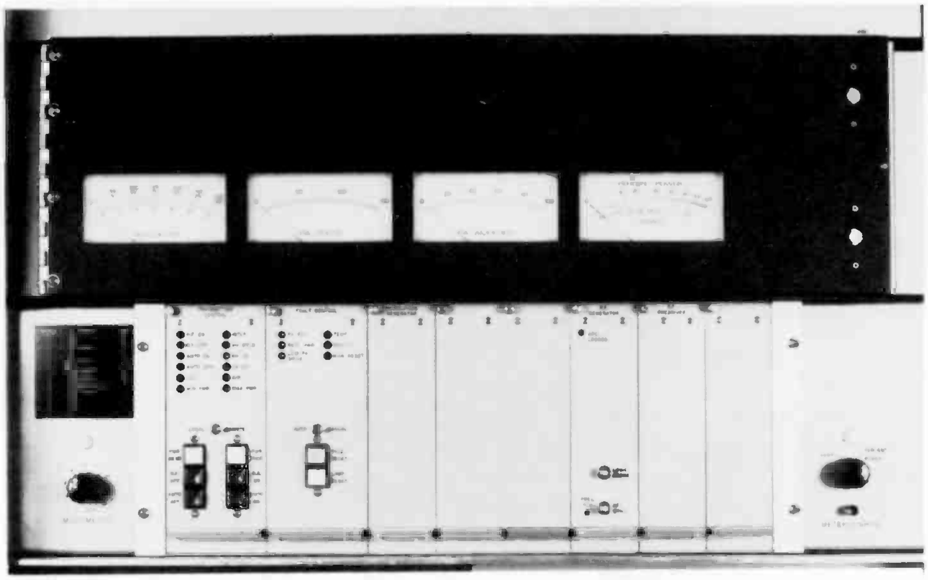


Fig. 4
Module nest in the BTA-5SS is designed to aid service of low-power-level module boards via a module extender.

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Dave Sauer has worked in broadcast transmitter engineering since he started his career with RCA in 1960. He has worked on 5-, 10-, and 50-kW broadcast transmitters and the 100-kW Ampliphase transmitter.

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develops a higher than normal operating temperature because a malfunction, the protection control circuitry turns off the system. In the event of a blower failure, the air-flow detector automatically reduces the transmitter output power and keeps the transmitter on the air. A front panel indicator is turned on when the transmitter is in this mode of operation. The transmitter has four illuminated meters to monitor the rf power-amplifier voltage, rf power-amplifier current, % output power/vswr, and 20 circuit parameters on a multimeter.

An automatic power control maintains the transmitter's carrier output at a level preset by the broadcaster. In addition, an automatic modulation control circuit will keep the modulation depth at a level preset by the broadcaster as the transmitter's power output is varied to eliminate the need to readjust the modulation level when a switch is made from high to low power or low to high power. The automatic features of the BTA-5SS are designed to make the task of utilizing the newly authorized automatic transmission system extremely simple.

In the design of a broadcast transmitter, it is very important to provide enough service features for routine inspection, cleaning, and in the event of a failure, easy repair. The BTA-5SS uses extensive modular construction, and the low-voltage-level modules shown in Fig. 4 are designed so that they may be operated on a module extender. The transmitter cabinet was made large enough to give easy access to all components. A multimeter on the front panel gives operating parameters in 20 different circuits throughout the transmitter, and several illuminated status indicators provide instant evaluation of operational status or fault conditions.

The future

The age of all-solid-state medium and high power a.m. broadcast transmitters is here and offers the broadcaster high performance, economy, and reliability.

As solid-state technology advances, powers greater than 5 kW will be possible. We will see a rapid increase in power output density in terms of watts per cubic foot of cabinet space. More self-monitoring and correcting features will be introduced as extensions of the present Automatic Transmission Systems authorized by the Federal Communications Commission.

Circular polarization for better tv reception

M.S. Siukola

Television broadcasters, mindful of what circular polarization has done for fm, are taking a closer look for possible holes in their coverage.

Circular polarization is well known to all branches of communications except broadcasting, where it has been used only by fm broadcasters. Even for fm, not all of the potential benefits are being realized. The main thrust there has been to improve automobile reception by simply adding a vertically polarized component (for whip antennas) to the horizontal component serving home receivers.[1] Nevertheless, this use of circular polarization, as restrained as it may seem, has increased the fm audience substantially. During the 60s, it lifted fm broadcasting out of a severe economic slump. But alas, there has been no further fm exploitation of circular polarization even though meaningful solutions to multipath problems are certainly possible.

The television broadcaster's interest in circular polarization dates back almost as far as that of the fm broadcaster. But at that time, because of the predominance of tv as an entertainment medium, there appeared to be no major unreachable audience, and therefore television experiments were not conducted.

The first real effort at conclusive circular polarization tests for tv was by the American Broadcasting Company in 1973, using experimental antenna facilities built by RCA for WLS Channel 7 in Chicago.[2] ABC then contracted with Smith and Powstenko, consulting engineers, to perform the experiments during 1974.[3]

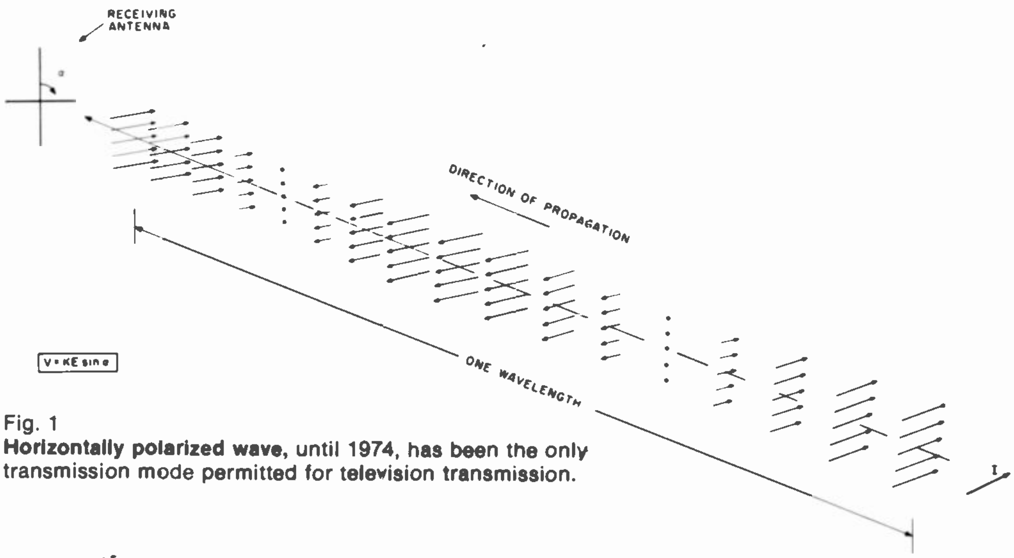

Fig. 1
Horizontally polarized wave, until 1974, has been the only transmission mode permitted for television transmission.

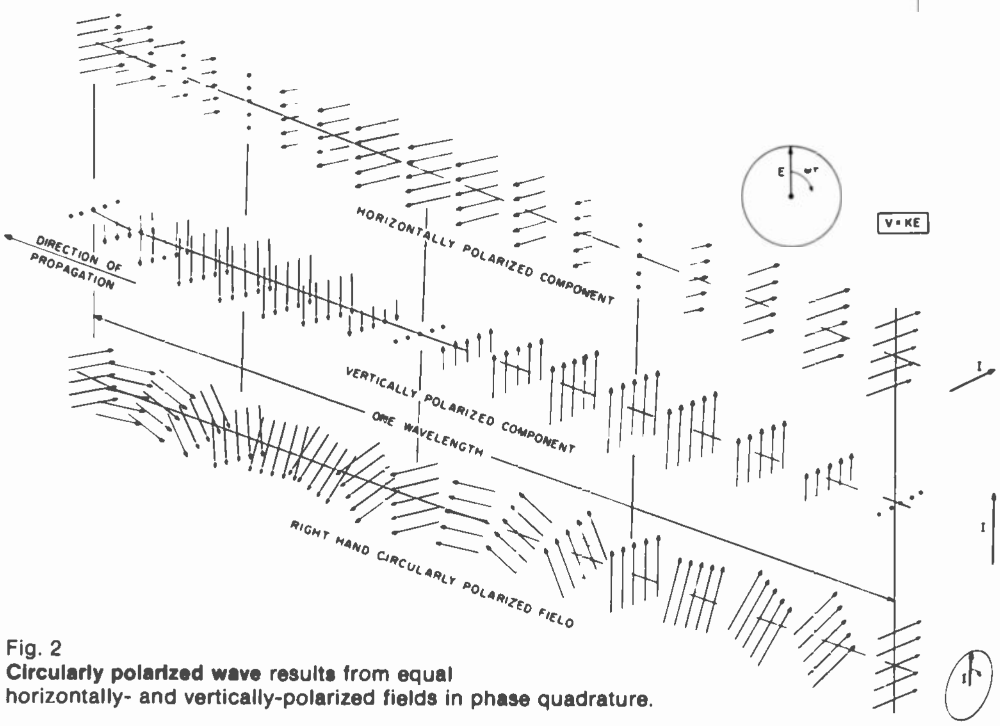

Fig. 2
Circularly polarized wave results from equal horizontally- and vertically-polarized fields in phase quadrature.

Polarization modes

The benefits of circular polarization may be seen by studying the characteristics of polarized waves and comparing their behavior during transmission and reception.

The polarization of an electromagnetic wave is generally defined by the direction of its electric field. Thus, the electric field of a horizontally polarized wave is always horizontal (Fig. 1). Such a horizontally polarized wave may be propagated by a horizontal dipole. Accompanying the electric field of the wave is, of course, a linearly proportional magnetic field that is orthogonal to the electric field (and therefore vertical).

A horizontal receiving dipole, perpendicular to the direction of propagation, will develop a voltage along its length as a result of the vertical magnetic field crossing the dipole and inducing an emf. A vertical dipole would see no source of potential since the electric field is perpendicular to the dipole and the magnetic field would be parallel to it. Thus, no signal would be received.

A circularly polarized field may be produced by generating two linear fields of equal magnitude, one horizontal and the other vertical. Propagated in phase quadrature, the two fields add vectorially to produce a right-hand circularly polarized wave with equal magnitude fields at various slant angles, resembling at any particular instant, a left-hand threaded screw (Fig. 2). It is obvious from the

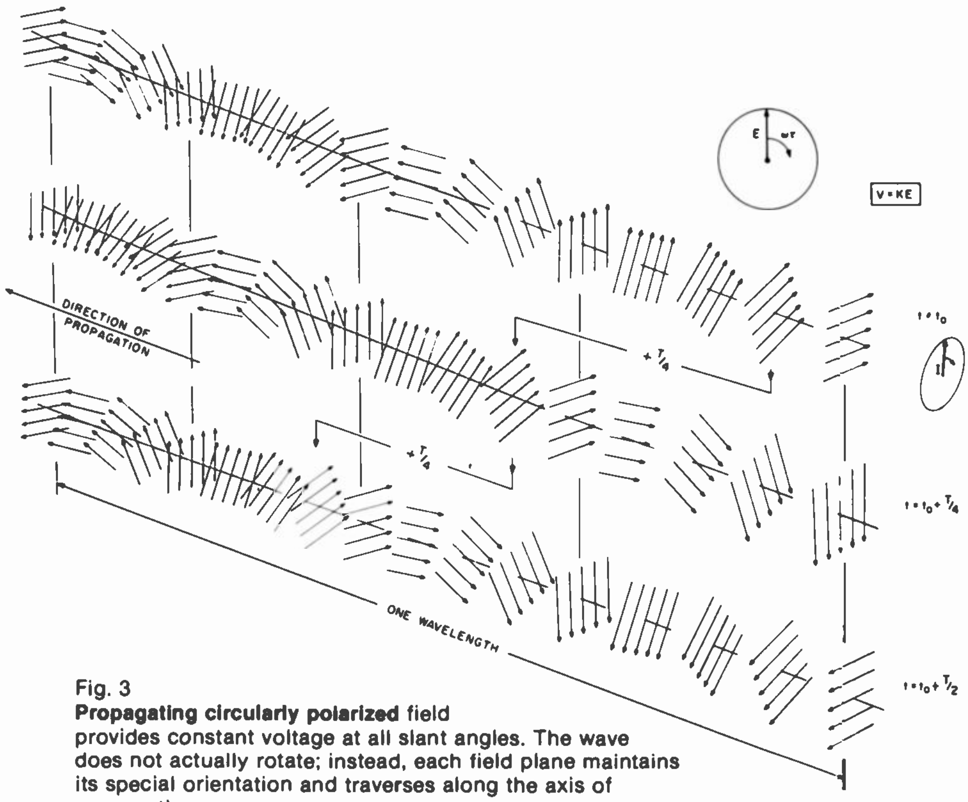

Fig. 3
Propagating circularly polarized field provides constant voltage at all slant angles. The wave does not actually rotate; instead, each field plane maintains its special orientation and traverses along the axis of propagation.

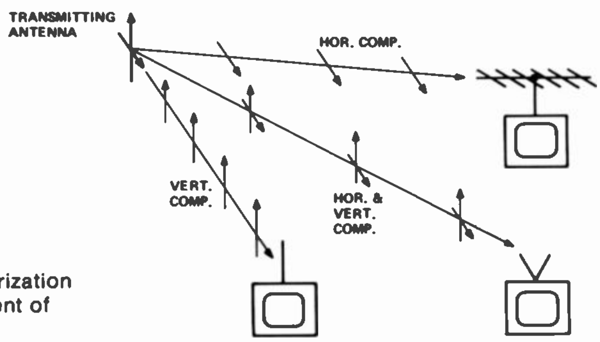

Fig. 4
More solid coverage for tv is one result of circular polarization since reception is independent of antenna orientation.

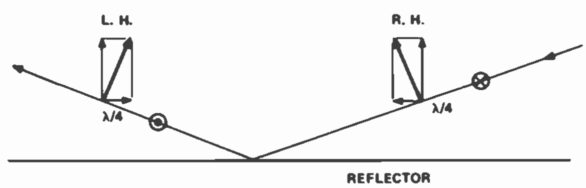

Fig. 5
At reflection, the sense of rotation of a circularly polarized wave tends to reverse.

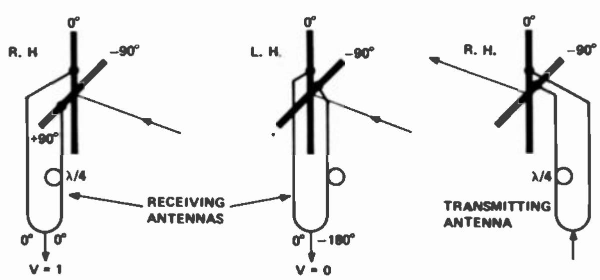

Fig. 6
A signal with opposite sense of rotation is rejected by the circularly polarized receiving antenna.

horizontal and vertical components that when the circularly polarized wave propagates, it does not rotate; instead, each field plane maintains its special orientation and traverses along the axis of propagation, in the manner of the lefthand screw being driven by a hammer (Fig. 3).

The wave illustrated is defined by IEEE Standards as a right-hand circularly polarized signal since, if the passing wave is observed in the direction of propagation at any particular point along the propagation path, the field will appear to rotate clockwise.

Improved audience penetration

Reception is improved with simple "rabbit-ears" receiving antennas, but CP antennas provide optimum reception.

Of course, the addition to the station's signal of an equal amount of energy in the form of a vertically polarized component, as permitted by FCC, should significantly improve coverage. Close-in, this doubled effective radiated power (ERP) better penetrates difficult urban locations, such as inside large buildings, where tv signals are received only by whip or rabbit-ear antennas (Fig. 4). For fringe areas, again twice the power provides higher signal-to-noise ratio for a given distance if circularly polarized (CP) receiving antennas are used to take advantage of all the power. Undoubtedly, many fringe-area viewers and, especially, CATV operators will use CP antennas.

Better picture quality

A circularly polarized signal with CP receiving antennas improves the received picture in several other ways. For example, ghosting in tv reception caused by multipath problems is reduced. With horizontally polarized signals, about the only way to reduce ghosting is to use highly directive receiving antennas, and orient them for minimum reflection and maximum signal. When a circularly polarized signal is reflected, its sense of rotation tends to reverse. A right-hand polarized signal, for instance, tends to become a left-hand polarized signal and vice versa. This phenomenon can be visualized by separately considering the parallel and perpendicular components of the signal at the point of reflection (Fig. 5). The perpendicular component of the field maintains its direction, but the parallel component reverses to meet the boundary conditions at the surface.

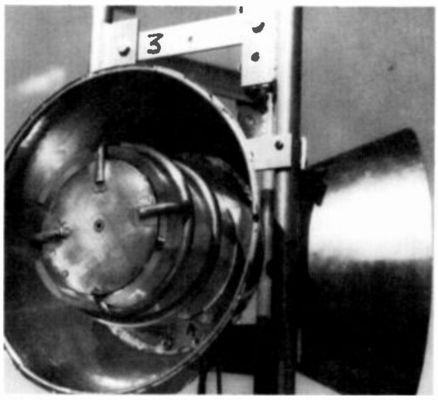

Fig. 7
An end-fire basket helix was used to transmit circularly polarized signal for the demonstratior at NAB in 1976.

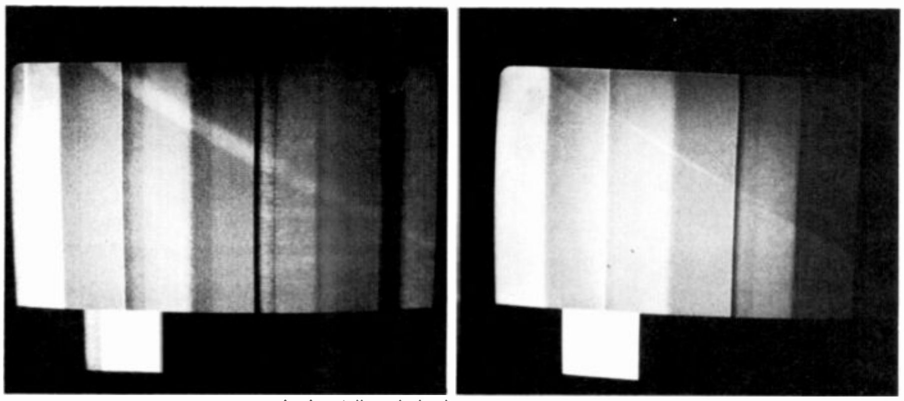

Fig. 8
These comparison photos show that circular polarization reduces the ghosting in received pictures of the test pattern. Horizontally polarized transmission and reception at left; circularly polarized transmission and reception at right.

The other factor is that, with CP, the receiving antenna has to be a right-hand polarized to receive a right-hand polarized signal (Fig. 6). A left-hand polarized receiving antenna will not extract energy from a right-hand polarized field. These two characteristics provide ghost-reduction capability for the complete system.

Another improvement in picture quality stemming from circularly polarized transmission is a reduction in adjacent-channel interference. At present, the main tool for reducing this type interference is a receiving antenna with a high front-to-back ratio. With circular polarization, a directive righthand circularly polarized receiving antenna theoretically can be either right-hand or left-hand polarized as seen from the back, and thus can be designed to reject an unwanted signal.

Circular polarization with some or all of these features—easier receiving antenna orientation, stronger signals in buildings, less noisy pictures in fringe areas, perhaps three to five miles more coverage, ghost reduction and/or adjacent channel interference reduction—may in any particular case improve service to the viewing public. It will, however, cost the broadcaster more for new transmitting equipment, and the viewer, who may also need a CP antenna to achieve the most from the circularly polarized system, will also have to pay for improved reception.

CP demonstration at NAB

An on-air, 10-mW-ERP transmitter and complete receiving system dramatically demonstrated the ghost-reduction capabilities of circular polarization at the 1976 National Association of Broadcasters convention in Las Vegas. The output of a Channel-56 exciter, modulated by a test pattern and live studio signals, was fed into either of two transmitting antennas: a butterfly antenna to produce the horizontally polarized signals; or an end-fire helix "basket" antenna to generate the circularly polarized signals (Fig. 7). The ghost signal was caused by a 3X5-ft metal reflector placed about ten feet from the antennas. A built-in delay line added "distance" to the reflected signal path to provide better separation between ghost and main signal. Horizontally and circularly polarized corner-reflector antennas received the signals some 25 ft away and displayed them on a color monitor. The dipole of the circularly polarized antenna was slanted and positioned in the reflector for nearly perfect circular polarization. Fig. 8 shows differences between the horizontal mode of operation and the circularly polarized mode. The display demonstrated the principle; no attempt was made to quantize the possible improvement.

The WLS experiment

These experiments were quite extensive and designed to provide adequate data to support the FCC's rule-making proceedings.

The transmitting antennas for the on-going WLS tests consist of butterfly for horizontal polarization and a modified Model BFB fm panel for circular polarization. These antennas were designed, built, and tested at the RCA Antenna Engineering Center in Gibbsboro, N.J.[3] During the tests, the signals were transmitted alternately in the horizontally polarized mode and in the circularly polarized mode, while measurements were made or pictures observed and rated.

Although many aspects remain to be proven by practical experience, the principal conclusions are as follows:[4]

1) The coverage of the circularly polarized signal, based on the horizontal component only, remains substantially the same as for the conventional horizontally polarized transmission mode. This is construed to mean that depolarization of the signal is minor and, therefore, any potential for additional co-channel and adjacent-channel interference does not exist. No change in the allocation table is indicated.

2) Pictures transmitted in the circularly polarized mode and received with circularly polarized receiving antennas suffer substantially less deterioration by ghosts.

3) Adjustment of rabbit-ear antennas is easier for the circularly polarized mode, but once the setting is optimized the picture quality is about the same for each mode of transmission.

4) Rabbit-ear antennas on existing installations, randomly oriented, give more ghost-free pictures when circularly polarized transmission is received.

5) Circular polarization reception with rabbit-ear antennas appears to be less sensitive to movement of people in proximity to the antenna.

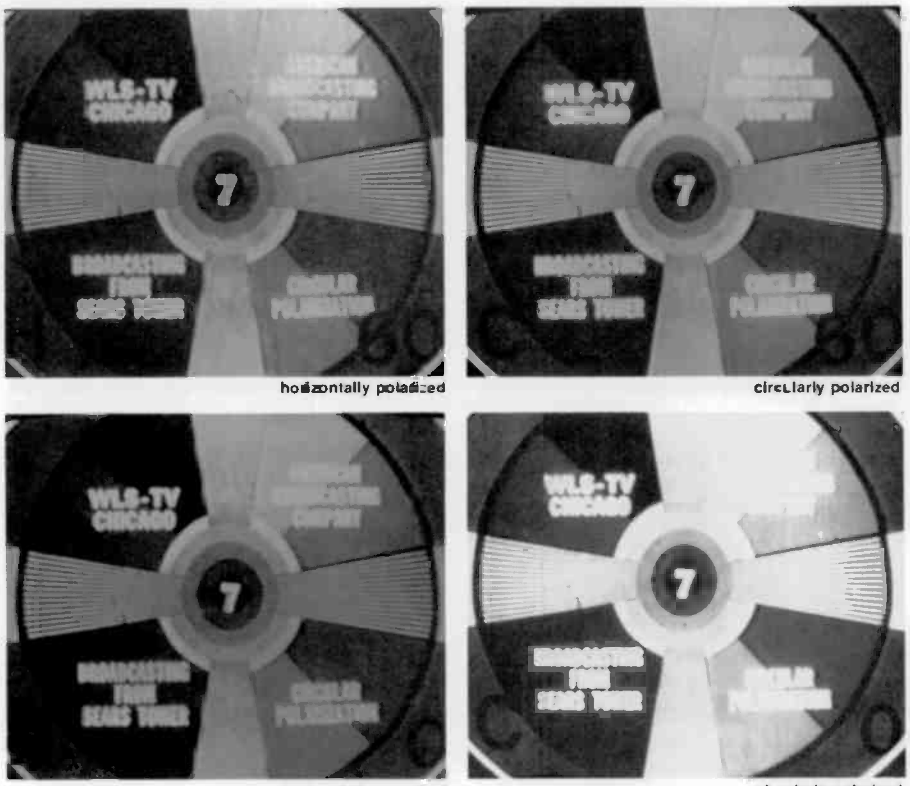

Fig. 9
Circular polarization "forgives" a receiving antenna misorientation of 60° in WLS field tests. Orientation of 60° and 0° with horizontal polarization (left); orientation of 60° and 0° with circular polarization (right). (The 0°-orientation is shown for reference.)

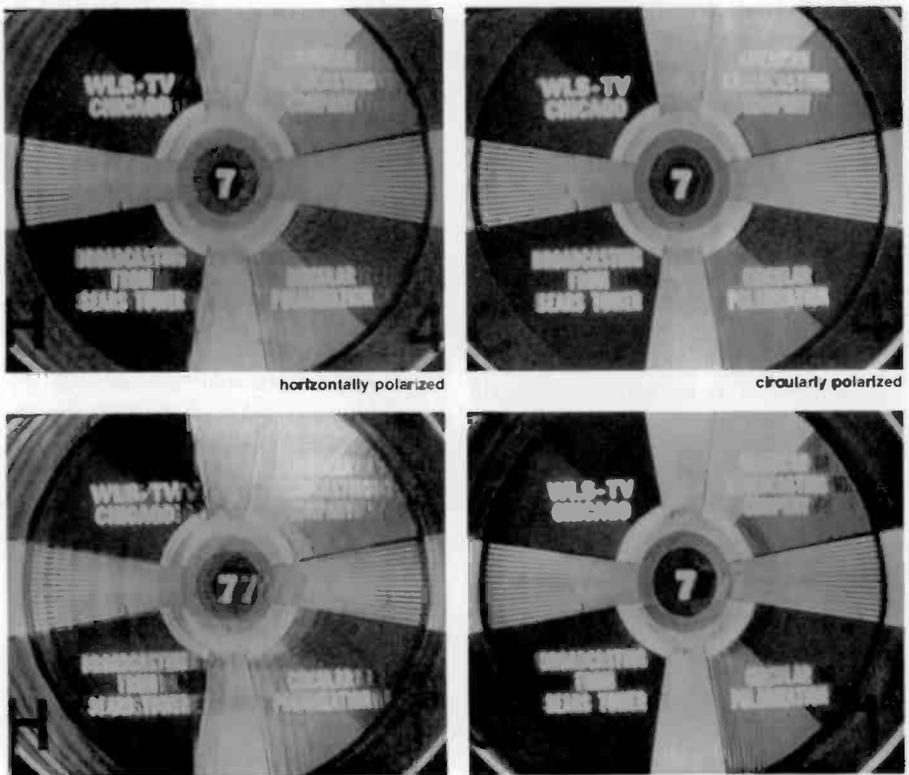

Fig. 10
Television receiver displays at two random locations (#4 and #1) during WLS tests demonstrate the superiority of circularly polarized system. Reception of horizontally polarized transmission at #4 and #1 (left); reception of circularly polarized transmission at #4 and #1 (right).

Fig. 9 compares the reception of horizontally and circularly polarized signals with a receiving antenna misoriented by 60°. Fig. 10 shows ghost reduction in two random locations when a switch was made to the circularly polarized transmission mode and circularly polarized receiving antenna. Further data can be found in reports to the FCC by the American Broadcasting Company.[4]

As stated, WLS continues to operate successfully in the circularly polarized transmission mode. It should be noted that circular polarization is fully compatible with the present mode of tv operation, and CP signals can provide some improvement in reception with conventional receiving antennas. For best results, however, circularly polarized receiving antennas are required.

Implementation of circularly polarized systems

Planning of a circularly polarized transmission facility requires, of course, that various types of receiving installations be served.

Presently, the best tv receiving installations employ horizontally polarized antennas. However, vertically polarized whip and rabbit-ear antennas are numerous. Therefore, the planned CP transmitting antennas must provide proper signals for existing as well as future circularly polarized receiving facilities. Thus, the horizontal and vertical radiation patterns, gains, video responses and other parameters must be designed for all types of receiving systems and to reduce ghosting and interference.

If the transmitting plant location is new, the design must provide proper horizontal field intensities for present receiving antennas as well as a good circularly polarized signal for the new receiving installations. In upgrading existing transmitting facilities, no compromises should be made that would deteriorate service to existing receiving installations.

Since the FCC allows as much effective radiated power to be transmitted in the vertically polarized mode as in the horizontally polarized mode, either the antenna aperture (gain) or transmitter power could be doubled, or some lesser increase of both could be effected. In practice, however, any increase in aperture should be carefully scrutinized, since a narrower vertical beamwidth may deprive some nearby viewers of a signal they are accustomed to receiving. Doubling transmitter power may be the only way to provide better service to the public.

The uhf station operators have still further tradeoffs to consider, since only a few of the stations are transmitting at the maximum allowable effective radiated power of 5 MW. Therefore, if an increase in power is contemplated, a judgment must be made whether better service will be provided by increasing the existing horizontally polarized ERP or by adding a vertically polarized component to produce the circularly polarized transmitted signal. The decision will likely be guided by many factors, including local conditions and type of service planned.

Available hardware

Since the early seventies, major manufacturers have been planning for high power transmitter components and circularly polarized transmitting antennas, the principal items required for a circularly polarized transmission. The necessary power levels are easily obtained by paralleling transmitters. The major challenge in transmitter design was the development of economical and efficient combining and filtering networks needed for vhf channels at power levels of up to 100 kW.

Circularly polarized service for fm began with the use of two separate antennas, one for the horizontally polarized signal and another for the vertically polarized signal. Except for the initial cost, the system performed well, since two essentially independent services were provided. Today, of course, fm antennas employ special elements developed to radiate circularly polarized signals.

However, the early fm-type antenna will not suffice for tv, since good axial ratio, a crucial characteristic in ghost and interference reduction, is difficult to obtain with separate horizontally and vertically polarized antennas. Therefore, a major effort of antenna manufacturers has been the development of circularly polarized transmitting antennas.

Following the experimental antennas for WLS by RCA, and for uhf station KLOC by Jampro, several new products have been announced. Jampro offers its helical antenna design for vhf and uhf channels. The Harris Corporation makes a panel-type antenna for vhf channels.

The RCA circularly polarized antenna line now comprises four standard antennas.

The Tetracoil antenna, TCL16, for Channels 7-13, is a single-channel, top-mounted omnidirectional antenna (Fig. 11) consisting of three layers of pole-mounted helical radiators. Each layer has four interlaced helices radiating in the second mode; that is, the field rotates 720° around the periphery. The feed system divides the input power between the three layers. It also determines their phase relationships and alters their relative phases verses frequency; the latter in such a way that a proper "null-filled" radiation pattern is obtained and the video transfer response is optimum for the service area. The end loadings terminate each of the helices radiating the remaining power and maintain low vswr along the helices. The resultant, in the nature of a traveling wave, assures proper radiation patterns and vswr across a channel. Transmitter power of about 50 kW is required to provide the allowable 316 kW ERP in both horizontally and vertically polarized modes, or 632 kW circularly polarized power.

The Fan-Vee, Type TFV (Fig. 12) provides an omnidirectional CP service for Channel 2-6 top-mount applications.[6] The antenna uses four horizontally polarized "batwing" radiators and four vertically polarized "V-dipoles," each fed in turnstile fashion and operating in mode one (360° around periphery). A "branch-type" feed system provides the excellent stability required for low channel operation. The seven-layer "dual-layer" model in combination with a 50 kW transmitter is generally a cost-effective choice for an ERP of 100 kW. A four-layer "dual-layer" model could be built as a replacement for present six-layer horizontally polarized superturnstile type antennas, since windloadings are about equal. Some 60 kW of antenna input power is required for an ERP of 100 kW.

The RCA Quatrefoil, Type TBK (Fig. 13) is a basket-type panel antenna, for Channel 2-6 and can be side mounted for directional patterns or stacked for omnidirectional radiation. For omnidirectional service, three panels around the tower are required.

The Channel 7-13 *panel antenna*, type TBJ, is designed for small-crossection towers to provide directional or stacking capability. Panel antennas provide flexibility in radiation characteristics and gain, but generally with slightly higher noncircularity, windload, and cost.

Fig. 11
RCA top-mounted Tetracoil Ch. 7-13 antenna, Model TCL16, for omnidirectional service.

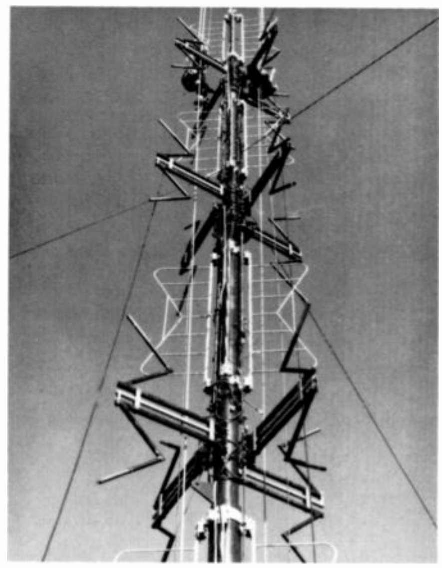

Fig. 12
Upper three layers of seven-layer Fan Vee antenna, Model TFV7A4, for tv station WTTV undergoing tests at RCA's Antenna Engineering Center in Gibbsboro, NJ.

Fig. 13
RCA Quatrefoil panel antenna, Model TBK, mounts on tower to provide directional service or stacking capability for omnidirectional service.

Some implications for equipment manufacturers

For more than two decades, horizontal polarization has been the only permissible mode of transmission for tv broadcasting. During this time, many new tv antennas have been developed—for more gain, to handle higher power, to sculpt special patterns—but always to radiate horizontally polarized waves.

TV broadcasters are studying with great interest the brilliant performance records of television station WLS which has been operating on CP by special authorization since 1974. Some are applying for permission to use circular polarization—use of which FCC has approved—to obtain the benefits in their particular areas.

Typically, conversion from horizontally polarized to circularly polarized transmission will require doubling the station's transmitter power. Some stations already have sufficient transmitter power capability for CP by way of available unused transmitter power rating or existing standby transmitter facilities that could be put into operation. Other stations would need to replace or add to their existing transmitter facilities in order to achieve double transmitter power. This requirement, plus the purchase of a CP antenna and possibly the installation of new transmission line, represents a substantial investment in new equipment.

On the other hand, many existing television transmitters and antennas are reaching normal retirement age and are already under consideration for replacement. This fact, plus the prospect of improved viewer reception, has caused the television broadcaster to take a careful look at the potential benefits of circular polarization.

In addition to the standard products mentioned, some manufacturers offer custom built transmitting antennas, and new ones will undoubtedly emerge.

No circularly polarized receiving antennas are being marketed as yet, although some manufacturers beside RCA are reported to be developing antennas. Of course, RCA manufactured the test receiving antennas for its part in the WLS experiment.

Circularly polarized tv—present and future

The experiments, though limited, indicated that the performance benefits closely followed theoretical predictions. There were no major surprises, either positive or negative; and FCC acted favorably in April 1977 to the petition by American Broadcasting Co.

Broadcasters in general have shown a high degree of interest despite the anticipated system costs. WLS, Chicago, continues its fourth year of eminently successful broadcasting in the circularly polarized mode. But this is only the beginning. WPBT, Channel 2, Miami, has just installed an RCA circularly polarized panel antenna which is meeting expectations and providing good reception on vertical and "rabbit-ears" antennas. KBYU is on-the-air with a Harris panel antenna. XETV, Channel 6, Tijuana, Mexico, is scheduled this winter to install a Fan-Vee antenna. A Fan-Vee antenna will be shipped to WTTV, Channel 4, Indianapolis, this winter. Further, RCA has under construction another Fan-Vee antennas for WRAL, Channel 5, Raleigh, N.C.

While circular polarization may not be of interest in all locations, one or more of its advantages should improve service enough to warrant the cost expenditure.

A better penetration of signal may be very important in some urban areas, or circular polarization may offer a welcome relief in ghost-ridden places. For the broadcaster interested in covering every mile of fringe area, the circularly polarized mode of transmission offers the most promising opportunty available today. It is therefore expected that a great number of broadcasters will adopt circular polarization for tv broadcasting, and promote the system to the public for mutual benefit.

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4. Four ABC Reports to FCC on Circular Polarization.
5. Paper presented at Broadcast Consultants Seminar, Washington, D.C. (Sep 1977) and to be published in the *IEEE Broadcast Transactions* this spring.
6. Paper to be published in the *IEEE Broadcast Transactions* this spring.

Reprint RE-23-4-3
Final manuscript received November 17, 1977.

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Long-line communication in Alaska—then and now

Climate, terrain, and population density, the factors that once made Alaska a communication engineer's nightmare, are now making Alaska the forerunner in effective satellite communications.

J.L. Rivard

Alaska's communication environment

There seems to be a tradition that every article written about Alaska must overflow with superlatives. Among the ones usually mentioned are vast distances, a harsh climate, and a sparse population. Undoubtedly, some of the statements are truthful. It is true, for example, that the state's current population is around 400,000, which corresponds to a population density of 2/3 person per square mile. People who enjoy the wide open spaces may prefer this density, but it presents major problems to the communication engineer.

Typical articles on Alaska also include a frightening reference to the climate. Permafrost does occur in approximately 80% of the state, in some areas to a depth of 2000 feet, and it presents a special challenge to the construction engineer. It can lift a telephone pole out of the ground in a surprisingly short time, but an antenna properly frozen into the permafrost could remain fixed until Alaska again becomes tropical. Along the southern coastline of the state, from Ketchikan to Attu, it rains—and rains—and rains. At higher elevations it snows, and at intermediate levels there is almost continuous fog. The communication engineer searching for a site to build a microwave repeater must be especially cautious. Snowfall, which can exceed 800 inches per year along the coastal range, could easily bury a repeater site, including the antenna. Foggy peaks are often inaccessible, even by helicopter, for weeks at a time.

Every article on Alaska must also mention mosquitos. The legend that large Alaskan mosquitos are frequently refueled by mistake at remote Air Force Bases is not generally true—it has happened only twice.

The early days

It once took a year for a message to travel both ways between Alaska and Washington, D.C.

Modern communication history in Alaska began in 1741 when Vitus Bering, a Dane sailing under the Russian flag, discovered what is now southeast Alaska. Bering, himself, did not complete his voyage of discovery; his ship was wrecked as it neared home, and Bering and many of his crew are buried on an island in the Northern Pacific Ocean named for the explorer. There is no doubt that little would have been heard of the first Russian discoveries in America for some time, if ever, had it not been for the beautiful furs brought back from Bering Island. In 1790, Alexander Baranof sailed from Siberia to firmly establish the Russian presence in Alaska. Baranof presided over the colonies for 30 years, a longer term than that of any of his successors during the 126-year period of Russian rule.

Communications in Alaska had not changed much by 1867, when Russia sold its interest in Alaska to the U.S.A. for $7.2 million. The U.S. Army formally took possession at Sitka on May 30, 1867, and regular communication was established between the new base at Sitka and headquarters in San Francisco. Ships could then sail that distance in about 15 days. To send a message from interior Alaska to Washington, D.C. and back generally required a year's time.

The real beginnings of Alaskan communications

If there is a single factor linked to the establishment of communications in Alaska, it is the discovery of gold in the Klondike Region in 1895.

The boundary between Alaska and Canada had never been defined and both countries now realized its importance. To protect American interests, and until the matter was settled, the United States Army again occupied the Territory. The Army soon learned that it had a far bigger problem with gold hunters in a practically lawless Alaska than it had in a boundary dispute with Canada. Within the next few years, prospectors were finding gold in many sections of the Territory; the Army followed them with a string of forts located primarily along the Yukon River. The Army was still the only form of government in the Territory and urgently needed a long-lines communication network interconnecting its new permanent bases with each other and with higher headquarters.

The early telegraph system was for the military first, civilians second.

On May 26, 1900, Congress passed an Act that established the Washington-Alaska Military Cable and Telegraph System, or WAMCATS. This Act expressly stated that the system would provide commercial service whenever this function would not adversely affect military traffic. Congress provided $450,000 for telegraph and cable lines connecting Department of Alaska Headquarters, at Fort St. Michael near the mouth of the Yukon, with other Army posts in the Territory. Alaska soon had its first long-line carrier, but did not have a circuit to the continental United States.

Reprint RE-23-4-8
Final manuscript received December 8, 1977.

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Elihu Root, Secretary of War during the McKinley administration, was determined not to make our communication dependent on another nation. (An interesting contrast to the recent decision by President Carter to transport natural gas from Alaska fields to the 48 states via a Canadian pipeline.) Additional funds were made available in 1903 and 1904 for submarine cables to connect Seattle with Juneau and to extend service to Valdez. Commercial business over these facilities was permitted insofar as deemed equitable and in the public interest by the Secretary of War.

The first wireless system had unusual maintenance requirements.

The year 1907 saw the beginning of the wireless system that eventually replaced the land lines in Alaska. The probable driving factor behind this decision was the high cost of maintaining the land lines. During 1904, there were over two hundred outages on the circuit, divided almost equally among blizzards, sleet storms, high winds, forest fires, and vandalism.

These early wireless stations were of the spark type. The 60-cycle, 500-volt output of the alternator was stepped up in a heavy transformer to 20,000 volts. This high voltage charged a Leyden-jar condenser, which discharged across a spark-gap formed by two metal rods. The radio energy thus produced coursed through a massive helical coil which had the terminals connected to the aerial and a ground system. The sending key was a heavy metal bar, a foot and a half long, to which was attached a hard rubber handle. After every six or eight messages, the operator was forced to shut down the transmitter and file the contacts, which became pitted by the arc that formed each time the key was opened.

Cables became so deteriorated that no one could understand why they continued to operate.

During the 17 years between the completion of the original submarine cable installation in 1906 and the close of 1923, little changed with the WAMCATS cables. A few route alterations and short cable additions were made. However, the cables had deteriorated so during those years that, despite the efforts of maintenance personnel, interruptions to cable service totaled 743 cable-days for the fiscal year 1924 and 1139 cable-days during the next fiscal year. The Seattle-Sitka cable, when laid in 1904, had an insulation resistance of four megohms. By 1924 it had dropped to 2000 ohms including the copper resistance to the faults. Cable theory does not readily explain why this cable had continued to operate satisfactorily.

In this period, the United States Army Signal Corps was also the commercial communication system in Alaska. Seemingly the very life of the entire Territory depended upon it—the economic development, the business, the administration of government, and the dissemination of news. Published figures reveal that from its inception, the system handled an ever-increasing amount of business, so that the value of traffic handled in 1924 amounted to over $400,000. This message traffic was about equally divided between commercial traffic and that of the various government agencies operating in Alaska. So, one can readily see

Just what does Alascom do?

RCA Alaska Communications, Inc. is the certificated long-lines communication carrier for message service in Alaska. This item of news is still, unfortunately, not widely known. The fact that some parts of this country are not now, and have never been, served by AT&T, or "Ma Bell," can still win bets in many a corner establishment. Throughout the entire length and breadth of the state of Alaska, all long-line (as opposed to local) message telephone service is provided by RCA Alascom.

Alascom, as the long-lines carrier in Alaska, is responsible for the design and development of a network that will allow a small number of persons, living in each of several hundred communities widely scattered about the state, to enjoy communication service similar to that which is available in the remainder of the country. The network design should result in an overall system that can be installed and operated at the lowest user cost. This interesting and exciting engineering challenge is underway today.

why Congress, in 1923, appropriated $1,500,000 for a new cable to connect Alaska with Seattle and replace the worn-out cables.

With funds now available, a study determined the routing of the new cable. Seward, the terminus of the Alaska Railroad, became the northern terminal instead of Valdez. The main relay point was established at Ketchikan, with one cable running south to Seattle and two branches running north to serve southeastern and central Alaska. The Seattle-Ketchikan-Seward cable was completed on October 10, 1924. The cable era ended on December 1, 1931, when use of the Seattle-Ketchikan cable was discontinued and all traffic between the United States and Alaska and within Alaska was handled by radio. The Seattle-Ketchikan and Ketchikan-Seward cables, while not in use, were still in excellent operating condition and tested daily. Even the system's name changed. The designation "Washington-Alaska Military Cable and Telegraph System" was changed by an Act of Congress, approved May 15, 1936, to "Alaska Communications System," or ACS.

The Second World War

World War II affected Alaska and its communications profoundly.

Alaska became a cornerstone of American defense and a bridge to Russia during World War II. Alaska was the site of the only armed invasion by foreign troops on the North American continent during the war. Communications were so poor during the early days of the war that the Japanese were able to bomb Dutch Harbor on the island of Unalaska with unalerted American fighter aircraft only forty miles away on Umnak Island. It was the Japanese attack on Dutch Harbor and their occupation of the Aleutian Islands of Attu and Kiska that convinced the War Department that Alaska's communications had to be upgraded immediately.

On December 9, 1941, certain radiotelephone circuits between Alaska and Seattle were withdrawn from commercial use and assigned to military traffic only. This was the first clear distinction to be drawn between military and public use of ACS.

As the enemy's grasp upon Alaska was pried loose and the pressure of defense operations lessened, ACS facilities were again made available for nonmilitary use. The first big break came in July 1944, with the reopening of the rehabilitated Seattle-Ketchikan and Juneau-Ketchikan ACS links to public and commercial messages.

The cold-war period

White Alice, DEW, and BMEWS were all part of the cold-war communications buildup.

As a result of the tremendous wartime expansion, civilian Alaskans had the use of a much improved communication system linking them with the southern 48 states after World War II. But then, the outbreak of the Korean War in 1950 caused another general build-up for the military in Alaska, and so placed a severe strain on Alaska's communications. ACS embarked on a 6-year, $10-million construction program of expansion and modernization. ACS built a new submarine cable system from Skagway to Ketchikan, where it met a new AT&T cable coming from Port Angeles, Washington. The AT&T cable was initially equipped with 36 channels, but was expanded to 48 in 1974. These two cables are in use today.

The White Alice Communications System (WACS) was a product of the Cold War. The Air Force asked AT&T to study the possibility of creating a fixed multichannel communications system. From this grew the technique first referred to as "Forward Propagation by Tropospheric Scatter." A network of tropo stations, coupled with microwave in the high-density areas, was submitted as a solution to the communication problems in Alaska. A series of Aircraft Control and Warning (AC&W) sites had been built and the communication system known as White Alice soon followed. The WACS began service in 1956, making high-capacity, high-quality, and very-high-reliability communication available to the various users, including the general public.

The Distant Early Warning (DEW) Line under the Alaskan Air Command was extended out the Aleutian chain to Nikolski in 1959 and on to Shemya two years later. The Ballistic Missile Early Warning System (BMEWS), established by the Air Force at Clear, Alaska in 1961, required more sophisticated and highly reliable communications.

Alascom enters the scene

Since 1904, when the telegraph line was completed, the military had tried to withdraw from its involvement in Alaska's commercial communications.

But it was not until 1967 that Congress passed Public Law 90-135, the Alaska Communications Disposal Act. The first system to go on the block was the Alaska Communications System. RCA Global Communications, Inc. submitted the winning bid of nearly $28.5 million, and on Jan 10, 1971 the

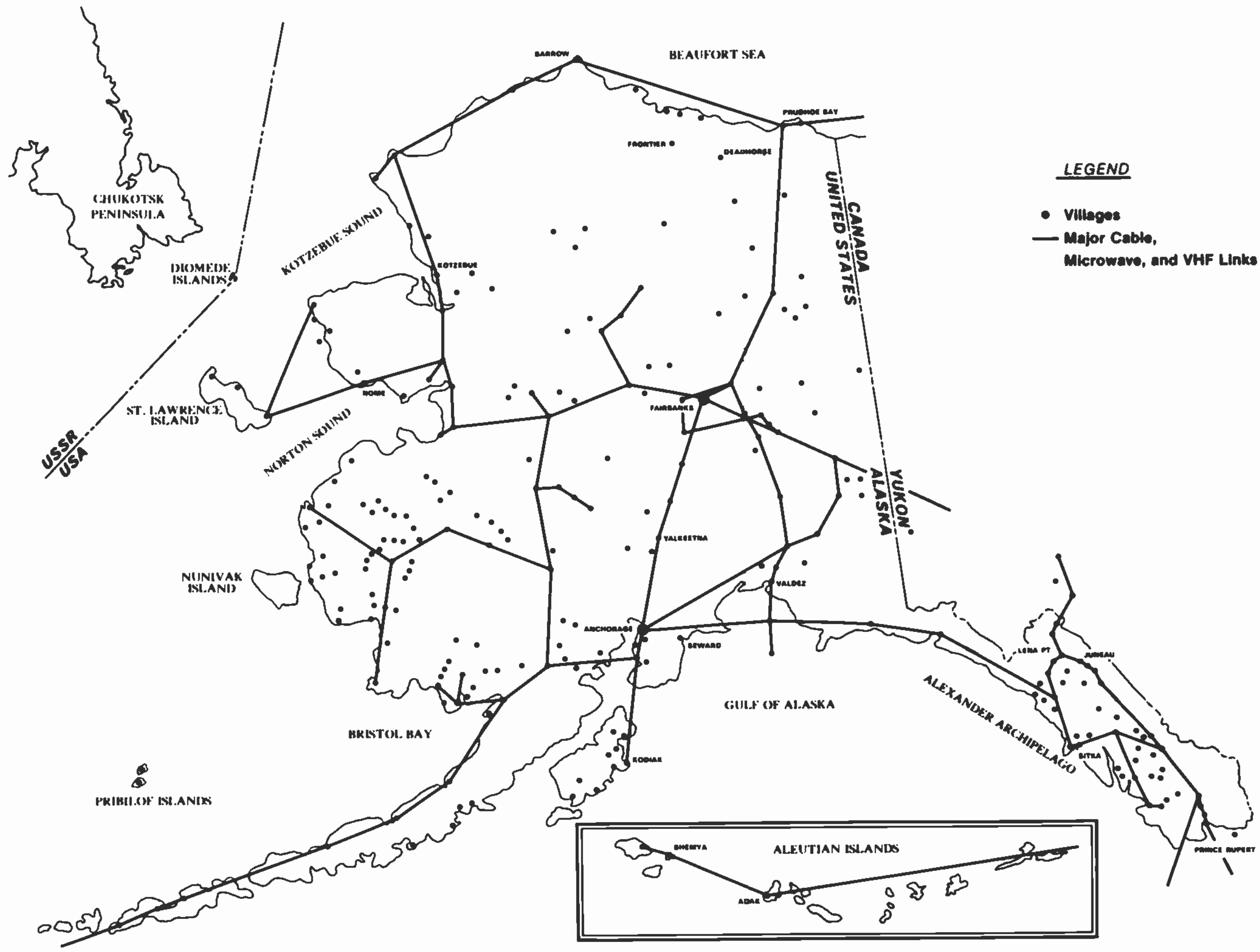


Fig. 1
In the beginning. This is the communication system that existed in 1971, when RCA took over the commercial outlets of the military system. Most, but not all, of the villages were connected to the system by high-frequency radio links.

ACS was transferred from the Air Force to the newly formed Alascom.

What RCA had purchased was the commercial outlets of the military system. Very little of the actual long-line system was sold. Alascom was established in Anchorage as the owner of four toll centers, a VHF marine radio network, open-wire and submarine-cable lines, and some isolated VHF radio endlinks. The Air Force retained, and still owns, the major long-haul terrestrial transmission network within the state. Fig. 1 shows the network as it existed in January 1971.

Alascom faced a multitude of problems. For one, it was a network without a network.

Alascom was the certificated long-lines carrier for the state, but the ACS facilities that had been puchased were not, *per se*, a long-lines network. More than two-thirds of the communities without adequate communications were remotely located and unable to even use WACS circuits, if any had been available. Key segments of the WACS were operating at capacity.

A preliminary evaluation of the communication needs of the state indicated that: 1) the WACS was already operating past its design life; 2) the network could not provide the required number of voice channels or accommodate wide-band circuits; 3) the network was grossly inefficient to operate and maintain; 4) the network would have to be excluded from long-range plans; and 5) a long-range plan to provide statewide communications would require a completely new long-haul transmission system and an extensive capital outlay.

Alascom's initial action was to install temporary facilities where the service demand was greatest and to begin the construction of permanent installations. The major temporary facilities that were added consisted of multiplex overbuilds to relieve the bottlenecks in the WACS. Early permanent facilities included four new microwave systems: Lena Point to Sitka, Anchorage to Talkeetna, Fairbanks to Talkeetna, and Anchorage to Seward. A new tropo link was added between Barter Island and Frontier Camp in the Prudhoe Bay area. New toll-switching machines were installed at Anchorage and Fairbanks and brought the first direct-distance-dialing service to Alaska. Service was ex-

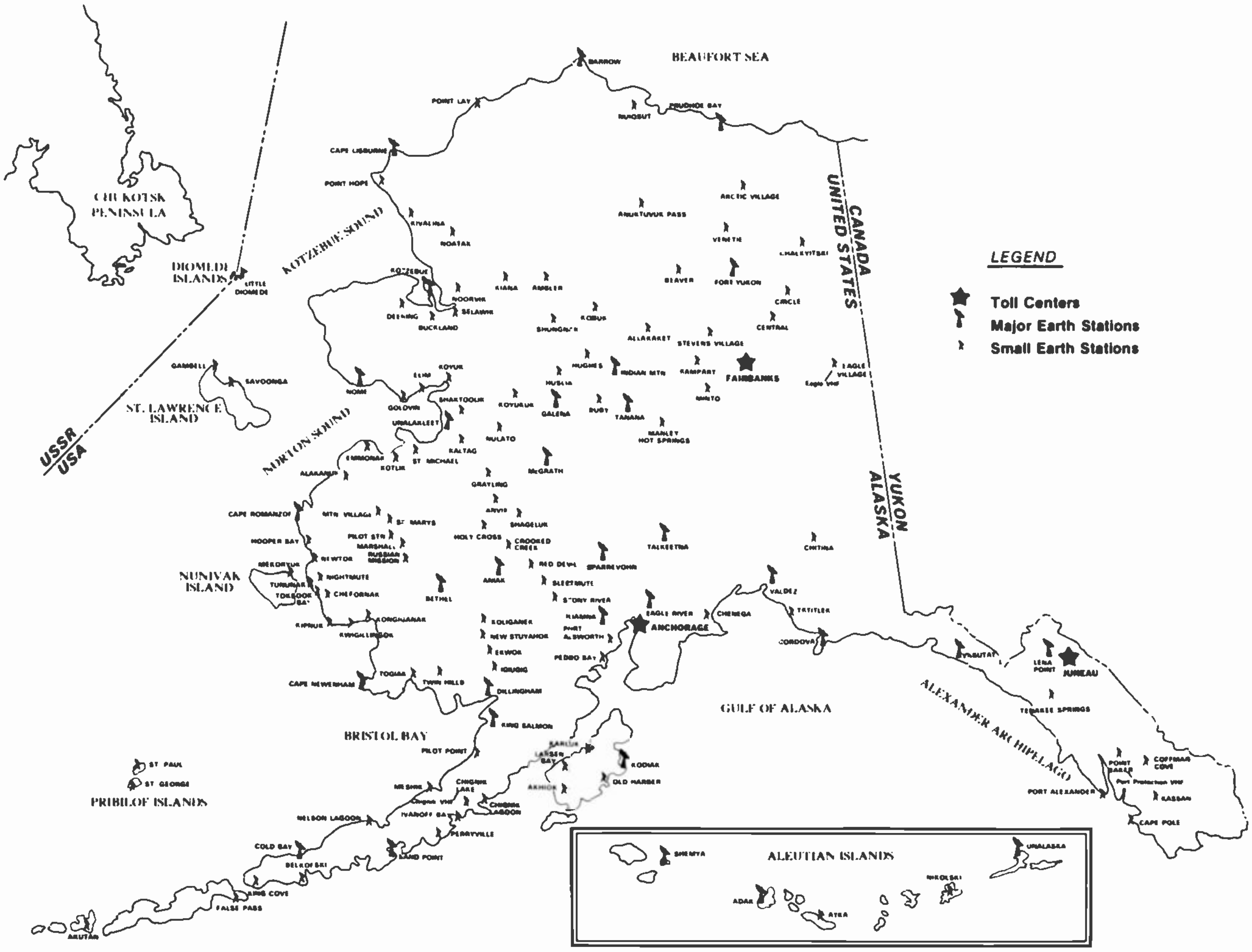


Fig. 2
The near future. Alascom's earth-station network as it will appear in 1980.

tended to additional villages in the Bush Telephone Program. The Class II-B Coastal Harbor Network was upgraded. Also, in keeping with new FCC regulations, Class III-B marine vhf service was provided from 14 locations. This service uses international channel assignments and is available to vessels of all nations.

In its offer to purchase the Alaska Communications System, RCA had proposed to proceed promptly with plans for a domestic satellite system for Alaska.

In 1973 Alascom purchased the Bartlett earth station from COMSAT and constructed the Lena Point earth station. Together with RCA Globcom, the nation's first operational domestic satellite system was inaugurated on December 20, 1973 using Telesat Canada's Anik satellite. Anik provided satellite circuits to Alascom at about one-half the cost of the Intelsat system and paved the way for extended satellite communication service to Alaska.

In 1974 Alascom installed earth stations at Valdez, Prudhoe Bay, Nome, and Bethel. A new class-5 switch was installed at Deadhorse for the development of the Prudhoe Bay oilfield, the first local service provided by Alascom.

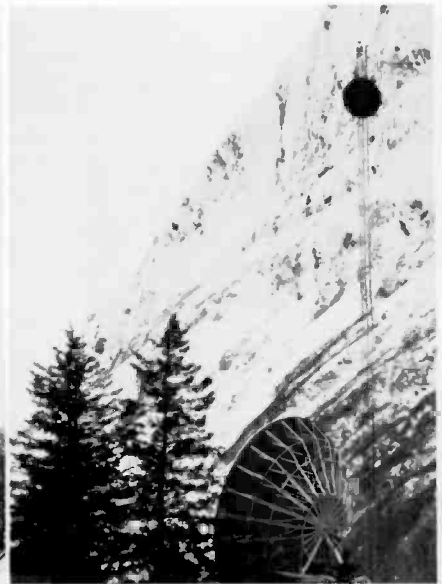
In May 1975, the FCC ordered Alaska traffic to be switched to Western Union's WESTAR Satellite. Alascom continued to lease transponders on WESTAR until the FCC authorized interim transfer to the RCA Satcom System in May 1976. The FCC has not yet ruled on who will be permanently authorized to provide satellite service to Alaska.

The first electronic toll-switching machine went into service in 1975 at Lena Point. Later in 1975, the Angoon-Ketchikan microwave system was completed and direct distance dialing was extended to the southeastern areas of the state from the Lena Point switch. In February 1976, the new Anchorage Primary Switching Center was placed into service. Also in 1976, Alascom turned up earth stations at Cordova, Yakutat, Gilmore Creek, and two pipeline pump stations, and constructed five transportable earth stations, including one standby unit.

Alascom now

In 1976 the Air Force agreed to lease the WACS to Alascom, ending a period of 76 years of service by the military to the state. The lease requires Alascom to replace the tropospheric scatter portion of the WACS with a modern




system relying primarily on twenty-one new satellite earth stations within 27 months, commencing July 1, 1976.

A major gateway earth station, equipped with a pair of 51-foot antennas, is under construction near Anchorage. The earth station will be interconnected to the Anchorage toll center with a twelve-tube coaxial cable. Alascom will have approximately 45 gateway, mid-route, and transportable earth stations in service by 1979.

Alascom also has an agreement with the State of Alaska to install 100 small earth stations in bush communities by the end of 1977.

Television-receive capabilities have been installed in 23 of the bush stations as a part of a state-funded experimental program. The map in Fig. 2 shows the earth-station network as it will appear in 1980. Present plans are to route approximately 70 percent of the interstate traffic via satellite and 30 percent terrestrially. Traffic to rural Alaska will rely almost exclusively on satellite, while all high-density intrastate and interstate routes will be backed up by terrestrial alternatives to ensure uninterrupted communications.

Ways to improve the satellite communications system and reduce costs are constantly being sought. In addition to dramatic decreases in space-segment costs, recent hardware developments have lowered the price of ground-segment components, notably low-noise amplifiers. Unfortunately, these decreases are being offset by cost increases for other components, notably antennas. Alascom is actively investigating new developments such as demand assigned multiple access (DAMA) systems. An extensive investigation has been conducted into single-channel-per-carrier systems and companders, and an investigation into frequency-division-multiplexed companders is presently in progress.

Tests are now being conducted on developmental hardware that will allow bush earth stations to be connected more easily with new local telephone exchanges.

The Alaska Public Utilities Commission is currently holding applications from several telephone companies seeking permission to install these local dial offices in most of the bush earth station locations. Formal hearings by the Commission are scheduled to start before the end of 1977. Installations will follow and Alascom is expected to be ready with a sufficient number of trunks. The intent is to remain current in the state-of-the-art of satellite communications and also seek ways to improve service and reduce costs.

Conclusion

In the era of terrestrial communications, particularly land-line facilities, the density of Alaska's population was an extremely significant economic factor; but today, with satellite communications, the distance between population centers is of little consequence. Thus, the characteristics of Alaska that in the past have worked against the development of communication systems are now working in favor of Alaska, making it the forerunner in the effective use of satellite communications.

In conclusion, the communications history of Alaska can be summarized in four chapters.

The first began with the gold rush at the turn of the century, which brought the Army and its need for communication. Commercial service was available to those persons who happened to live near the military stations.

The second chapter is associated with World War II. The tremendous military buildup throughout the state included an accompanying communication network.

The cold war of the 50s brought the largest effort to date. An extensive communication network criss-crossed the state, but again the facilities were designed to satisfy military requirements.

The fourth and final chapter is the story of RCA Alascom. Now, for the first time in Alaska's history, the communication needs of the entire population are being considered. Everyone—both the military and the local communities—will be able to receive service, wherever they happen to be located.

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Statistical coding methods speed up image transmission

M.E. Logiadis

Advanced encoding techniques allow documents to be transmitted over standard communication lines at ten to eleven times the uncoded rate.

Quite often, cost/performance considerations keep common-carrier communication-channel bandwidths too narrow for the message being transmitted. Thus, to successfully transmit a message with bandwidth requirements wider than those of the available communication channel, the information is "compressed." The techniques that produce this data compression are frequently based on non-statistical properties of information sources. Rather than exploit the statistical properties of the sources, these methods take advantage of the receivers' ability to tolerate some distortion and still correctly interpret the message. In this article, however, we will concentrate on data-compression techniques based on the statistical nature of information.

Principles of encoding

Most source symbols appear with unequal frequency, and this is where the usefulness of statistical coding lies.

Encoding capitalizes on the unequal frequencies of source symbols by assigning codewords of the shortest possible length to symbols with the highest frequency. This is achieved by statistical encoding, a technique that translates source symbols into a new set of codewords, according to the symbols' probability distribution.

For example, Morse code uses a single dot for *e*, the most commonly occurring letter in the English language. The letter *q*, on the other hand, occurs quite infrequently and so has the lengthy code of dash-dash-dot-dash.

Coding applications in image transmission

Images are inherently highly redundant. Eliminating the redundancy from the transmission media produces a significant reduction in the amount of transmitted data. Consider, for example, a black-and-white document. We notice with tv-type scanning, the transitions from white to black and vice versa are relatively few. Various techniques have been developed to remove redundancy. The following ones are the most important and have wide applications in image transmission.

Table Ia
Variable-length relative address code (RAC) assigns the shortest lengths to the shortest distances from the "standard elements." The code is a combination of unique codes and F(N) RLC codes of Table Ib.

Distance	Code
+0	0
+1	100
−1	101
N (N≥1)	111 F(N)
+N (N≥2)	1100 F(N−1)
−N (N≥2)	1101 F(N−1)

Run-length coding (RLC) takes advantage of the above-mentioned distribution of transitions to remove redundancy.

As its name implies, this technique encodes black/white run-lengths between transitions. Codes are based on the probability distribution of such runs for several documents. An optimum code assigns codewords inversely proportional in length to the probability of occurence of run lengths. However, implementing this code in image transmission requires a large memory, which makes the equipment quite bulky and costly. In practice, therefore, the average length of a code is usually longer than in this optimum situation.

There are several RLC codes. An example of a variable-length RLC code, which assigns the shortest code lengths to the most frequent runs, is shown in Table Ib. Note that the runs 1-4 are coded with the

Table Ib
Variable-length code assigns the shortest code lengths to the runs that occur most frequently. This code supplements some codes in Table Ia; asterisks stand for all the binary representations of each group of runs. For example, F(20) = 101111.

N	F (N)
1~4	0**
5~20	10****
21~84	110******
85~340	1110********
341~1364	11110**********
1365~5460	111110************

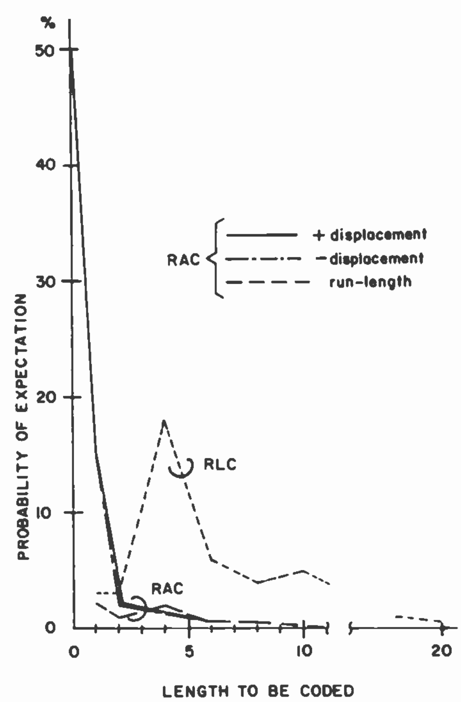

Fig. 1
Distance between white/black transitions has this probability distribution for an English-language document scanned at 200 x 200 lines per inch. RLC is for run-length coding, RAC is for relative address coding.

shortest code lengths, as they appear with the highest frequencies.

The code in this table is based on the probability distribution of black/white run-lengths (Fig. 1) for the standard CCITT digital fax chart #1 (English text). This RLC code achieves a data-compression ratio of 9 at a resolution of 100 × 100 lines per inch. At a data rate of 4800 b/s, the standard document will be transmitted in 25 seconds.

As stated earlier, the effectiveness of a run-length code depends on the probability distribution of black-and-white run-lengths. Since no two documents are alike, the RLC code generally favors documents with run-length probability distributions closely resembling that of the document for which the code was designed.

In reference encoding, a black/white transition on the line being scanned is referenced to previous transitions on the preceding and present lines.

In the example shown in Fig. 2, these reference entries are used as follows:

Left (*L*)—transition one position to the left of the previous line transition.

Right (*R*)—transition one position to the right of the previous line transition.

Same(*S*)—transition one position below the previous line transition.

The reference-encoding method also uses RLC to code transitions that cannot be coded by reference encoding. Take, for example, the transition at position #20 in Fig. 2. This transition cannot be coded as "S" because of an unused transition at position 18 in the preceding line. To avoid error, we have to use RLC to code the run-length between the transition at position 20 and the previous transition at position 17. Therefore, RL = 3.

Transitions encoded by the reference technique are termed *reference transitions*; all others are termed as RLC transitions. Several reference transitions, such as "S - L - L - . . . . . S," can be grouped and encoded according to the probability distribution of these runs. The combinations appearing most frequently are assigned short-length codes, with the longer-length codes reserved for the least frequent combinations. Generally, reference encoding offers an average increase in data-compression ratio of approximately 25%

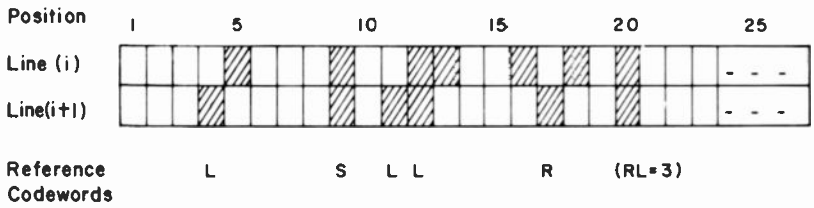

Fig. 2
Reference encoding achieves shorter codes by referring to the transitions in the preceding scanned line. "L" indicates transition one position to the left of the transition on the line above; "R" indicates a transition one position to the right of the transition on the line above; and "S" indicates a transition directly below the one above. Run-length coding is used for situations that do not fall into these categories, as with the transition at position 20 in the second line. If "S" were used, it would erroneously refer to a transition at position 18. An RL = 3 code solves the problem.

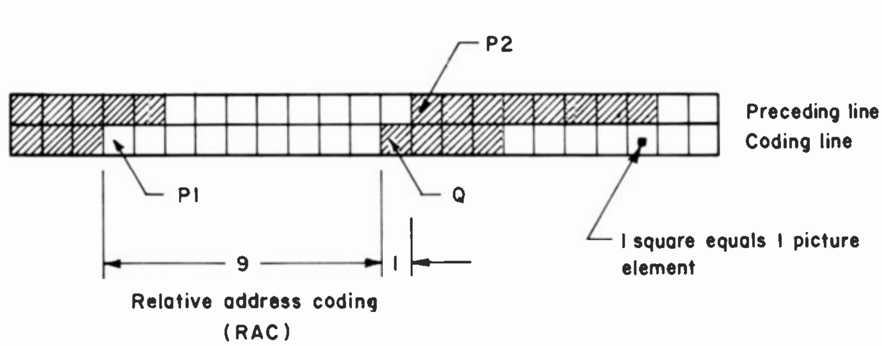

Fig. 3
Relative address coding (RAC) encodes transition at *Q* by determining its distance from the "standard element," which is either *P1* or *P2*, according to the formulas given in Table II and text. Method is more complex than run-length coding, but faster.

over the RLC technique for photograph-type images. However, for certain black-and-white documents, the increase approaches 100% over the RLC technique. Reference encoding requires many reference transitions and many high-order run lengths to be effective. The hardware of reference encoding is therefore usually more complex than RLC and so is more costly.

Relative-address coding (RAC) is similar to reference encoding, but achieves higher data compression.

Relative-address coding (RAC) is used by Kokusai Denshin Denwa Co., Ltd. (KDD) of Japan in their "Quickfax" terminal. For a brief description of relative-address coding, consider the two sample scanning lines of a black-and-white document in Fig. 3. Suppose we want to code transition element *Q*. Two transition picture elements are already encoded, *P1* (last transition element on present line) and *P2* (transition picture element on preceding line nearest to *Q*). If neither reference element exists, *P1* is taken as the first picture element of the present line and *P2* is taken as an imaginary element next to the last picture element of the preceding line.

The coding for transition element *Q* is determined by its distance from the "standard element" that is selected from the two transition elements *P1* and *P2* as follows:

If the distance between *P1* and *Q* is more than one picture element and less than the distance between *P2* and *Q*, *P1* is selected as the "standard element." The distance from *P1* to *Q* is always expressed in picture elements. In all other cases, *P2* is selected as the "standard element" and the distance from *P2* to *Q* is expressed in picture elements with a plus, a minus, or no sign. A plus sign indicates *P2* is above and to the left of *Q*. A minus sign means *P2* is above and to the right of *Q*. No sign means that *P2* is just above *Q*.

Table I gives the code; Table II shows how the "standard element" is selected, along with the definition of signs for the distance of *Q* from the "standard element."

Since the first line of a document cannot be referenced to a preceding line, it is always

Table II

Relative address coding (RAC) requires determination of the "standard element" and sign to go with the distance from the standard element. Distances are measured in picture elements.

RELATION BETWEEN $\overline{P_1Q}$ AND $\overline{P_2Q}$	STANDARD ELEMENT
$\overline{P_1Q} < \overline{P_2Q}$	P_1
$\overline{P_1Q} > \overline{P_2Q}$	P_2
$\overline{P_1Q} = \overline{P_2Q} = 1$	P_2
$\overline{P_1Q} = \overline{P_2Q} \neq 1$	P_1

STANDARD ELEMENT	ADDRESS RELATIONS BETWEEN Q AND P_1/P_2		SIGN(+)(−)
P_1	$\overline{P_1Q}>0$	P_1 is on the left of Q on the same line.	No-sign
P_2	$\overline{P_2Q}\gtreqless 0$	P_2 is just upon or on the left of Q on the preceding line.	(+)
	$\overline{P_2Q}<0$	P_2 is on the right of Q on the preceding line.	(−)

Table III

Compression factor for RAC is superior to that for RLC by about a factor of 2 for a standard English-language document, but compression factor and transmission time vary significantly with different document types.

RES.	CODING	DOCUMENT 1	2	3	4	5	6	7	8
8x8 200x200 L.P.I.	RAC	28.0	48.9	18.2	7.1	16.1	30.0	7.3	27.0
	RLC	12.9	14.9	7.6	4.3	7.2	9.6	4.3	8.6
4x4 100x100 L.P.I.	RAC	13.7	24.5	9.1	3.5	7.9	15.8	3.6	13.5
	RLC	9.0	9.2	5.3	3.16	5.03	6.49	3.05	5.4

CCITT TEST DOCUMENT	TRANSMISSION TIME (SEC.)	
	RLC METHOD	RAC METHOD
1. Letter	25	19
2. Circuit	23	11
3. Invoice	40	25
4. French	72	63
5. French	45	30
6. Graph	34	15
7. Japanese	73	62
8. Memo	45	18

coded in RLC. One disadvantage of RAC is that an error caused by the communication media will propagate to all lines following the line in which it occurred. In a 4-wire communication system, this can be avoided by retransmitting the line in error. The return path is used to notify the sending terminal that a line was received in error and request its retransmission.

The protocol employed to control the link between the terminals is the High-level Data Link Control (HDLC) adopted by the International Standards Organization. In two-wire operation, a hybrid approach is being used to stop error propagation, i.e., both RAC and RLC techniques are interleaved over K scanning lines as follows:

> If K is chosen as 1, then every line is RLC coded. For K=4, the first line is RLC coded, lines 2, 3, and 4 are RAC coded, the $K + 1 = 5$ line is RLC coded, etc. Thus an error in line 2 propagates to line 4 and stops there. In a two-wire system, retransmission of a block in error is possible, but time-consuming because of the turn-around delay encountered in reversing the direction of transmission. For this reason, the RAC technique is mostly used in four-wire systems with K=∞. (Remember, the first line is always RLC coded.)

Getting back to Fig. 1, we observe that the distribution curves of RAC are more or less exponential, with the probabilities corresponding to displacements 0, −1, and +1 equal to 0.5, 0.13, and 0.13, respectively. Hence, the displacement from the "standard element" is not greater than one picture element 76% of the time. This observation suggests that the codes employed for these most frequent displacements should have minimum lengths. The other, not-so-frequent displacements (24% of the time), are represented by codes with longer lengths. This method of coding therefore produces a significant data compression and reduces the transmission time for certain types of documents.

Table III shows the transmission time and the compression ratio for CCITT test charts 1-8 using both the RAC and RLC techniques. It is evident that the RAC method of encoding is superior to the RLC method by a factor of approximately 2:1. However, as with reference encoding, the electronics required to implement RAC encoding are far more complex and costly than for RLC. Another disadvantage is that although the RAC technique is quite effective in four-wire systems, it is not so effective in two-wire systems because of the problems with reversing transmission directions if errors are transmitted.

The data compression and transmission times for RAC encoding shown in Table III were confirmed by tests performed early this year by RCA Globcom and KDD betweeen New York and Tokyo over transpacific cable/satellite facilities. As a result of these tests, RCA Globcom is offering international switched store/forward and bureau-type facsimile services in the near future. Present plans are to inaugurate Quickfax service to Japan (Fig. 4) in the first quarter of 1978 and to other countries shortly thereafter.

Encoding techniques of the future

Conditional probability distribution is based on the statistics of past symbols.

For example, in a black-and-white document we can predict if the next picture element will be black with a certain probability if we know if its previous picture element was black or white.

In statistics, this technique is called a "Markov process of the *n* order." The order is determined by the number, *n*, of the previous symbols, whose statistics forecast the next symbol. In RLC and RAC encoding, the probability distribution of the

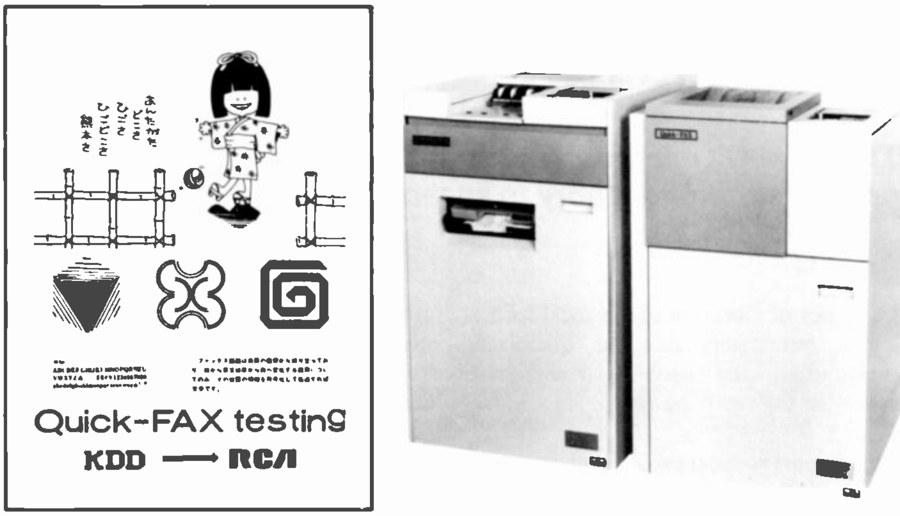

Fig. 4
"Quickfax" system uses relative-address coding to improve transmission rates for facsimile copies of documents. International service will begin in early 1978.

transitions is based on independent samples. Using a Markov process, we take into account past symbols in determining the probability distribution that would be more favorable to encoding. This could produce a code with codewords having an average length less than those currently in use and so would improve transmission time per page substantially (perhaps 20-30%).

Adaptive encoding would automatically adapt its algorithm to many classes of documents rather than favor certain types of documents.

Obviously, such a method would require an "intelligent" terminal that could determine what code to employ for each class of documents. This technique would have applications in point-to-point communications with fully compatible terminals or in public data/fax networks capable of handling dissimilar terminals, provided the code employed is known to the network before transmission. A modified version of the HDLC protocol (CCITT recommendation T.30) could be used for signaling and control functions between facsimile terminals.

Theoretically, the techniques outlined earlier for black-and-white pictures could be applied to pictures with shades of gray, if combined with other techniques.

With gray-level encoding, the transmission time is a function not only of the resolution rate, but also of the number of shades present. Since pictures with gray levels are loaded with redundant information, a more efficient approach would be to develop an encoding technique that also accounts for the psycho-physiology of the human eye. By exploiting the limitations of the eye with regard to fine detail, improved data-compression ratios could result.

Conclusion

Comparing the encoding techniques described earlier, we conclude that the average data-compression ratios achieved for the CCITT test documents at a resolution of 100 × 100 lines per inch are approximately:

for run-length coding	6:1
for reference coding	10:1
for relative-address coding	11:1

The two last techniques produce almost identical results because they are based on similar principles, differing only in the details of encoding.

All three techniques, as well as other variations, are presently being used in high-speed facsimile terminals for transmitting documents, graphics, and newspaper/magazine pages to remote locations over regular telephone lines. These statistical coding developments have helped to open the way to the electronic mail era. However, statistical coding applications are still in the formative stages of their development, growing steadily with improvements in computer software and hardware.

Reprint RE-23-4-4
Final manuscript received September 20, 1977.

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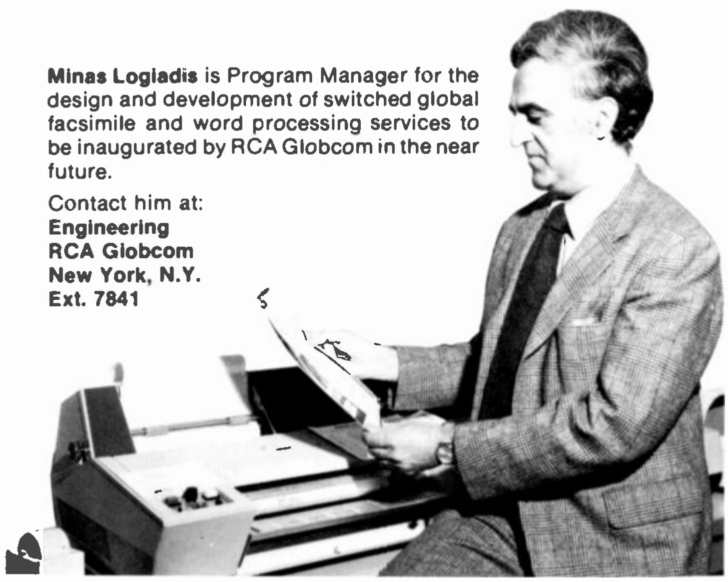

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Linear predictive coding to reduce speech bandwidth

J.R. Richards | W.F. Meeker

The ATMAC microprocessor allowed us to apply linear predictive coding theory to speech bandwidth compression.

The speech waveform is highly redundant. Therefore, communication system designers have expended a great deal of effort to reduce the bandwidth of transmitted speech by removing some of this redundancy. In the past few years, interest has arisen in a technique for analyzing and synthesizing speech by means of linear predictive coding.

Standard transmission bands are not wide enough for encrypted speech.

A transmission band extending from about 300 Hz to 3000 Hz is generally adequate for speech communication. However, present military systems require that the speech signal be converted to digital form before being encrypted. If straight-forward pulse-code modulation (PCM) is employed, a sampling rate of 8 kHz and at least 6 bits are required to represent the amplitude of each sample. Thus a data rate of 48 kb/s is required. However, the practical data transmission rate for normal telephone lines is 2.4 to 4.8 kb/s. Hence, speech transmission by PCM over telephone is not feasible. Various modifications of delta modulation allow the data rate to be reduced to about 20 kb/s for good quality, and to about 10 kb/s for speech of substantially reduced quality.

The channel vocoder is one solution.

The channel vocoder has been used extensively to provide digital speech transmission at data rates in the range of 1.8 to 2.4 kb/s. This device has a bank of 16 or 18 filters covering the speech range. The rectified output of these filters can be lowpass filtered to provide a slowly varying representation of the speech spectrum. The vocoder makes further use of the nature of speech by determining whether the speech at any given time is voiced or unvoiced (that is, whether it is produced by vocal cord vibration or by air turbulence); if the speech is voiced, the vocoder also determines the pitch (the fundamental frequency of vibration of the vocal cords). These parameters can be quantized, transmitted, and used to reconstitute speech at the receiving end.

The channel vocoder performs satisfactorily for some voices but is objectionable for others. Speech produced by a linear predictive coding system is more natural than that produced by a channel vocoder. This improvement in quality of narrow-band digital speech, together with the adaptability of the linear predictive coding process to large-scale integrated-circuit techniques, is largely responsible for the interest in such systems.

Reprint RE-23-4-9
Final manuscript received November 11, 1977.

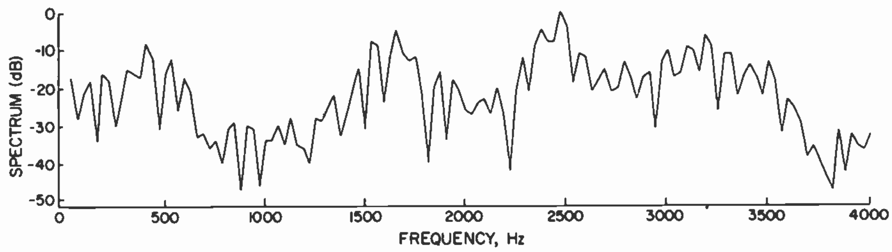

Fig. 1
Spectrum of a 20-ms segment of the vowel *i* as in *slid*. The spectrum was obtained by a 256-point Fourier transform with preemphasis for the high frequency portion.

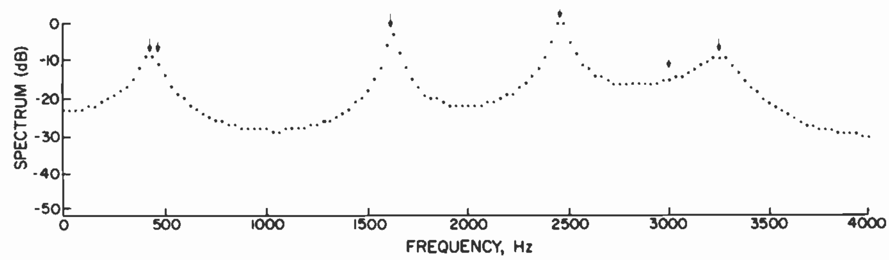

Fig. 2
Simplified spectrum envelope of the vowel *i* as in *slid* was produced by exciting a 10th-order all-pole filter with repetitive impulses. The filter was determined by the linear predictive coding process.

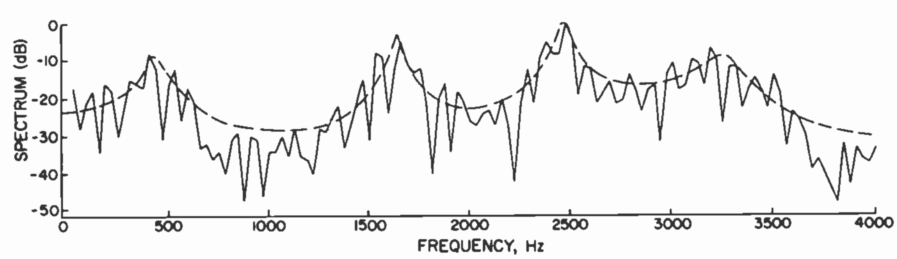

Fig. 3
Comparison of the simplified spectral envelope (Fig. 2) and the original speech spectrum (Fig. 1) shows that the impulse response from the LPC-produced filter closely matches the envelope of the original speech.

Linear predictive coding

Linear predictive coding (LPC), as applied to speech processing, derives from early statistical work on time-series analysis, in which the next term in a time series can be predicted from linear combinations of past terms. While the application of linear prediction methods to speech processing is relatively recent, it has attracted the interest of many workers so that there are now many papers and reports describing various aspects of the approach and the mathematics involved.[1-5] Consequently, we omit the mathematics of the process and concentrate on the approach and a possible implementation.

The LPC system provides a simplified representation of the short-term spectrum of speech.

In linear predictive coding, the spectrum is described as the coefficients of a 10th-order all-pole filter. Figs. 1, 2, and 3 show how this simplified spectrum approximates the speech spectrum. Fig. 1 shows the spectrum of a 20-ms segment of the vowel *i* in *slid.* The spectrum was obtained by means of a 256-point Fourier transform with preemphasis for the high-frequency portion of the spectrum. Fig. 2 shows the impulse response of a 10th-order all-pole filter determined by the linear predictive coding process. If the filter were excited by repetitive impulses, Fig. 2 would describe the envelope of the resulting spectrum. Fig. 3 shows the correspondence between the two representations (Figs. 1 and 2). The simplified spectral envelope closely approximates the envelope of the original speech.

The resonances of peaks in the spectral envelope are called formants; their time variation in amplitude and frequency carries most of the intelligence in speech. Thus, the LPC process determines an all-pole filter whose impulse response approximates the envelope of the short-term speech spectrum. A 10th-order filter requires only 10 coefficients to specify the response, and these can be quantized for an efficient representation. Although digital computers can do linear predictive coding, the process is so complex that until recently digital computers fast enough to implement a system in real time were not available. When implemented in discrete or MSI components, such computers or processors are still too expensive to permit widespread use. However, personnel of RCA Advanced Technology Laboratories have designed the ATMAC microprocessor,[6] which permits implementation of a cost-effective, low-power, real-time LPC system.

LPC speech bandwidth compression

A bandwidth-compression system employing linear predictive coding is shown in Fig. 4. At the transmitter, analog input speech (appropriately band limited) is converted to digital samples. The digitized speech is fed to a pitch extractor, which determines three parameters: 1) the voiced/unvoiced decision; 2) pitch, if voiced; and 3) some measure of amplitude. The digitized speech is also fed to a scaler and a linear predictor to generate the coefficients of the filter to model the short-term speech spectrum. The digitized speech is processed in blocks of 144 samples, each block representing 22.5 ms of speech samples at 6.4Hz. Each block of input speech thus produces a corresponding output block of 12 parameters: pitch, voiced/unvoiced amplitude, sync, and nine linear-predictive coefficients. These can be quantized so that they can be multiplexed to a 2.4 kb/s data stream. (See Table 1.)

Table I
Bit allocation for speech parameters obtained from 22.5-ms segment of speech.

Parameter	*Bits*	*Remarks*
Amplitude	5	voiced/unvoiced
Pitch	6	if voiced
K_1,K_2	12	
K_3,K_4,K_5	15	Prediction
K_6,K_7,K_8	12	Parameters
K_9	3	
Sync	1	
	54	Total bits/22.5-ms segment

At the receiver, the parameters for each block are demultiplexed from the input data stream. The nine linear predictive coefficients are fed to the linear predictor (all-pole filter) which establishes the shape of the output spectrum. The voiced/unvoiced decision then determines which of two excitation sources to use. The excitation function for voiced sounds consists of a stream of pulses from the pitch generator, with the repetition rate controlled by the pitch signal. For unvoiced sounds, the excitation function is a stream of pulses with random spacing. The output from the linear predictor is then scaled to restore the original amplitude, converted to analog form, and appropriately lowpass filtered to produce the speech output.

We built a working model of the speech bandwidth compression system using LPC and modem techniques.

To demonstrate the quality of speech when encoded to 2.4 kb/s using linear predictive

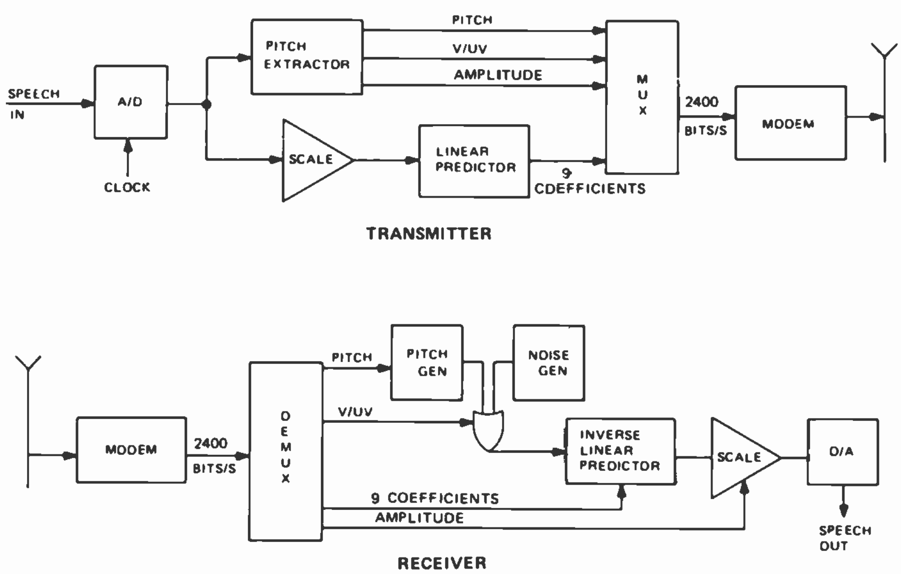

Fig. 4
Speech bandwidth compression system using linear predictive coding. The 2.4 kb/s output can be transmitted on normal telephone lines.

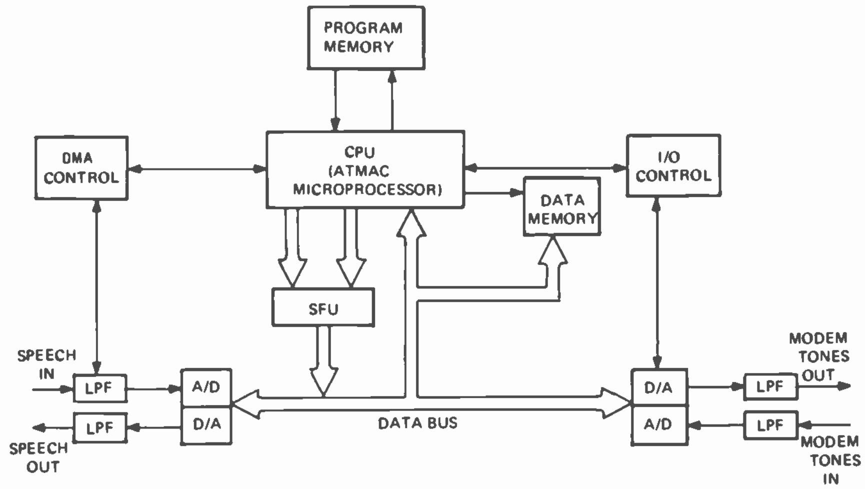

Fig. 5
Laboratory model speech-bandwidth-compression system demonstrates that high-quality speech can be encoded to 2.4 kb/s using linear predictive coding. Note that a 16-tone modem was also incorporated, showing that it is feasible to process both LPC and modem algorithms with a single processor.

coding, ATL built a laboratory model (Fig. 5) of a speech bandwidth compression system incorporating an ATMAC microprocessor. A 16-tone modem was also implemented in the system to demonstrate that both the LPC and modem algorithms could be performed with a single microprocessor. The major components are described below.

ATMAC microprocessor consists of two data chips and two control chips

In ATMAC, the basic chips are eight-bit modular building blocks which allow various microprocessor sizes, expandable in eight-bit increments.[6] The processor is partitioned into the data-execution unit and the instruction-and-operand-fetch unit. For a 16-bit machine configuration, a total of four chips are used: two data chips in the data-execution unit and two control chips in the instruction-and-operand-fetch unit.

Program memory is a ROM simulator for design flexibility.

In a final hardware design for a fixed application, the program would be stored in read-only memory. However, during development it is necessary to be able to readily modify program memory. A Scientific Micro Systems, Inc. Model 1000A ROM Simulator, used for the program memory, incorporates fifteen 512×8-bit modules. Since instruction words are 24 bits long, this unit provides 2560 words of alterable program memory having an access time of 100 ns. The ROM simulator is loaded by paper tape produced on an ATMAC cross-assembler, running on a Univac Spectra 70/45 computer. Program memory contents can also be changed by pushbuttons on the simulator control panel.

Data memory is more than adequate.

Data memory employs RCA MWS5501D memory packages, 1024×1 random-access static memories, whose CMOS/SOS construction is well suited for this application. These memories have an access time of less than 100 ns and operate at the same 10-V signal levels as the microprocessor, so that no level shifting is needed. Their power consumption is low.

Data memory is implemented on two circuit boards, which, when fully populated, provide 6k of data memory; operation requires less than 3k of data memory.

The special function unit increases the computational speed of the microprocessor.

The ATMAC architecture provides for simultaneous output of two 16-bit operands to a special function unit (SFU). In the narrowband speech demonstration system, the special function unit consists of a 16×16-bit two's complement multiplier with a 32-bit accumulate option. Operating modes are determined by instructions from the processor; 16 instructions are available to the SFU, of which 8 are used in the present unit. Either the most significant

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word or the least significant word may be placed on the data bus, where it may be written into data memory or into a processor register as determined by instructions. Multiplication (or a multiply and accumulate operation) and subsequent writing of the product to a processor general register or to data memory are accomplished in two instruction cycles. The multiply and accumulate operation itself is complete in 500 ns.

The speech and modem data input/output devices use the ATMAC interrupt facility.

Speech input and output are handled by the ATMAC direct memory access (DMA) facility. Both input and output are accomplished with a single DMA facility by interleaving the speech input and output data in memory. One instruction cycle is required for each data word transferred, and one interrupt must be serviced for each frame of speech data.

The I/O controller coordinates the transfer of data between the microprocessor and external devices such as the A/D and D/A converters. It directs two-way communication with the microprocessor via the I/O data bus.

An interrupt request is raised by the I/O controller when one of its devices requests service. While the microprocessor itself has a single interrupt line, the I/O controller can permit independent priority interrupts on a priority basis determined by the software.

Since the speech is processed in 22.5-ms blocks, full-duplex operation of both the LPC and modem can be achieved with the 70-ns clock.

The ATMAC microprocessor executes short instructions in four clock cycles and long instructions in five cycles. ATMAC was expected to achieve a 70-ns clock cycle period, resulting in short and long instruction times of 280 and 350 ns, respectively. Our initial samples of the ATMAC chip operated with an 80-ns clock when not using the LIFO stacks, and a 110-ns clock when running with the LIFO stack. Subsequent examinations of the chip that contains the LIFO stock uncovered some limitations in speed caused by design and layout; these are being corrected.

Since revised chips were not yet available, the demonstration system used chips having a speed limitation. A 110-ns clock period was needed to demonstrate operation of full-duplex linear-predictive coding and half-duplex modem processing. The execution times for both programs are given in Table 11. The table includes the execution times achieved on the present system as well as the execution times that will be achieved with several planned imporvements. The most significant improvement is in the modem, where a 50% speed increase can be achieved by 1) using an FFT rather than a time series to synthesize the modem tones and 2) by adding a FIFO register to the modem interface to permit the transfer of a block of data for each interrupt rather than a single word. The program and data memory requirements are also given in Table II.

Table II
Processing time and memory needed for linear predictive coding and modem algorithms.

	Processing time (ns)				*Memory*	
	With 110-ns clock cycle		With 70-ns clock cycle		RAM	ROM
Algorithm	As presently coded	With planned improvements	As presently coded	With planned improvements	(16-bit words)	(24-bit words)
LPC analyzer	11.73	9.91	7.46	6.30	1073	1373
LPC synthesizer	4.49	4.49	2.85	2.85	1021	1441
Modem transmitter	9.70	3.98	6.18	2.53	610	458
Modem receiver	8.53	4.47	5.43	2.84	1212	864

Hardware projections for the speech processor

The laboratory model of the speech bandwidth compression system is the first step in the development of low-cost low-power narrowband systems. The ATMAC microprocessor, which performed the majority of the processing functions, consumes less than 1 watt. A six-chip set, including four 8X8 multiplier chips to implement a 16X16 multiplier and two 16-bit accumulators, can be built to operate in conjunction with the microprocessor and consumes less than 600 mW. Hence, the entire processor subsystem can be fabricated with ten CMOS/SOS LSI chips, which would consume less than 2 W. Eight of the ten required chips have already been developed by RCA. To build a complete low-power, half-duplex speech terminal capable of both modem and linear predictive speech processing, a total of 154 standard off-the-shelf CMOS packages are required in addition to the ten LSI chips, with a power dissipation of 9 W. If 4k CMOS RAM and ROM memories with 100-ns access time (presently under development by RCA and other companies) replace the 1k chip, and if the clock and interface chips are implemented with two LSI chips, the entire system can be reduced to 48 chips housed in a 5X5X10-in. package, with a power dissipation of less than 5 W.

The progress of LSI, particularly in CMOS/SOS, has made the development of a small cost-effective low-power LPC speech processor possible, an accomplishment that five years ago was thought to be impossible.

Acknowledgments

The authors gratefully acknowledge the splendid efforts of Stan Ozga, who developed the ATMAC microprocessor, as well as the work of Jim Barger, Al Nelson, Dave Benima, and Dave Bryan, all of whom were key individuals in the development of the narrowband speech system. The authors also thank Richard Wien at the U.S. Army Electronics Command (USAECOM) for his help and support throughout the entire program.

The work was sponsored in part by USAECOM (Fort Monmouth) contracts DAAB07-76-C-0340 and DAAB07-75-C-1314.

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Engineering Information Survey results Part 2

H.K. Jenny | W.J. Underwood

High vs. low achievers—how are they different?

This is the second article in a series that reports corporate-wide results of the Engineering Information Survey. The first article in the October-November, 1977, issue of the *RCA Engineer* reported on:

- Importance of keeping up-to-date
- Importance of efficient access to information
- Use and value of various sources of information
- Reading effort and obstacles

That article compared responses of engineers, leaders, and managers; this article compares high and low achievers, ignoring organizational level. By identifying and describing the characteristics of high achievers, a kind of role model is developed for use by all engineers.

For this article, an achievement index was developed based on the answers to six specific questions in the survey. The achievements and their survey questions are:

Technical currentness: How would you rate yourself in terms of being up-to-date with the current state-of-the-art in your technical field?

Awards: How many awards or recognitions (of a technical-professional nature) have you received?

Patents: How many patents (sole or with colleague) do you have?

Publications: How many papers have you as author or co-author published in the past five years?

Presentations: How many formal paper presentations have you made to engineering or scientific groups in the past five years?

Effectiveness as an information source: How frequently do other engineers seek you out to discuss technical information?

The achievement index was constructed by translating answers to these six questions to a common scale and by judgmentally weighting the factors. [At the end of this article we give the details of how the achievement index was constructed; from this information, you can calculate your own score.] The resultant achievement index yielded the distribution shown in Fig. 1. High and low achievement groups were defined as the upper and lower 30%, placing approximately 950 respondents in each group.

This achievement index is important in its own right. But more important, such an index may be related to job performance.*

How important is keeping up to date?

The previous article in this series established that engineers consider keeping abreast of new technology quite important to both their present job and to their future goals. This analysis asks, is it equally important to both high and low achievers?

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

Importance	*Hi*	*Lo*
Extremely	54%	15%
Quite	38	43
Somewhat	7	30
Slightly	1	10
Not at all	1	2

*In a separate study, four engineering organizations in different MOU's each identified six high and six low performers and supplied data on patents, papers, and awards. When these combined achievements were compared, we found that high performers had produced 17 times more achievements.

Other research has demonstrated a relationship between performance and several of the achievement variables. Three such studies are reported in:

Managing the flow of technology by T.J. Allen (MIT; 1977) p. 141-168

Scientists in organizations by D.C. Pelz and F.M. Andrews (U. of Mich.; 1966; 2nd ed.) p. 284-285

"Merit rating and productivity in an industrial research lab," by A. Grasberg in the *IEEE Transactions on Engineering Management* (Mar 1955)

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

Importance	*Hi*	*Lo*
Extremely	51%	22%
Quite	42	49
Somewhat	6	25
Slightly	1	4
Not at all	1	1

High achievers answered heavily in the two strongest degrees of importance both for present job (92%) and future (93%). Only 58% and 71% of low achievers considered keeping up-to-date equally important. The highest scale position—*extremely important*—is also revealing. Nearly four times more high achievers assigned this degree of importance to the present job and more than twice as many assigned it for future goals. Appreciably more low achievers consider technical currentness more important for their future than for their present jobs. Perhaps this implies that low achievers are in jobs that are not very technically challenging and either hope or expect the challenge will increase in the future.

What's management's role?

Most people in an organization respond to, or at least try to respond to, what they think is valued and expected of them by their management. It is important, therefore, to examine how these groups perceive their management's emphasis on technical currentness.

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

Emphasis	*Hi*	*Lo*
Very strong	16%	2%
Strong	30	12
Moderate	34	36
Minor	15	32
None	6	17

Three times more high achievers regard management's emphasis as strong. Perhaps more significant, nearly half of the low achievers believe that management's emphasis is either minor or nonexistent. Low achievers would not find much encouragement from this influence to keep themselves up-to-date technically.

What information is important?

Efficient access to relevant information is needed for the effective performance of engineering. The survey explored the relative importance of five categories of information.

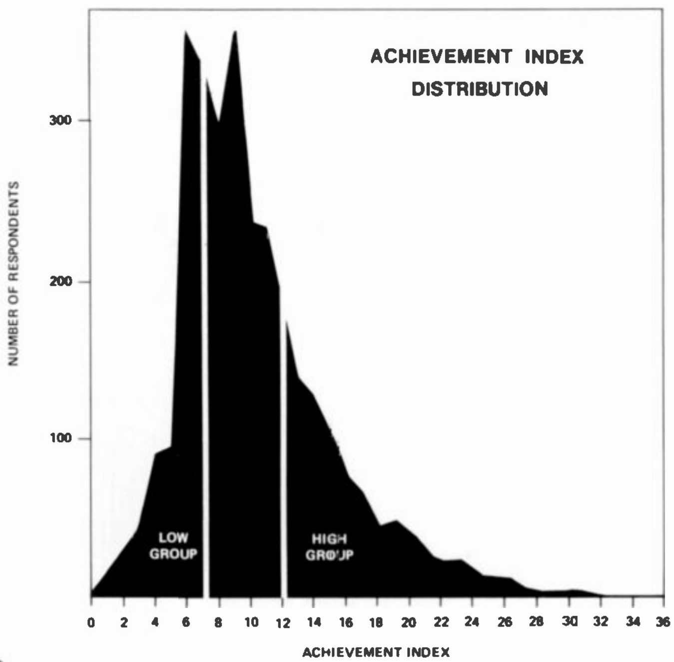
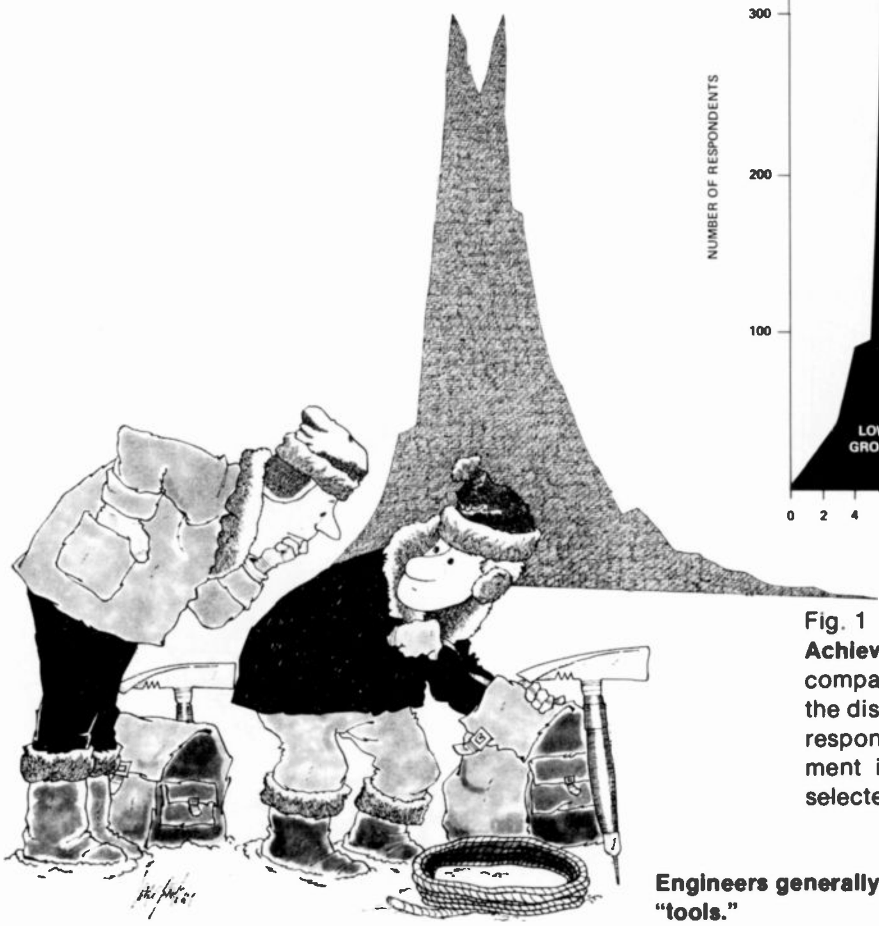


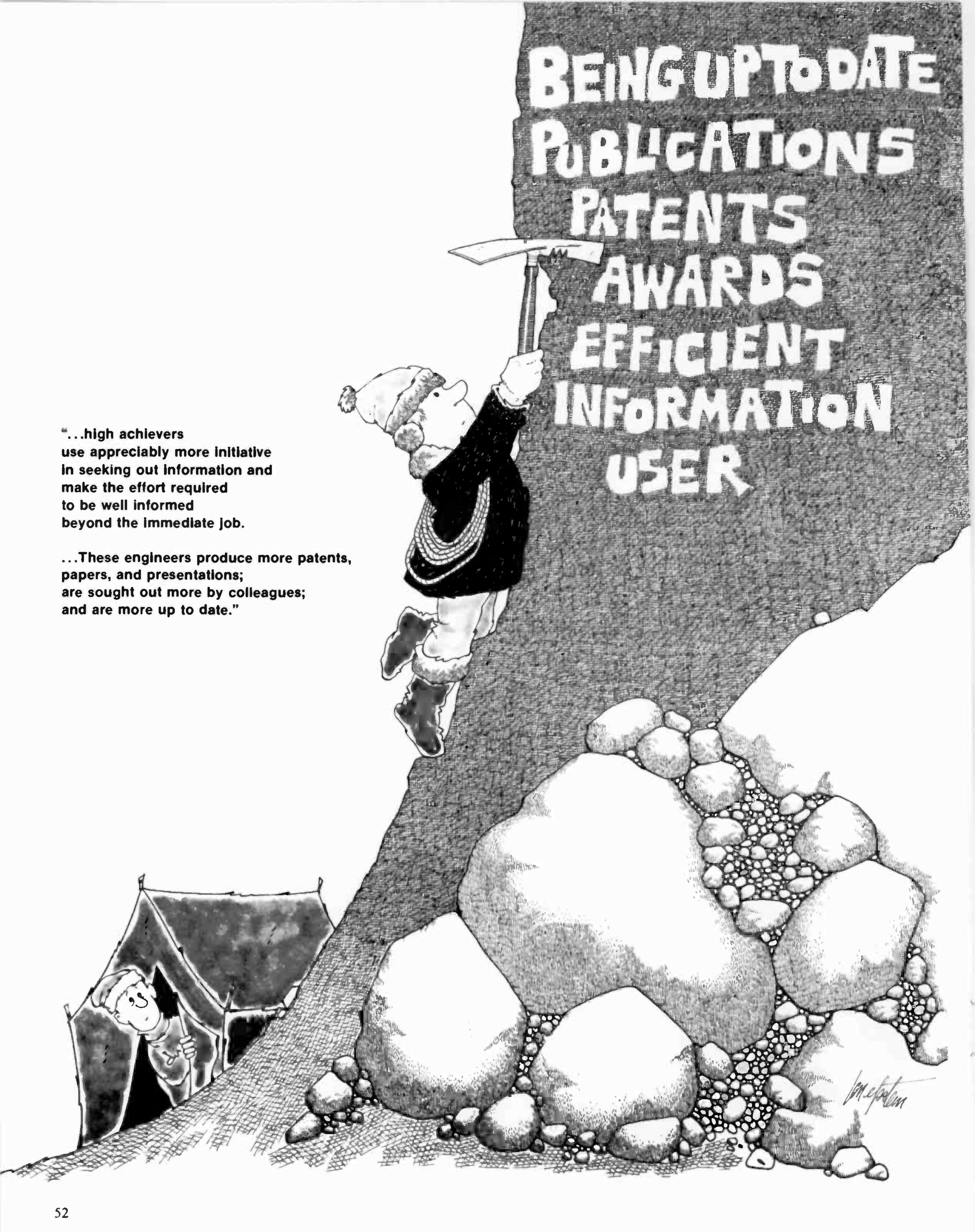
Fig. 1
Achievement index was selected as the basis for comparing groups of engineers. This graph shows the distribution of more than 3000 RCA engineers responding to the survey as a function of achievement index. The top and bottom "thirds" were selected for this study.



Engineers generally start their careers with the same basic "tools."

"...high achievers
use appreciably more initiative
in seeking out information and
make the effort required
to be well informed
beyond the immediate job.

...These engineers produce more patents,
papers, and presentations;
are sought out more by colleagues;
and are more up to date."



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

Category	*Hi*	*Lo*
Technical—job related	96%	88%
Technical—other	82	62
Business—RCA	48	39
Business—related industry	45	35
Professional—engineering field	37	28

Numbers in the table are the percentages of respondents who selected the two highest scale values of importance (of a five-point scale). Both groups rank the categories of information in the same order. However, all types of information are more important to a larger number of high achievers. The largest difference between high and low achievers is in the category *Technical—other*. The detailed response to this category is shown below.

How important is "Technical—other" information?

Importance	*Hi*	*Lo*
Extremely	35%	17%
Quite	47	45
Somewhat	14	32
Slightly	3	5
Not at all	1	1

Twice as many high achievers assign the highest degree of importance to this category.

What are the important information sources?

The survey also presented 32 sources of information that could be used by engineers. Respondents assigned a value to each source from a four-point scale: *very valuable, moderately valuable, somewhat valuable, little* or *no value*. High achievers assigned more value than low achievers to 25 of the 32 sources. The left column below lists the sources high achievers valued appreciably more than did low achievers; the right column lists the seven sources that low achievers considered more valuable. These are also ranked in order from greater to lesser difference.

Valued more by high achievers	**Valued more by low achievers**
Conference proceedings	Military specs and standards
Papers external to RCA	Standards handbooks
External conventions and meetings	RCA standards
Outside technical journals	Educational courses—internal
Professional societies	Educational courses—external
RCA technical reports and engineering memos	Handbooks/manuals
RCA libraries	Catalogs
RCA engineers at other locations	
RCA-authored papers	
Internal meetings and seminars	
Engineers at my location	
RCA technical journals	

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 are being reported in this series of articles in the *RCA Engineer*. This article concludes the *general* corporate-wide results; the next will examine the specifics of some of the RCA information services, namely: the RCA Libraries, the *RCA Engineer*, *RCA Technical Abstracts* and *TREND*. 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.

Except for educational courses, convenience or immediacy seems to be a difference. The sources valued more by low achievers tend to be the available working tools of engineers. Those valued more by high achievers have to be sought out, requiring more initiative.

Note: The sources valued by low achievers should not be interpreted as either unimportant or of lesser importance. These are lists of differences between the two groups of engineers, not an importance ranking of sources. An importance ranking was given in the first paper of this series (see the October-November, 1977, issue of the *RCA Engineer*).

A more specific inquiry was made regarding RCA-related information sources. Respondents were asked to indicate where they obtain the major amount of technical and non-technical information about RCA. There were no substantial differences between the groups concerning non-technical information. Their responses to RCA technical information sources, however, were:

Where do you obtain your technical information about RCA?

Source	*Hi*	*Lo*
Discussions with associates	84%	74%
RCA Engineer	75	52
RCA technical reports & engineering memos	73	39
TREND	56	58
Discussions with supervision	55	44
RCA seminars and lectures	39	19
RCA educational courses	30	20
RCA Technical Abstracts	25	8
RCA Review	23	10

In every instance but *TREND*, high achievers made more use of the sources. The largest difference is for RCA technical reports and engineering memoranda, which drew nearly two times more high achievers' responses. Substantial differences also exist for the *RCA Engineer* and for RCA seminars and lectures. In terms of each group's rank ordering, low achievers assigned *TREND* a second position, whereas high achievers assigned it fourth.

Other points of difference between high and low achievers concern use of the library and the *RCA Engineer*.

Library use	*Hi*	*Lo*
I do not use the RCA technical library at my location	4%	12%
I use the RCA library more than once a month	70	45
I use the RCA library for literature searches	82	37
I use the RCA library for journals and proceedings	65	27
I know how to use the library effectively	89	64
RCA Engineer use		
I receive the *RCA Engineer* at home	84	46
I do not have access to the *RCA Engineer*	5	33
What percent of the *RCA Engineer* do you read?	21	16
What percent of the *RCA Engineer* do you scan?	60	37

How much time is devoted to reading?

Since high achievers rather consistently value and use more information and since reading is an important method, it is not surprising to find the following difference in reading time.

On the average, how much time during and after working hours in a typical week do you spend reading?

	Reading hours per week	
	Hi	*Lo*
Technical—job related	6.3	4.4
Technical—other	3.3	2.6
Business—RCA	1.5	1.1
Professional	1.7	1.3
Business—other	1.3	1.2
Total	14.1	10.6

High achievers spend about one-third more time reading. The largest difference (43%) is in *technical—job related* materials. Both groups allocate about 50% of their reading to working hours.

The survey also inquired about obstacles to reading.

Which...are obstacles to you in keeping abreast of new developments in technology by reading?

Obstacle	*Hi*	*Lo*
Insufficient time at work	71%	62%
Insufficient time at home	52	41
Use of other methods to keep abreast	31%	23%

Management does not condone reading	18	22
Need a better grasp of mathematics	10	19
Need a better grasp of science	5	13
Lack interest in reading	3	6
Reading wouldn't help in my job	1	8

The dotted line separates the responses by whether high achievers or low achievers responded more frequently. Numbers indicate percentage of response to the instruction, "check all that apply." The two groups differ most on the last four obstacles. Twice as many low achievers need a better grasp of mathematics and science and lack interest in reading, and some believe that their jobs do not require reading.

What is a high achiever?

From these data, we can construct a profile of the high achievers. These engineers use appreciably more initiative in seeking out information. They do not limit themselves to information that is handy, which requires little effort to obtain. They place high value on being well informed and make the effort that is required. They consider that being well informed includes their technical field *beyond* the immediate job. As a result, high achievers participate more in professional societies as one means of maintaining breadth, use a wide variety of sources of information, and develop contacts with engineers outside their work group and even outside their locations. They study proceedings of conferences, outside technical papers, and journals.

Internally, high achievers use the RCA libraries extensively, and read RCA technical reports and engineering memoranda, *RCA Technical Abstracts*, and the *RCA Engineer*.

In general, high achievers keep their technical skills sharp, permitting them to comprehend information that often contains heavy mathematics and basic science. These engineers produce more patents, papers, and presentations; are sought out more by their colleagues; and are more up-to-date. Their information gathering habits can be recommended as a model for all engineers.

Reprint RE-23-4-13
Final manuscript received December 13, 1977.

To determine your achievement index and see where you stand compared to the RCA engineers who responded to the survey, use the following procedure:

Answer the following six questions. [These questions are taken directly from the survey.]

1. How would you rate yourself in terms of being up-to-date with the current state of the art in your technical field?

| | 1 In the upper 10% of RCA engineers
| | 2 In the upper quarter
| | 3 About average
| | 4 In the lower quarter
| | 5 In the bottom 10%

2. How frequently do other engineers seek you out to discuss technical information?

| | 1 Very frequently
| | 2 Frequently
| | 3 Occasionally
| | 4 Rarely
| | 5 Never

3. How many papers have you as author or co-author published in past 5 years?

4. How many formal paper presentations have you made to engineering or scientific groups in the past 5 years?

5. How many patents (sole or with colleague) do you have?

6. How many awards or recognitions have you received? (For example, David Sarnoff Achievement Award, Technical Excellence Award, Status in Professional Society, etc.)

Use the table below to determine a subscore for each question. Then multiply each by its indicated weighting factor. Adding all six results gives you your achievement index. Use this index and Fig. 1 to determine your standing.

Q1 technical currentness	*Q2 info. source effectiveness*	*Q3 No. of papers*	*Q4 No. of presentations*	*Q5 No. of patents*	*Q6 No. of awards*	**Subscore**
5	5	0	0	0	0	0
4	4	1-2	1-2	1-2	1-2	1
3	3	3-5	3-5	3-5	3-5	2
2	2	6-9	6-9	6-9	6-9	3
1	1	9	9	9	9	4
2	**1**	**1.5**	**1**	**1.5**	**2**	**Weighting factor (multiply subscore by ...)**

Example: Suppose you rate yourself as shown below:

Question	*Answer*	*Subscore* (From table above)	*Weighting factor* (From table above)	*Score*
1	In upper quarter [2]	3	2	6
2	Occasionally [3]	2	1	2
3	1 paper	1	1.5	1.5
4	3 presentations	2	1	2
5	4 patents	2	1.5	3
6	no awards	0	2	0
		Achievement index (total score)		=14.5

Your achievement index of 14.5 would place you with the upper quarter of RCA engineers (see Fig. 1).

Now compute your own standing. Are you satisfied with it? If not, consider the data in this paper carefully to gain some insights on how to improve.

Biographies and photographs of the authors **Hans Jenny** and **Bill Underwood,** were published with their first article of this series in *RCA Engineer*, Vol. 23, No. 3 (Oct-Nov 1977) p. 30. To discuss this paper or related issues, contact them at:

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A high-performance switching regulator for advanced spacecraft power systems

C.A. Berard

Heavier power demands are making the design of spacecraft power supplies and controls more challenging.

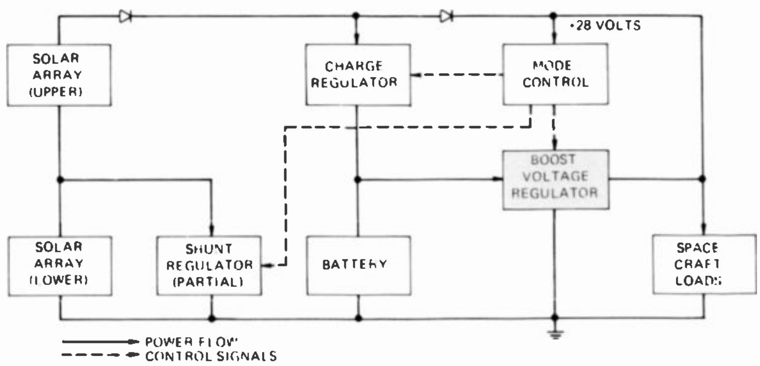

Fig. 1
Direct energy transfer power system centers around mode control and boost-voltage regulator.

Table I
Performance levels of the DET system are high; systems have operated four years on ground and sixteen months so far in space with no failures or degradations.

System parameters	*Performance level*
Output interface	
Regulated output voltage	+28.0 V + 0.56 V − 0.30 V
Load range	45 to 450 W; 530 W peak
Output ripple and noise	<50 mV p-p
Output impedance	<200 mΩ and 0.3 μH
Boost regulator	
Regulated output voltage	+27.9 V ± 0.2 V
Load range	0 to 450 W; 530 W peak
Conversion efficiency	>89% (110-280 W load) >87% (450 W load)
Source characteristics	
Solar array current	0 to 32 A
Solar array voltage	0 to 55 V (open circuit)
Battery voltage	16 to 23.5 V (discharge) 21.0 to 26.1 V (charge)
Environment	
Space operational life	>3 years continuous
Thermal range	−5°C to +50°C in vacuum
Radiation	400 to 500 nmi (polar orbit)
Vibration (3 axes)	22.5 g rms random 15 g peak sine
Shock (3 axes)	15 g peak

A new generation of high-performance weather satellites developed by RCA uses a spacecraft power system that satisfies demanding performance requirements and is highly reliable, lightweight, and highly efficient. Using a direct-energy transfer (DET) approach with a boost-mode switching voltage regulator, this system provides optimal performance for earth-orbiting satellites above 400 nautical miles altitude. At high altitudes where the effect of eclipse is less, system efficiency can approach 100 percent.

The system features load power greater than 500 W at +28 V, line-load regulation under 0.5%, output ripple and noise less than 50 mV peak-to-peak, and efficiency greater than 90%. The design includes parallel paths with current sharing, hot-carrier rectifiers, and a modular, easy-access packaging approach.

Performance requirements

The direct energy transfer power system generates, stores, regulates, and controls the power used by all spacecraft systems.

The DET system accepts power from the solar array and battery, both highly unregulated sources, and delivers load power from a well regulated, low-impedance power bus; it also controls battery recharging power from the solar array. (See Fig. 1.)

System operation is master-minded by the mode control, which not only maintains regulation but establishes the priority distribution of available power (#1—loads, #2—battery, #3—shunt regulator). The boost-voltage regulator operates in eclipse periods and when the spacecraft's load demand exceeds solar-array power. Energy available from the solar array is returned to the battery via the charge regulator; shunt regulators dissipate energy in excess of load and battery requirements. Mode-control signals provide proper sequencing, guard-bands, and bus voltage control.

Table I summarizes performance for the DET system in its entirety and for its boost voltage regulator. While an overall regulation of 2% is not in itself difficult, requirements on the control electronics are indeed stringent, considering that the range of source and load powers is greater than 1300 W. All electrical performance is maintained over the worst-case extremes of line and load variation, temperature, radiation and aging drifts, and single-point failures.

Boost regulation techniques

In its simplified form, the boost-voltage regulator resembles the conventional boost-configuration switcher.

Referring to Fig. 2, output voltage is sensed and compared to a voltage reference by a comparison amplifier. The error signal is amplified and loop stability is compensated before pulsewidth modulation occurs. A duty-cycle-limited, constant-frequency pulsewidth modulator circuit converts voltage error into a time-ratio error, which controls the transistor power switches. When the transistor switch is on, the inductor current increases and stores energy in its magnetic field. When the transistor is off, energy is transferred via the flyback diodes to the loads and energy-storage capacitors. The transistor switches operate at a frequency well above the resonance of the inductor-capacitor network.

The transfer function can be easily derived by equating the net change of inductor current to zero over a period of the transistor switch. Assuming the input source voltage, E_s, and output voltage, E_o, are essentially constant, this simplifies to:

$$E_o = E_s/(1-\alpha)$$

where α is the proportion of the period that the transistor switch is on.

However, dealing with real switching regulators requires the inclusion of (at least) the first-order non-ideal parameters. The applicable equation is then

$$E_o = [1/(1-\alpha)]\,(E_s - E_{sw} - I_s R_L) - (E_d + I_s R_w)$$

where

E_d is the flyback diode forward voltage drop

E_{sw} is the transistor switch voltage drop

I_s is the source current

R_L is the resistance of the inductor, and

R_w is the equivalent resistance in the flyback circuit.

This equation determines the maximum required duty cycle accurately and helps calculate power transfer efficiency.

Circuit techniques

Using switching regulators in high-current applications usually presents serious component-selection problems.

Paralleling transistors and diodes is undesirable because of the difficulty and high cost of achieving and maintaining (over life and temperature) suitable matching. Very-high-current transistors exhibit relatively slow switching times, which are incompatible with high-frequency and high-efficiency operation.

Parallel-path power sections can provide a unique way around some component problems.

A three-section approach (Fig. 3) had a lower component weight than a single-section design and also had no non-recoverable single-point failures. Components in each section are rated to carry one-half the load to further enhance reliability and ensure continued operation after partial failure. All are driven simultaneously from a common pulsewidth-modulated error signal and are connected to common input and output points. Without selecting or matching components, the sections share current within rather close tolerance (measured data confirms ±4% tolerance with full 450-W load and 23-A total input current). Inductor L' and capacitors "$3C$" form a filter to remove high-frequency noise caused by the non-ideal characteristics of the main filter capacitor banks "$6C$." This circuit has been space qualified in 1-, 2-, 3-, and 4-channel versions; a 5-channel regulator is currently under development.

Reprint RE-23-4-11
Final manuscript received May 19, 1977. A similar version of this paper was presented at Powercom 3, June 24-26, 1976, Los Angeles.

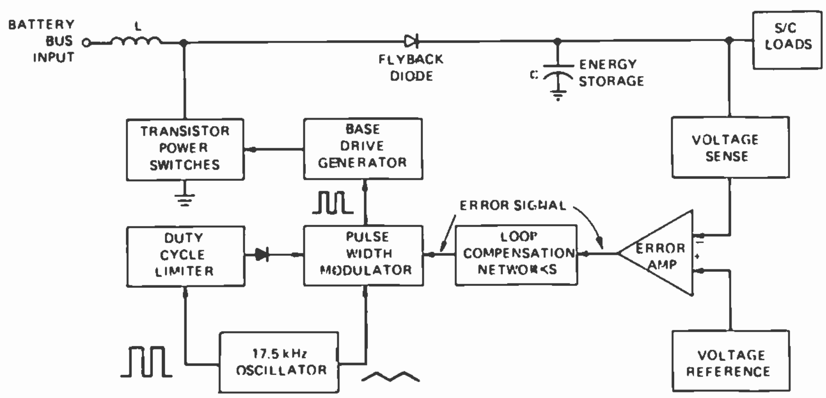

Fig. 2
Boost regulator uses error signals to control transistor power switches, which regulate energy flow to the loads from the flyback diode/storage capacitor network.

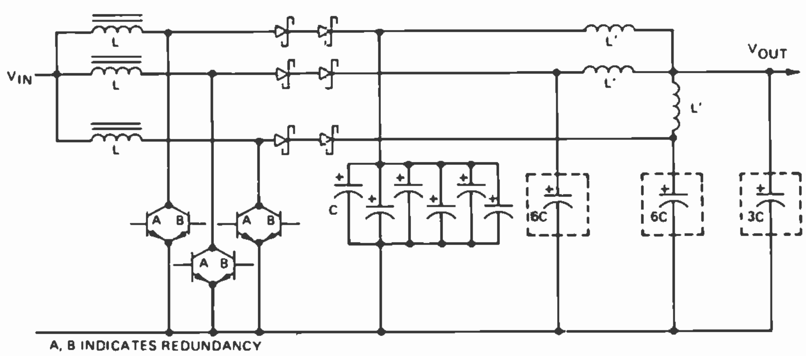

Fig. 3
Parallel-path power sections have weight and reliability advantages.

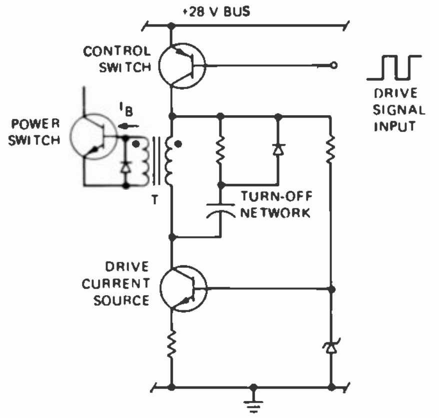

Fig. 4
Base-drive circuit uses transformer inductance in a resonant flyback network to generate a reverse base current for rapid turn-off.

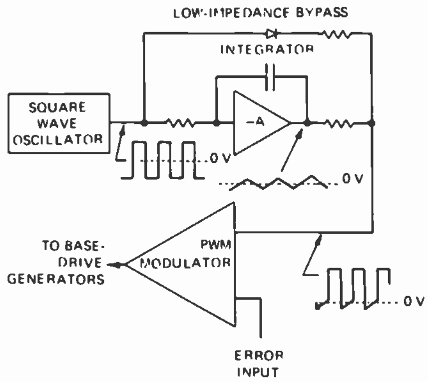

Fig. 5
Duty-cycle limiting avoids continuous application of base-drive current to protect switching transistors.

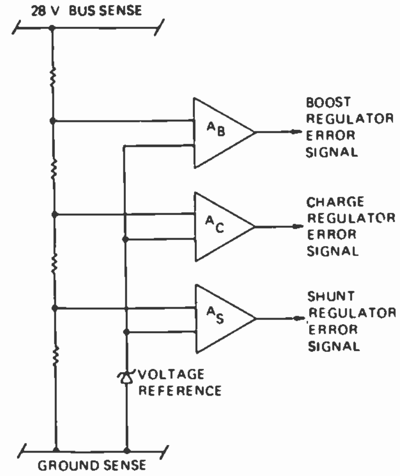

Fig. 6
Mode-control circuit establishes load priority among the system modes, also provides error-detection and feedback points for the three regulation modes.

Identical base-drive circuits for each boost regulator section enhance high-efficiency performance.

Each section (Fig. 4) provides constant-current base-drive to the switching transistor; the novel feature is using the transformer inductance in a resonant flyback network to generate a reverse current of about 400 mA for rapid turn-off. Efficiency and ground isolation are enhanced by the transformer coupling technique; 3 A of total base drive current is provided by using less than 165 mA from the +28V output bus. Operation is (by design) controlled by the passive components; thus, performance is not influenced significantly by transistor parameter variations.

Duty-cycle limiting is a positive means to prevent continuous application of base-drive to the boost-regulator switching transistors.

Duty-cycle limiting (Fig. 5) protects the regulator's switching transistors from overcurrent failure by using signals available within the sawtooth oscillator. A diode-resistor network gates a saturating level to the output to hold the pulsewidth-modulator output low (no base drive to switches) while the sawtooth (integrated square wave) provides normal modulator action during the remainder of the period. By using an asymmetrical oscillator, any duty-cycle limit may be generated; our design incorporates a 65% limit.

A mode-control circuit (Fig. 6) provides the load priority, sequencing, and guardbands between system modes; for voltage regulation, it provides the error-detection and negative-feedback summing points for each of the three regulators. A shared reference-voltage source and resistive divider maintain the tight tolerances for each function and the tracking necessary to ensure proper guardbands between modes.

Component selection

Component selection for a switching regulator is a complex process requiring trade-offs of performance, weight, cost, and (for space applications) reliability and previous applications history. Semiconductors are among the most difficult to select and rely heavily on new component technology.

Switching transistors were the most difficult parts to optimize.

Fast switching times, high current gain, low saturation voltages, broad safe-operating-area limits, high voltage and current ratings, and isolated case construction were all desired. A 100-V, 30-A device was chosen for its performance characteristics. It is a double-diffused epitaxial type (similar to a 2N5330) with an acceptably high second-breakdown resistance, though it is not as rugged as a single-diffused chip. Spacecraft loads are well defined, removing much of the uncertainty of stress levels that would be present in the design of a laboratory- or OEM-type power supply.

Flyback diode selection was driven by several requirements, all indicating an almost-ideal diode.

Low forward drop was needed for efficiency, especially considering the desirability of using series-connected, redundant diodes. Fast switching and low recovery current spiking are necessary to meet the low ripple and noise specifications without excessively complex filtering. Hot-carrier rectifiers satisfied these stringent requirements best; a screened version of the TRW type SD-51 was ultimately selected and used.

Inductors in the power-switching network must withstand high dc bias and be of low-loss design.

A gapped C-core of 3% silicon steel wound with a 1.4" by 0.004" copper strip and Kapton insulation provides suitable characteristics. Each 500-μH, 15-A choke weighs 10 oz. and has 20 mΩ dc resistance. The core is rugged and needs no special mounting provisions for vibration and shock resistance.

Capacitor selection is, like the semiconductor choice, one of trade-offs.

Rectangular-case, hermetically sealed, tantalum-foil capacitors have been used in RCA satellites for over a decade without failure or discernible performance degradation. Our tradeoff evaluations have consistently shown tantalum-foil capacitors to have superior performance to gelled-electrolyte types,* especially with respect to low equivalent series resistance (ESR) and weight efficiency (and they are not degraded by reasonable reverse voltage). Low ESR is essential to minimize internal heating (under high rms current conditions) to prevent high temperature, which shortens capacitor life; voltage stress levels are much less significant. The rms ripple-current ratings for "identical" MIL-spec capacitors vary drastically among parts from different manufacturers. Capacitors are one component where the tradeoff result may change as new developments increase the performance capabilities of competitive types.

Reliability techniques

Basic reliability techniques derived from years of spacecraft design experience were applied to all components used in the power system electronics. These techniques include extensive testing, screening, inspection, and burn-in operations, all needing no further elaboration.

Configuration design and redundancy are the primary means used to guarantee a high probability of success for the boost-voltage regulator. Mode-control and low-power boost-regulator circuits are independent, and back-up circuits in 'cold' (unpowered) redundancy are provided. Automatic +28-V bus failure-sensing and under- and over-voltage protections increase reliability. High-power portions of the booster have parallel-path redundancy inherent in the three-section configuration. The mode control and boost regulator have a probability of success predicted to be greater than 0.9995 for three years of operation.

Packaging design

The power-supply package is designed for ease of assembly; removal of plug-in circuit cards and simple unbolting of covers or side panels provides access to any circuit.

The package has two distinct compartments. The EMI-gasketed end houses all components of the boost-regulator high-power switching networks, filters, and base-drive generators (the major EMI-generating networks). Non-noise generating circuits, including low-level

*Trade-offs consider worst-case effects relevant to space power-supply applications, including temperature extremes and aging degradation in a radiation environment.

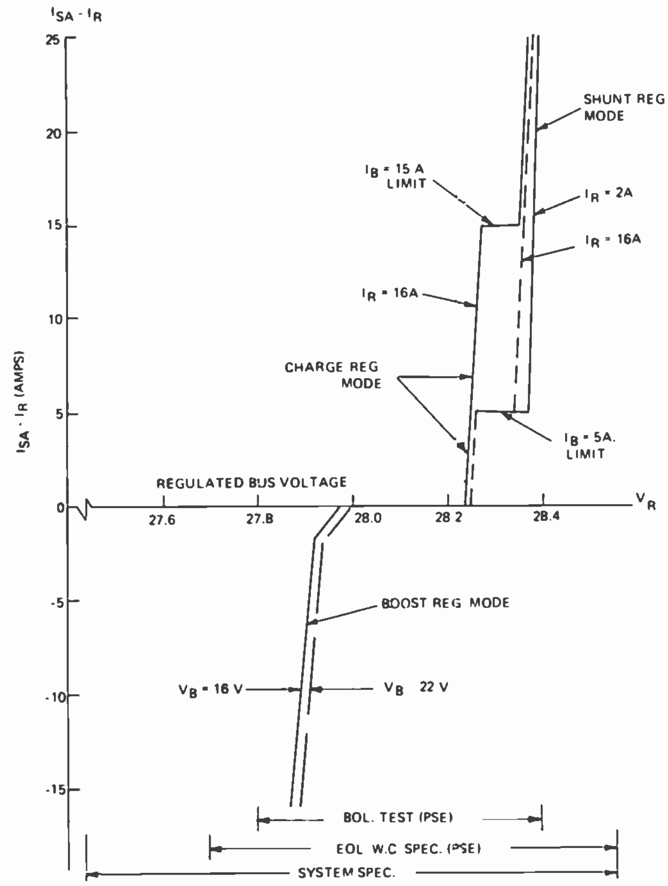

Fig. 7
Static regulation for the three modes of the direct-energy transfer is well within system specification; boost-regulator load regulation is 50 mV (0.18%) over normal load range.

portions of the boost regulator, final output filtering, and output power buses, are located in the opposite end, primarily on plug-in printed-circuit cards. Connections between the compartments use low-capacitance feed-through terminals; discrete capacitors selectively decouple noise and spikes where required.

Performance results

Every boost regulator made achieved the predicted performance goals with adequate margin from specification limits. Characteristics are identical within millivolts from unit to unit, and retest of the prototype after almost four years of ground use on several spacecraft showed no change in performance; on-orbit performance is identical to the original test results.

Static regulation characteristics for the direct-energy transfer power system are reproduced in Fig. 7. The vertical axis is scaled as a net current to make the results interpretable for all load/source combinations. Line regulation for the boost

Clem Berard was lead design engineer for the spacecraft switching regulator described here. He is manager of a design and development group that is responsible for power supplies, high-speed motor drives, servo electronics, and other analog functions.

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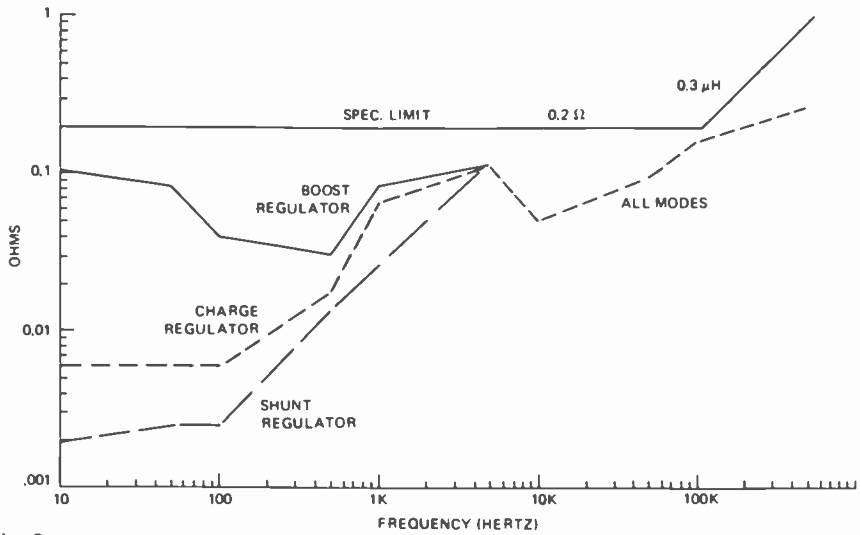


Fig. 8
Output impedance for each of the regulators remains below the 0.2-ohm, 0.3 microhenry specification.

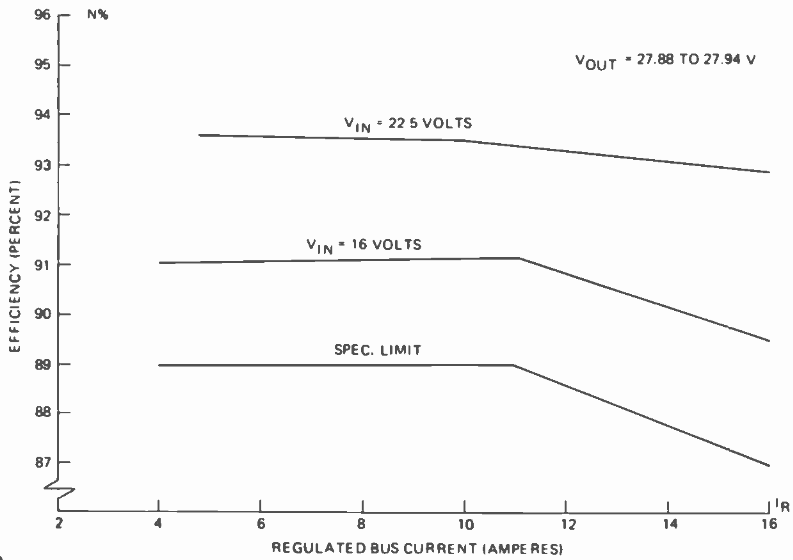


Fig. 9
Power transfer efficiency is generally above 90%. Efficiency drop at higher loads is intentional, to reduce weight, because full-load operation is of short duration.

regulator is 20 mV (0.071%). Over the normal load range of 2.5 to 16 A, load regulation is 50 mV (0.18%).

Output impedance, measured for each of the three regulators in the DET power system, is shown in Fig. 8. Design of the boost-regulator filter network is strongly influenced by the output-impedance specification. High-frequency performance is controlled by capacitor and wiring characteristics.

Boost-regulator efficiency is generally 90% or greater and exceeds the specification requirements (Fig. 9). Under orbital load-current profiles, full load is applied only for data-readout transmissions (5-10 minutes duration) so the slightly lower full-load efficiency, caused primarily by resistive losses, is intentional to achieve lower weight. At light loads, efficiency is reduced by the bias losses of the base-drive and control circuits. Bias currents are 110 mA for the entire DET power system.

Ripple and noise measurements were taken under worst-case conditions of minimum input voltage and maximum load. Actual performance of 25 mV peak-to-peak (0.09%) as shown in Fig. 10 reflects the conservative worst-case design philosophy necessary for space applications. Less than 10% variation is experienced over the full operating-temperature range.

Environmental exposures have had no effect on the observed performance.

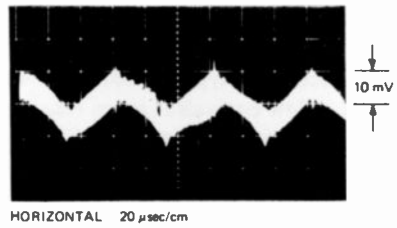


Fig. 10
Ripple and noise are only 25 mV p-p in worst-case conditions.

Thorough electrical testing has been performed over the operating-temperature range and after four years of ground use with no discernible shifts. During vibration and shock tests, the unit was powered at full load with oscilloscope monitoring of the regulated output voltage; no variations were observed. Performance is completely nominal for a unit with over sixteen months on-orbit performance, even after exposure to a thermal environment exceeding the design range.

Summary and conclusion

A high-current power system employing a boost-mode, pulsewidth-modulated switching voltage regulator has been developed, qualified for space applications, and flown; stringent performance requirements have been achieved.

This design has been adapted for application to NASA and Air Force meteorological satellites with even higher load-power requirements and multiple-battery source arrangements. The basic techniques reported in this paper are easily adapted to varying mission requirements.

A high-efficiency, high-performance, boost-voltage regulator extends the DET system usefulness and provides a well-regulated power bus over a wide range of orbits.

Acknowledgments

The boost regulator described in this paper was developed for the DMSP satellite by RCA Astro Electronics under contract F04701-72-C-0221 from the U.S. Air Force Space and Missiles Systems Organization (SAMSO). Personnel directly involved in this development project were: Major O.E. Severo, Spacecraft Project Engineer (SAMSO); J.S. Kinsley, Electrical Design Engineer; J.A. Streleckis, Mechanical Packaging Engineer; and R.A. Hoffmann, Electronic Technician.

The Universal Second-breakdown Tester: electronic cage for the power dragon

H.R. Ronan

What do you do when testing costs too much and sometimes destroys the power semiconductor? This solution produced some unexpected benefits.

If you never had to design and manufacture a power inverter or amplifier, you may not be familiar with the second-breakdown phenomenon. Many of RCA's customers do design power circuits and are familiar with the problem it presents. Consider the following hypothetical situation. Your company has just experienced a rash of field failures of an audio power amplifier that you had spent many months designing and evaluating in the lab. How is it possible? After an engineering investigation of the returned amplifiers, you find that, in each case, the conservatively rated power-output transistor has a collector-to-emitter short. You're upset, so is your boss, and your company is out a considerable amount of money. What has happened? You have just been victimized by the power dragon—second breakdown.

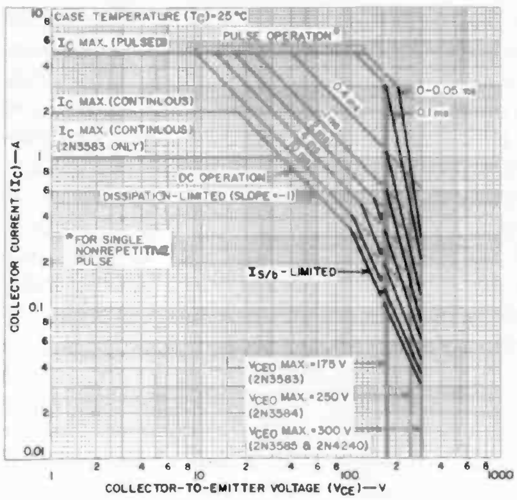
Second breakdown—what is it?

When the energy absorbed by a transistor reaches a critical level, collector-current focusing takes place and produces localized heating or "hot spots" in some areas of the substrate. If the current focusing, and hence the heating, is left unchecked, the collector-to-emitter voltage will collapse, the junction will melt, and the transistor will experience a collector-to-emitter short—second breakdown will have taken place. Second breakdown can occur when the transistor is operating in either its cut-off or active region.[1,2] It is this latter region, where the transistor is forward biased, that is of concern in this paper.

Four variables are important in second breakdown:

1) Case temperature
2) Collector voltage
3) Collector current
4) Time

It is common practice, however, to speak of forward-biased second breakdown in terms of the transistor collector current, with the other three variables held fixed. If you review *RCA Power Devices* you will see the symbol used for this set of conditions, $I_{s/b}$, listed under room-temperature electrical characteristics. Normally, the value specified refers to a corner point on a maximum operating-area chart published for the device (Fig. 1).



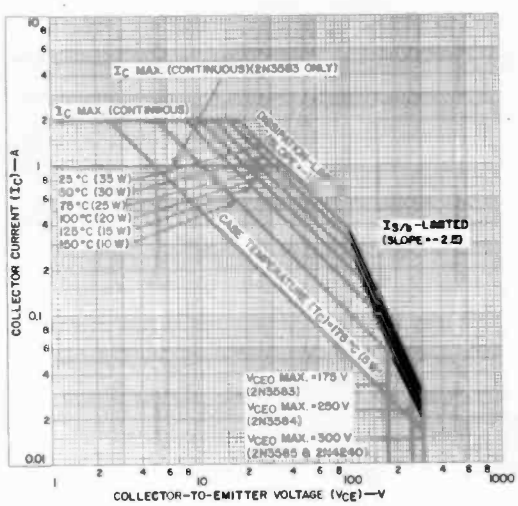


Fig. 1
Second breakdown is a limiting corner point on maximum operating area charts for devices.

Definitions

$I_{s/b}$	second-breakdown collector current
I_b	base current
I_c	collector current
I_{Cbo}	collector cutoff current, emitter open
V_{CE}	collector-to-emitter voltage
V_{BE}	base-to-emitter voltage
f_T	unity-gain cutoff frequency
Q-point	static (dc) collector operating point with no input signal
β	collector-emitter current gain

The maximum operating-area chart offers a concise profile of a power transistor, and is extremely useful for comparative and preliminary application information, but it cannot guarantee the operational integrity of the device in a specific application. Therefore, cogent second-breakdown tests must be performed on each device shipped to a customer. And therein lies the rub. To protect his customers, a transistor manufacturer would have to accept considerable profit loss as a routine risk and engage in testing brinkmanship by performing production second-breakdown tests. During tests, he would have to run the risk of bringing about second breakdown in, and consequently destruction of, his product. RCA Solid State Power has accepted and met this challenge, perhaps the only power transistor manufacturer to do so.[3]

Second-breakdown test equipment is not a standard product. Therefore, because of the importance of this test, and because of the risks and costs involved in a second-breakdown testing program, the RCA power activity studied the possibility of providing a "risk-less" nondestructive test. This paper chronicles the problems, complexities, and past experience with $I_{s/b}$ testing and shows how, through persistence, RCA finally reduced second-breakdown testing to a routine virtually without risk.

Early test circuits

For many years, the basic circuit configuration used in testing second breakdown remained unchanged.

The test (Fig. 2) consists of three basic elements: Class A operation of the transistor under test, use of an active series switch, and an $I_{s/b}$ failure-detection circuit. The most important element is the requirement that the transistor under test be operated Class A; i.e., be held to a specified V_{CE}, and I_C independent of current gain. Since transistor current gain varies widely from family to family, unit to unit, and operating point to operating point, a feedback circuit must be used to regulate I_C.

This is done for two reasons. First, it minimizes operator error in setting test conditions. Second, it retains a reasonable testing rate in the factory; the higher the rate the lower the cost. But in regulating collector conditions to achieve circuit stability, it is all but impossible to divorce the gain-frequency characteristics of the transistor from a major role; and it is difficult enough to test a transistor to near-destruction without having to worry about stability.

Attempts at a practical solution to these problems have led to a plethora of manual test equipments with limited applicability.

All require an extra insertion for testing $I_{s/b}$, and so increase testing costs. Approximately five years ago, RCA developed a second-breakdown test circuit, Fig. 3, that was a step closer to the ideal. It allowed us to at least get a "feel" for the second-breakdown capability of most of our volume types. It covered collector conditions of 7 A, 150 V, and 200 W in both n-p-n and p-n-p types. Because we had settled on a 50-ms standard pulsewidth, we could perform $I_{s/b}$ tests in our computer-controlled, automatic, dc-parameter (SCOPE) test sets.[4] This standardization helped eliminate the need for a separate insertion in discrete second-breakdown test sets, but was, in reality, a tenuous solution.

The four transistor stages, including the transistor under test (TUT), of the test circuit's five-stage amplifier are unstable when the feedback loop is closed. This is where the operational amplifier enters the scene. In addition to providing a convenient means of closing the control loop, the op amp acts as an integrator and stabilizes the amplifier.

This approach seriously limits the pulsewidths that can be handled by this circuit, but the circuit is perfectly adequate to handle our nominal standard of 50 ms

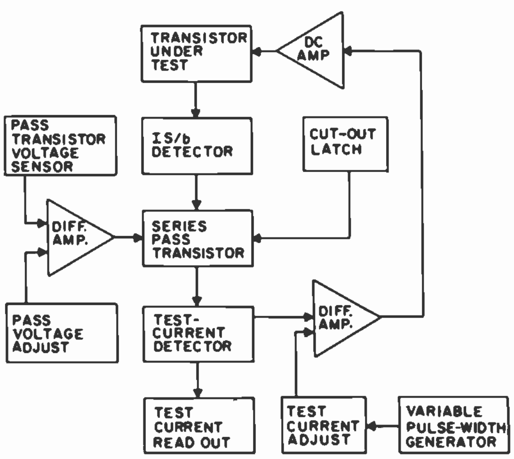


Fig. 2
Conventional circuit configuration uses second-breakdown detector along with feedback circuit that holds the transistor under test to a specified operating point.

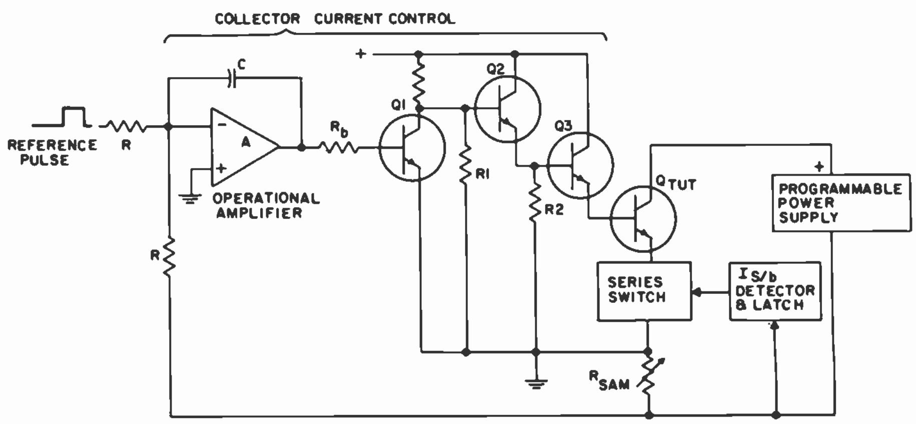


Fig. 3
Computer-controlled tester made standardized testing possible and eliminated need for a separate second-breakdown test set. Op amp closes the feedback loop and stabilizes circuit, but also limits the pulsewidths that the test circuit can handle.

for $I_{s/b}$ pulse testing. This circuit is also sensitive to changes in TUT characteristics and becomes unstable when the TUT gain increases from 30 to 200.

Historically, the failure-protection circuits incorporated in second-breakdown test equipment have been collector-current oriented.

These circuits detect an increase in collector current, amplify the signal, and use it to drive a transistor in series with the TUT. Such a current-control circuit can in no way be expected to limit a sudden increase in I_C because of its inherent slow speed, a limitation that places a premium on detector and series-switch speed if $I_{s/b}$ damage to the TUT is to be prevented. The common practice of employing commercial power supplies for V_{CE} compounds the protection problem. These supplies invariably have a huge output filter capacitor that is capable of delivering extremely high short-circuit currents, essentially limited in value only by wiring inductance. Devices under test that have excessive I_{Cbo} (excessive to the extent that the protection circuit is tripped without the TUT going into second-breakdown) yield false test results and further complicate the matter.

Inaccuracy is an additional problem precipitated by the current-detection approach. The Class-A-operated series switch in the test equipment makes precise automatic control of TUT V_{CE} all but impossible. Second breakdown is extremely sensitive to collector voltage, i.e.:

$$I_{s/b} \propto V_{CE}^{-n}$$

where n ranges between 1.5 and 4, depending on device design. Therefore, if collector current is not carefully controlled, serious errors can occur. Fig. 4 shows experimental data for a 2N3055 transistor for which a 9% shift in V_{CE} at constant I_C resulted in a 2000% change in energy capability.

The solution— The Universal Second-breakdown Tester

In the face of these many problems, persistance, cooperative effort, and ingenuity have produced a nondestructive, accurate $I_{s/b}$ tester, called the Universal $I_{s/b}$ Tester.

The key to the Universal Tester is in preventing the dynamic characteristics of the TUT from having a detrimental impact on overall circuit stability.

Fig. 5 illustrates the approach and Fig. 6 shows the collector-current control circuit in more detail. The TUT is connected in a grounded-base configuration. A constant-current generator in series with the emitter controls circuit current; a simple voltage source determines collector voltage. Regenerative feedback of base current and base-emitter voltage regulates a specified Q point, I_C, and V_{CE}—independent of TUT gain variations. (The Q point is the static (dc) collector operating point with no input signal.) This feedback is necessary because the collector current is controlled through the emitter and V_{CE} through V_{CB}.

The value of this circuit approach can be illustrated by the following statements:

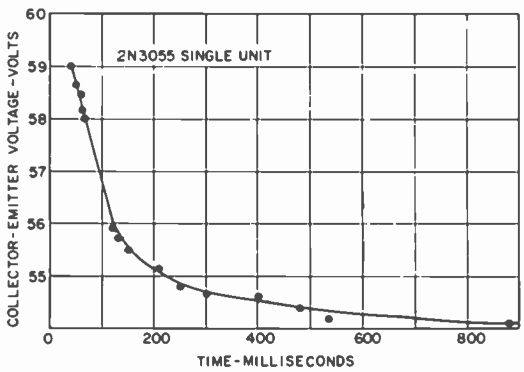


Fig. 4
Slight changes in collector-emitter voltage can lead to serious errors in testing. For 2N3055 device shown here, 9% voltage change produced 2000% change in energy capability. Such sensitivity makes the current-detection approach potentially inaccurate.

1) The circuit is unconditionally stable without regard to the transistor tested and without the need of added compensation.

2) The bandwidth of the circuit is unaffected by the gain of the transistor tested because the variations in the expression $\beta/\beta+1$, where β is transistor current gain, can hardly be expected to be more than 20%.

3) The bandwidth is extremely broad and always larger than the value of the unity-gain frequency cutoff, f_T, of the TUT. For example, substituting standard values into the circuit of Fig. 6 produced a roll-off frequency 10^4 times f_T. The bandwidth of the test circuit is, then, four powers of ten better than that of the unit tested!

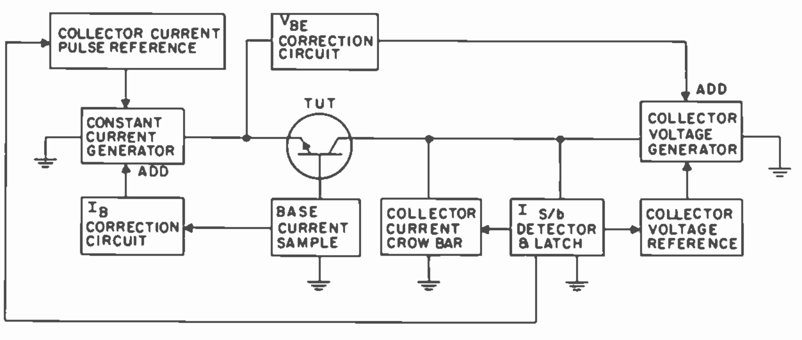


Fig. 5
The solution—the Universal Second-breakdown Tester. Testing method keeps the dynamic characteristics of the transistor under test from having a detrimental impact on overall circuit stability.

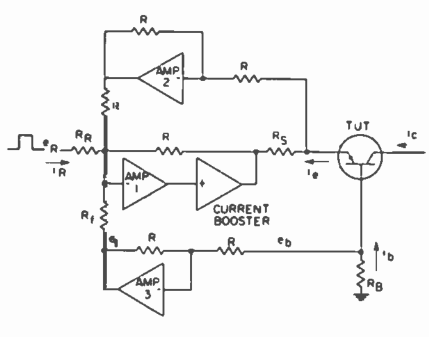


Fig. 6
Collector-current control portion of the universal tester. Feedback circuit keeps Q point stable.

Making the "unfeasible" feasible

An industry newspaper[3] recently reported that

> "...while it would be a great idea for manufacturers to test each power semi to the limit of its safe operating area [the second-breakdown point], it doesn't seem feasible at present. ...[the manufacturers] don't test for the parameter [Safe-Operating Area, SOA], so the SOA spec is only an implied guarantee—something they will not or cannot test. ...it's something that most manufacturers are not skilled to handle. ...SOA can't be known with certainty...".

The Universal Second-breakdown Tester seems to obsolete this opinion.

4) The current risetime for the circuit is approximately 1 μs, a truly impressive test-circuit credential!

What has this circuit configuration done for second-breakdown testing?

1) High TUT current gain actually reduces the necessary feedback. Darlington transistors present no problems.

2) The frequency response of both the emitter-current generator and collector-voltage drive can be maximized without regard to the TUT. The circuit can be easily reproduced.

3) Control circuits can be checked out and repaired independently of the TUT, greatly easing maintenance tasks.

4) Test-set proliferation is drastically reduced.

5) The high-speed series-switch $I_{s/b}$-shutdown transistor circuitry is no longer necessary. An increase in emitter current caused by TUT second-breakdown collapse is instantly resisted by an effective rise in the output impedance of the emitter constant-current generator. Without a series switch, V_{CE} control is accurate.

Circuit descriptions and advantages

The many limitations on collector-emitter voltage-supply design imposed by second-breakdown testing are effectively handled by the universal circuit.

The V_{CE} control portion of the tester circuit is shown in Fig. 7. The maximum allowable second-breakdown fault current is defined for all V_{CE}, I_C conditions by using a fixed "brute-force" voltage and series resistor. As test-current ranges are changed (I_C = 1A, 2A, etc.) the series resistance is varied to maintain the power available for testing approximately constant. This technique wastes power, but prevents test-set damage in the event of misprogramming.

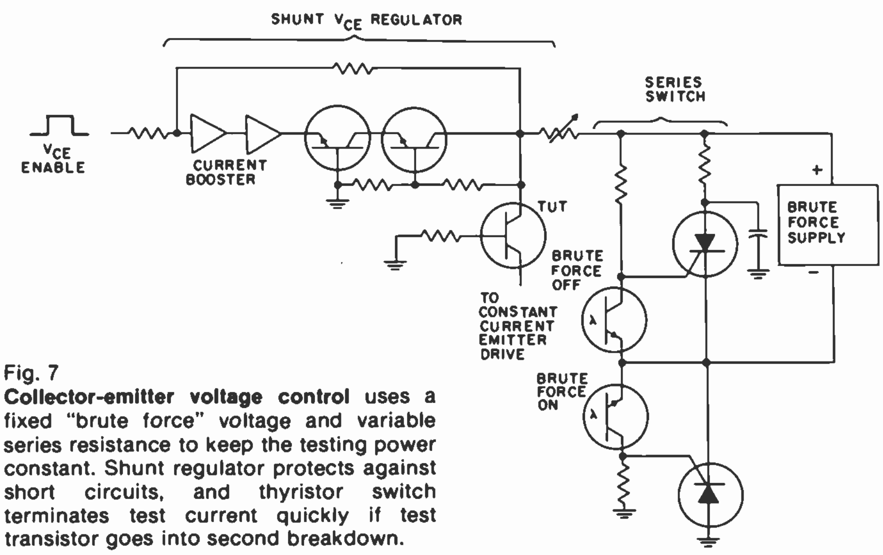


Fig. 7
Collector-emitter voltage control uses a fixed "brute force" voltage and variable series resistance to keep the testing power constant. Shunt regulator protects against short circuits, and thyristor switch terminates test current quickly if test transistor goes into second breakdown.

The shunt-regulator configuration protects the test set from short circuits and reduces the dissipation absorbed by the regular circuit when it is operating with test-pulse times of up to one second. The thyristor switch in series with the brute-force supply prevents excessive dissipation when the circuit is in a standby (not testing) condition, and helps to quickly terminate test current if the TUT goes into second breakdown.

The shunt regulator is emitter-driven to enhance step response time. Circuit stability is not sensitive to pass-unit current gain in this configuration, and the only requirement for the series string is to block voltage. The voltage capability of the circuit is easily modified by adding pass units—up to 600 V have been handled in this manner without adversely affecting the dynamic response of the circuit.

Second-breakdown testing offers a poor environment for digital logic because of the transients inherent in switching large voltages and currents.

The potential for self-destruction of the TUT, coupled with the potential loss of tester effectiveness, makes sound control of second-breakdown test equipment rigidly exacting. The four-to-one noise immunity advantage that COS/MOS devices maintain over bipolar integrated circuits makes them the first choice of logic family. The system logic design is not so clear-cut. Monostable multivibrators (one-shots) are tempting because they are efficient, automatically reset themselves, and adapt well to the wide range of timing required. Unfortunately, circuits using one-shots are extremely sensitive to noise.

The only recourse would appear to be a synchronous approach based on a clock. While a clocked system handles sequential events efficiently, it is cumbersome to apply to a wide time range and requires careful bookkeeping of event flip-flop set/reset lines, particularly when external sources initiate some of the signal inputs. The usual method of handling these signal inputs, edge-setting flip-flops with RC differentiating networks, would have negated the noise immunity gained by using a clocked system. None of these compromises were made in the final design of the Universal $I_{s/b}$ Tester. Not one capacitor was used in the logic network.

The key to the success of the tester control circuit is the gating circuit illustrated in Fig.

8. This circuit issues a *single complete* output pulse, independent of the phase relationship between the clock pulse and input-level change. The only requirement needed for an output is that the input be true during one period of the clock. (If the input goes false before the appearance of the first clock pulse, no output is issued.) This arrangement allows event flip-flops to be triggered with a solid pulse of known energy and frees the designer from detailed set/reset bookkeeping.

An unexpected dividend accrues from this technique. When an element in the logic network fails to function for any reason, the system stops in that state—an invaluable aid for debugging. A further refinement of this circuit was reached by using multiphased clock pulses developed from every other stage of a Johnson counter; the refinement eliminates the possibility of a logic race anywhere in the control circuit. Fig. 9 is a flowchart of Universal $I_{s/b}$ Tester operation.

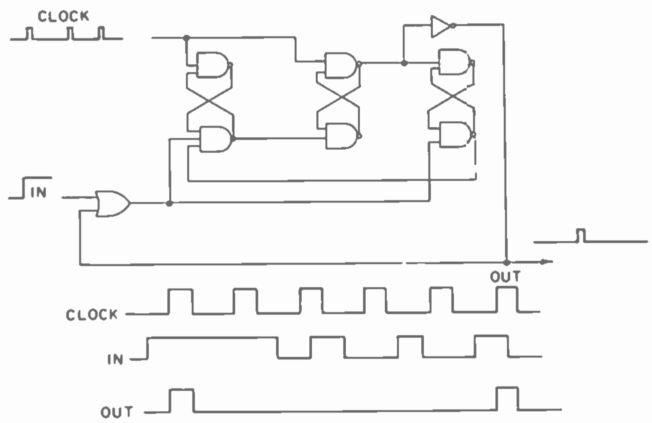
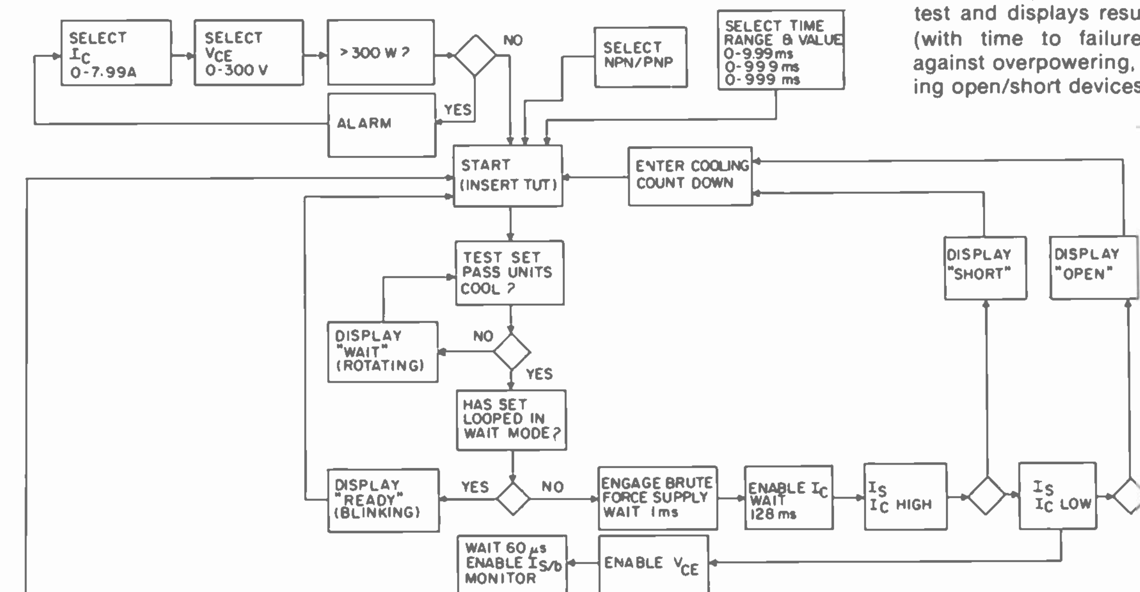
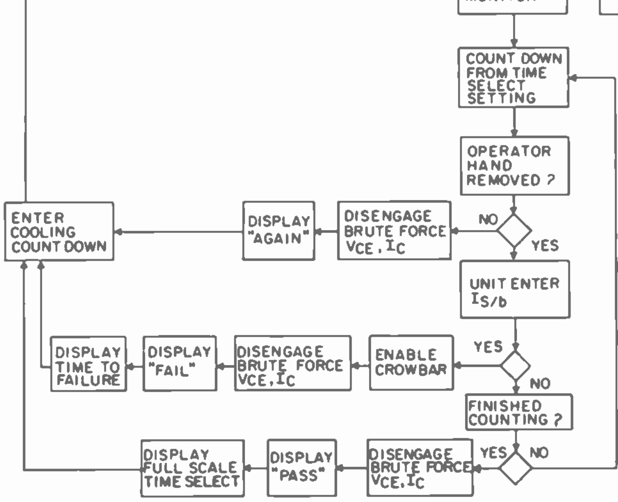
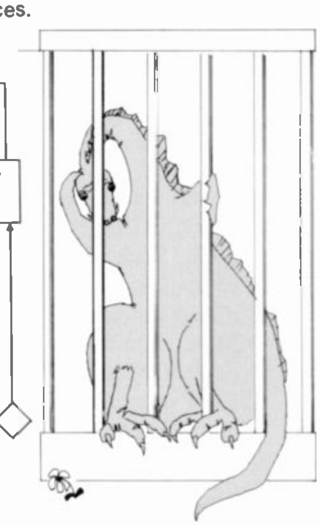


Fig. 8
Gating circuit solved timing problems without introducing noise. Circuit issues single output pulse, independent of clock/input phase.



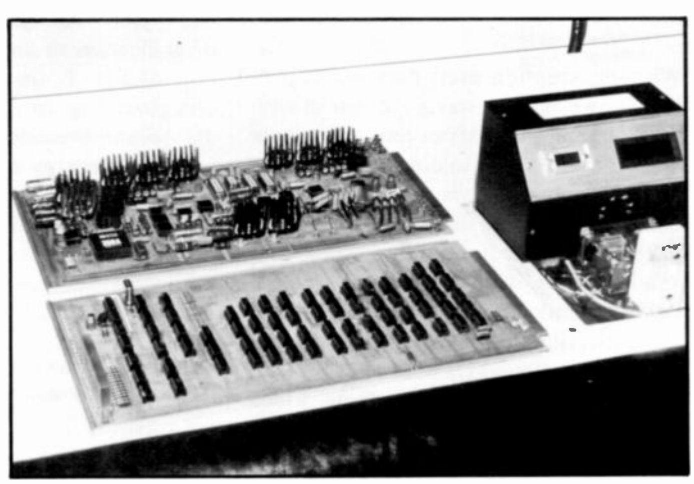


Fig. 9
Operating for over a year on the production line, tester gives devices second-breakdown test and displays results as "pass" or "fail" (with time to failure). Notice protection against overpowering, overheating, and testing open/short devices.

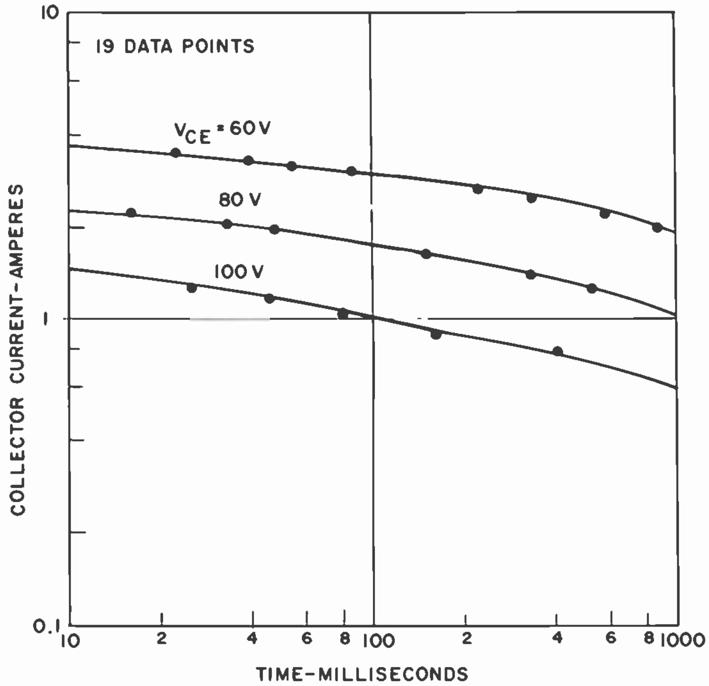


Fig. 10
Typical second-breakdown curves (a magnification of a small section of the curves in Fig. 1) show uniform and repeatable readings, with no apparent error introduced by tester. Curves also show that second-breakdown capability is nearly a constant-energy characteristic, and that readings at 50 ms can be related to readings at 1 s.

Factory experience

After a year of operation in the production line, the Universal Second-breakdown Tester has more than met expectations.

It has successfully tested every device within its 300-W power range, or 90% of Solid State Power's product line. The equipment has performed with minimum maintenance and has been oscillation-free. More importantly, it has afforded tight control of second-breakdown characteristics since exact and *repeatable* readings can be made on individual devices without fear of unit degradation or destruction.

The new tester has eliminated much of the past frustration associated with second-breakdown testing.

Without exception, every previous second-breakdown test set was go/no-go in concept, making every device test an attribute assessment only. Holding test sets in calibration had to be done indirectly. Establishing limit units for correlation purposes was a tedious, unrewarding task. After starting with 100 devices and investing countless hours "inching" each unit up to its failure point (destroying most of them along the way), one was left with perhaps four or five units, about which only one second-breakdown point was known. The old methods had meager dividends for such prodigious effort.

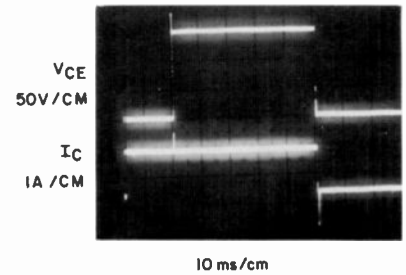
New knowledge

Second breakdown appears to be a nearly constant energy characteristic.

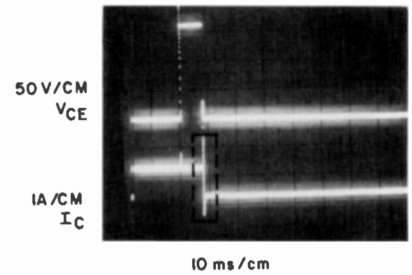
As a part of the Universal $I_{s/b}$ Tester evaluation, 100 2N3585 devices were studied in detail. A family of second-breakdown curves was developed for each unit; each unit was repeatedly driven into second-breakdown 40 to 50 times with 80% survival. The plotted results are most interesting; Fig. 10 is typical. The lack of dispersion of the readings solidly supports the view that errors contributed by the tester are negligible and that the phenomena demonstrated are both uniform and repeatable. Keep in mind that this plot represents a considerable magnification of an extremely small portion of Fig. 1, the maximum-operating-area chart. Fig. 10 also shows that for fixed V_{CE}, second-breakdown capability is nearly a constant energy characteristic, and that readings at 50 ms are related to those obtained at 1s. This relationship had always been clouded in the past because of the inability to generate large volumes of data on individual units.

Second breakdown may be non-destructively predictable.

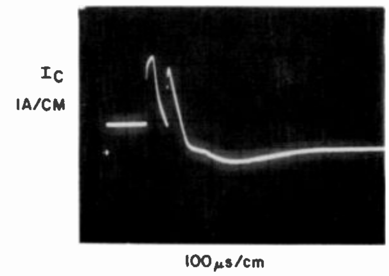
During tester evaluation, a great many oscilloscope photographs of typical



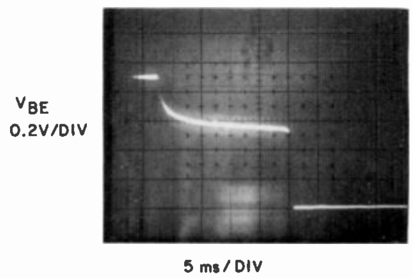
a) Collector current and collector-emitter voltage for 2N5240 device;



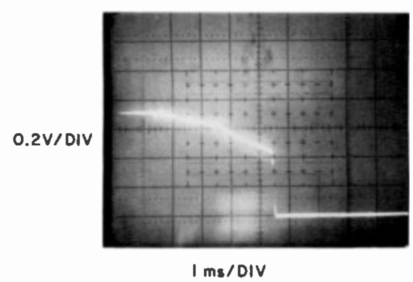
b) same device as in a), but with voltage increased to induce second breakdown;



c) second-breakdown current;



d) different device, 2N3585, before second breakdown; collector-emitter voltage is 100 V and collector current is 700 mA;



e) 2N3585 after damage; collector-emitter voltage is 170 V and collector current is 200 mA.

Fig. 11
Typical waveforms taken during tester evaluation demonstrate the second-breakdown process.

waveforms were taken (Fig. 11). These photographs show that the average slope of unit V_{BE} as a function of time is inversely proportional to the energy capability of the device—a very startling observation. More photographs were taken and the average slope graphically determined. The result, plotted in Fig. 12, established the relationship of V_{BE} to time beyond a doubt. Because second breakdown is a thermal failure, one must conclude that the average pellet temperature is a reasonable measure of hot-spot temperature, and that the V_{BE} measurements actually indicate the change in hot-spot temperature, independently of changes in I_C and I_B. Further study reveals that:

1) I_C cannot add to variations in V_{BE} as a function of time because tester circuits regulate it to a constant value; I_C can only contribute to the static V_{BE} offset.

2) When the collector operating point is such that β varies widely with temperature, the I_B is small enough to contribute only a few percent to the *change* in V_{BE}.

3) When the base current I_B is a large contributor to V_{BE} (low-β Q point) it changes very little with temperature and again contributes but a few percent to the change in V_{BE}.

It is possible that the observed relationships may be peculiar to the 2N3585 device; however, it is difficult to avoid speculating on the possibilities should the relationships prove to be generally applicable. The first that comes to mind is using V_{BE} slopes as a second-breakdown indicator without actually inducing second breakdown. A second, and potentially more important, application is in using the relationships to investigate and eventually control transistor real-time thermal response without using sampling techniques.

Second-breakdown damage may leave "fingerprints."

In obtaining the data for Fig. 12, a number of units were damaged. (Damage was confirmed by subsequent data points that would not match the previously developed second-breakdown history for the units.) In each case, the device exhibited a dual V_{BE}-characteristic slope as in Fig. 11c. Should the dual slope after damage prove universal, it would firmly establish whether any given circuit was responsible for the damage of a device. The implication is that *without* prior knowledge of device

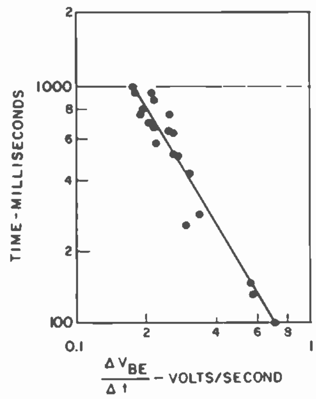


Fig. 12
Second-breakdown prediction without inducing breakdown or damage may be possible by developing curves showing base-emitter voltage *vs.* time to failure. Plot here is for a 22-unit sample for one device.

capability, observation of V_{BE} characteristics in a Class-A circuit is sufficient to establish damage. No more in-house disputes or factory/customer confrontations.

How the tester will help SSD business

The new Universal $I_{s/b}$ Tester will without doubt improve Solid State Division's power semiconductor business posture. Specifically, it will help us in these three areas:

1) *Distributor market*—since our standard products typically have 2 to 3 times the capability of published ratings, we will be able to guarantee higher second-breakdown ratings and command the premium price the higher ratings warrant.

2) *Custom market*—Marketing will have a competitive edge because we will know our power capability accurately.

3) *High-reliability market*—We will be able to supply data-logged readings of second breakdown, a capability that up to now has not existed in the industry.

Acknowledgment

The author thanks Dr. R. Sunshine of the RCA Laboratories, Princeton, for his unstinting support and encouragement during the pursuit of a viable test-circuit design. The assistance of Nicholas Magda during the difficult experimental and debugging stages of the design is also recognized; his original ancillary circuits were a valuable contribution to the final design.

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Reprint RE-23-4-10
Final manuscript received October 6, 1977.

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Spares allocation for cost-effective availability

H.R. Barton

Which spare parts should you stock? This method of selection has cut spares costs by as much as 75% and simultaneously improved system availability.

Initial spare-parts allotments for electronic systems are normally computed item by item, but this approach does not necessarily maximize total system availability for each dollar invested in spares. Spares quantities can, however, be determined in a way that accomplishes that objective. The method described here, marginal utility, determines which spare will achieve the greatest increase in system availability per additional dollar invested. The marginal-utility model adds that item to the inventory list, determines the increased availability, and then iterates the procedure until the availability objective is achieved.

Spares requirements

Reliability analysis of a system allows the engineer to assess the consequences of single and multiple failures of each spareable item. More than one failure may be required for a system failure if the system has redundancy or if some degradation of performance is allowable. Once the number of failures required for system failure is determined for each spareable item, a spares protection criterion can then be established.

The number of failures required for system failure should be an independent number for each item. Independence simplifies the computation of spares requirements.

Independent failure criteria can represent perfectly only those systems which have simple redundancy relationships or compensating rules.

Fig. 1 gives an example of a system with simple redundancy. Failure of the system requires failure of a critical number of any subsystem boxes. Fig. 2, however, describes a system with dependent redundancy. Two failures of subsystem box type *C*, *D*, or *E* are necessary for system failure, but only if failures have not occurred in others of these box types. A failure of *C*1 and *D*2 can produce system failure with or without failure of *C*2. Simultaneous failure of *C*1 and *D*1 cannot cause system failure, however, without a failure in the second chain. Exact representation of dependent redundancy effects upon spares requirements is beyond the scope of this discussion, which is restricted to independent failure and spares protection criteria.

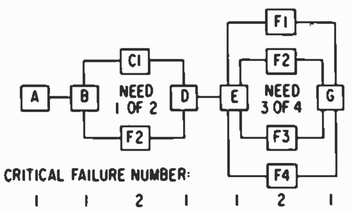

Fig. 1
Simple redundancy. Failure of this system requires the failure of the number of subsystems listed below each subsystem box.

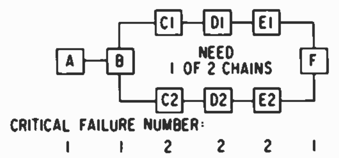

Fig. 2
Dependent redundancy. With "cannibalization" allowed, these numbers of subsystem failures are required for system failure.

However, it is possible to establish operating rules to support independent spares protection criteria. For example, a cannibalization rule would permit exchanging *D*1 for *D*2 if *C*1 and *D*2 failed and no spares were available for either. This rule would establish the failure number at two for boxes *C*, *D* and *E*. Without a cannibalization rule, a failure number of two could be assigned to one of the box types and a failure number of one to each of the others in the redundant chain.

The spares assignment should provide a predetermined probability that the system will not be unable to recover from a failed state because of an unavailable spare.

This can be expressed as a probability of spares sufficiency, spares confidence level, or spares availability. Since operational availability represents a probability averaged over time, spares availability should also be expressed as an average time value.

Spares protection is determined by the probability of having sufficient spares for a designated period, and also by the resupply method.

Some spares replenishment policies call for relatively continual replenishment of depleted supplies; other policies require replacing a whole inventory's depletions in one batch. Most land-based systems have continual access via depot "pipeline" and so fall into the first category. Shipboard or airborne inventories are not generally accessible for replenishment except in port, so inventory deficiencies must wait until then for batch replenishment.

Because of the random nature of demands under a policy of continual replenishment, the expected spares-replenishment delay does not vary with time. Spares availability can thus be computed in terms of the probability that the number of failures during a replenishment period will not exceed the critical failure number plus the number of spares, for each type.

Batch replenishment creates a more difficult computation problem because the expected spares-replenishment delay does vary with time. A stock failure near the beginning of a mission may well abort the mission because of an intolerable replenishment delay. A stock failure at the end of a mission, on the other hand, would be inconsequential. Computing the spares availability under batch replenishment requires time averaging to account for the varying replenishment delay.

Computing probability of demand

If the operating population of an item is large or the failure expectancy is very small, the spares demand rate is relatively constant for any likely failed state. This situation is possible even with a population of one, if the probability of failure is very small. In this circumstance, the probability

Reprint RE-23-4-1
A similar version of this article appeared in *Logistics Spectrum*, Winter 1976.

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of a stock failure can be approximated by the Poisson distribution.

Some inaccuracy is introduced by using the Poisson process to represent failure probabilities of items that are in the system in small numbers. This is especially true where expected use is significant, or where active redundancy exists. The true failure distribution is binomial with no spares and approaches the Poisson as the number of spares approaches infinity. A reasonable representation of the process is possible with the state probability model, which is similar to the Poisson, but differs when the number of operating units decreases with succeeding failures.

The Poisson model is limited to spareable items with expected usage of somewhat less than 150 because of computer exponent limitations. One way of overcoming this handicap is by approximating the Poisson with the normal distribution. When expected usage is 100 or more, the approximation is reasonably accurate.

Optimizing spares allocations

When an inventory consists of a large number of items, a large number of alternative inventory allocations can satisfy spares availability constraints.

In order to choose among the acceptable alternatives, a ranking criterion is necessary. The most favored criterion is cost. Storage space could be used, but would have an advantage over cost only if spares costs are low relative to the space that spares occupy, an unusual situation.

The optimum allocation is achieved iteratively by applying marginal utility.

At each step in the optimization process, the spareable items are compared with each other to determine which spare should be added to maximize the increase in protection per unit cost. Mathematically, the model determines Max $\Delta P_f / C$ where

ΔP_f = increase in protection achieved by adding a spare, and
C = cost of adding that spare.

The spare having maximum cost-effective protection is added and the comparison is made again. The process is continued until the spares protection criterion is met.

The marginal utility process is valid only with monotonically decreasing functions. Although a probability density function is not generally monotonic throughout its range, a monomodal function has a maximum at or near the mean value. The validity of the optimization is assured by providing an initial number of spares of each type to cover expected usage for the replenishment delay.

To reduce computation requirements, the number of optimizing steps should be as few as possible. To do this, P_{max} is defined as one minus the minimum spares protection requirement. Then, since the total probability of stock failure is constrained to be less then P_{max}, the probability of stock failure for each item must certainly be less than P_{max}. Mathematically, since

$$\sum_{i=1}^{n} P_{fi} \leqslant P_{max}, \text{ then } P_{fi} \leqslant P_{max}.$$

Upon this basis, spares of each type are added when necessary to reduce the probability of stock failure per type to P_{max} or less, prior to optimization. Fig. 3 illustrates how the optimization process is applied.

Batch replenishment has two significant differences from continual replenishment.

First, there is a periodic opportunity to restore the inventory. This is not possible under continual replenishment because the consumption of spares becomes negligible in comparison with resupply rate during the replenishment action. Thus, 100% spares availability is not very probable under continual replenishment because that system implies a continual state of system operation and spares demand.

The second major difference between continual and batch replenishment is the sensitivity of availability to the time of failure. In batch replenishment, if an item's inventory is exhausted near the beginning of a mission, the system is likely to the inoperable for a major part of its mission time. If such a depletion occurs near the end of the mission, the consequences are much less serious. In order to relate spares protection to operational availability, *protection time* must be considered as well as *protection probability*. This can be accomplished by integrating the spares protection probability over the mission duration. The result is defined as spares availability.

Optimizing redundant-unit allocation

Redundant-unit allocation can be optimized as readily as spares allocation.

The techniques described here can establish the optimum configuration of redundancy for a system that meets the requirements described under the earlier section on redundancy. Applying this method to redundancy requires careful consideration of the similarities between the analysis of spares protection and the analysis of redun-

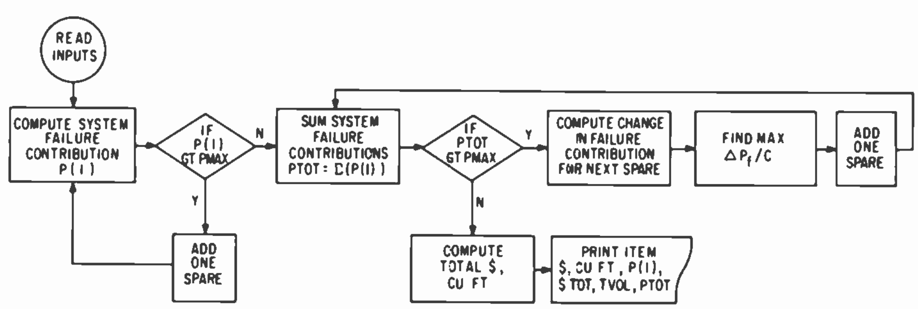

Fig. 3
Marginal utility process determines the increase in protection that each additional spare will add, along with the cost of adding that spare.

dancy. Redundant units enable continued system operation while a failed unit is being repaired or replaced. If the repair/replacement period is made equal to the period for spares protection, inherent availability can be analyzed by the same models used for spares availability. This is more evident when inherent availability is considered to be a probability, as in operational availability.

Some systems experience varying times for restoration to active service, depending upon characteristics of the failed unit. A modified version of the spares model makes it more convenient to treat this variation by using individual item restoration times.

Analyzing redundancy derived from using standby units is relatively easy, since the redundant units are equivalent to collocated spares. Analyzing redundancy obtained with active units is a more complex problem, since the model must account for the increased operating failure rate with the added redundant units.

The model can analyze inherent availability and optimize the allocation of standby or operating redundant units to meet a criterion of inherent availability. Operation is like spares allocation, and is addressed to a permissible level of unavailability, which is related to common or individual repair/restoration periods. The model may be used with either continual or batch restoration.

Table I
Conventional spares provisioning has very low aggregate availability when compared to the optimized provisioning.

	Conventional provisioning (0.90 *per item*)	*Optimized provisioning* (0.90 *aggregate*)
Average probability of sufficient spares per item	0.9808	0.9996
Aggregate probability of sufficient spares, 270 items	0.0053	0.9245
Cost	$134,000	$167,000

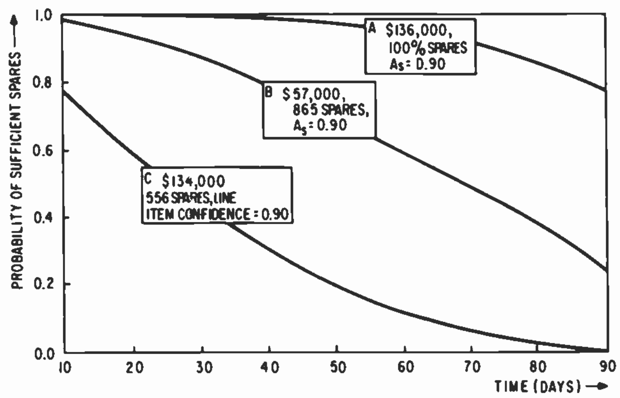

Fig. 4
Comparison of conventional and marginal-utility spares allocation methods. Area above each curve represents the probability that the system will be inoperable because of the lack of a spare. Curve *C* is for the standard spares allocation, where each item on the spares list has a 90% confidence level of availability at the end of the mission. Curves *A* and *B*, however, use the marginal utility method. *B* produces an aggregate *system* availability of 90% at lower cost; *A* produces an aggregate *system* availability of 99.1% at cost roughly equal to the standard method's.

Application experience

The marginal utility method can increase availability or decrease cost.

Two different models have been used to allocate spares requirements for several major systems. The batch replenishment version was used to estimate the cost of shipboard spares. An initial review of one shipboard system showed the possibility of reducing spares cost by 75% while increasing spares availability several orders of magnitude. In another case, the continual replenishment version established the required site spares for a land-based system. In addition, the models have been used, with some modification, to optimize active and passive redundancy in operating systems under design.

Fig. 4 shows three different spares availabilities that can be achieved for a system by using three different spares inventories. The area above any given curve represents the probability that the system will be non-operational because of the lack of a spare. Curve *A* represents the time-variant availability of a spares inventory that provides an average mission spares availability of 0.991. Approximately 270 inventory line items are involved. An availability of nearly 1.0 can be observed after 10 days, decreasing to less than 0.80 after 90 days. This is interpreted to mean that the probability of sufficient spares to support system operation is about 80% after a 90-day mission.

Curve *B* illustrates the effect of establishing a 90% average mission spares availability for the same system. The spares investment is cut in half, at the cost of a very low spares availability at mission's end, about 22%. Even at the mission's half-way point, spares availability is only 75%. Even this inferior protection, however, is better than what can be provided with the conventional 90% confidence level (spares availability) at the mission end for each line item, represented by curve *C*. Curve *C* also has a cost nearly as great as curve *A*, but far fewer items.

Table I compares conventionally derived and optimized inventories for continual replenishment. Note that the spares availability of the conventionally derived inventory averages significantly better than the 90% criterion. This is because each item must better the criterion, and only integer numbers of spares can be added. When these numbers are small, their effects upon availability can change it by several orders of magnitude. Nevertheless, aggregate availability is relatively small. In fact, no line-item availability criterion can provide the same protection as an aggregate criterion with optimized allocation.

The model has been used for redundancy optimization in the design of two communications systems. The first application was to a seaborne communications receiver comprised of four major assemblies. The model allocated standby redundant units to meet an inherent availability requirement and also allocated remote spares to meet an operational availability limit. Both allocations were achieved on the same computer run.

In the second system, redundancy optimization was applied to a communications grid of more than 100 transmitters. The model allocated actively redundant units to meet a high level of inherent availability.

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.

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 6-11, 1978—**American Ceramic Soc. 80th Annual Mtg. & Expo.** (ACS) Cobo Hall, Detroit, MI **Prog Info:** Frank P. Reid, Exec. Director, The American Ceramic Society, Inc., 65 Ceramic Drive, Columbus, OH 43214

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

JUN 4-7, 1978—**Intl. Conf. on Communications** (IEEE, et al) Sheraton Hotel, Toronto, Ont. **Prog Info:** F.J. Heath, Power System Operation Dept., Ontario Hydro Electric Power System, 700 Univ. Ave., Toronto, Ont.

JUN 5-8, 1978—**Natl. Computer Conf.** (AFIPS, IEEE, ACM) Anaheim Conv. Ctr., Disneyland Hotel Comp., Anaheim, CA **Prog Info:** Stephen Miller: SRI Intl., ISE Division, Menlo Park, CA 94025

JUN 5-8, 1978—**13th Photovoltaic Spec. Conf.** (IEEE) Shoreham Americana Hotel, Washington, DC **Prog Info:** John Goldsmith, M/S 169/422, JPL, 4800 Oak Grove Dr., Pasadena, CA 91103

JUN 13-15, 1978—**Power Electronics Specialist Conf.** (IEEE) Syracuse, NY **Prog Info:** F.B. Goldin, Mail Drop 30, General Electric, Genessee Street, Auburn, NY 13021

JUN 21-23, 1978—**Machine Processing of Remotely Sensed Data** (IEEE) West Lafayette, IN **Prog Info:** D. Morrison, Purdue Univ. LARS, 1220 Potter Drive, West Lafayette, IN 47906

JUN 26-28, 1978—**Design Automation Symp.** (IEEE) Las Vegas, NV **Prog Info:** POB 639, Silver Spring, MD 20901

JUN 26-29, 1978—**Conf. on Precision Electromagnetic Measure** (IEEE, NBS, URSI/USNC) Conf. Ctr., Ottawa, Ont. **Prog Info:** Dr. Andrew F. Dunn, Natl. Research Council, Montreal Road, Ottawa, Ont.

JUN 27-29, 1978—**Intl. Microwave Symp.** (IEEE, et al) Chateau Laurier, Ottawa, Ont. **Prog Info:** A.L. VanKoughnett, Communications Research Ctr., POB 11490, Station H, Ottawa, Ont. K2H 8S2

JUL 18-21, 1978—**Nuclear & Space Radiation Effects Conf.** (IEEE, et al) Univ. of New Mexico, Albuquerque, NM

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.

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

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

Patents

Astro-Electronics

L. Muhlfelder| G.E. Schmidt, Jr.
Closed loop roll/control system for satellites—4062509

Advanced Technology Laboratories

W.A. Borgese
Apparatus for measuring a dimension of an object—4063820 (assigned to U.S. government)

Automated Systems

R.F. Croce| G.T. Burton
Holographic high resolution contact printer—4043653 (assigned to U.S. Government)

T.J. Dudziak
Cylinder firing indicator—4055079 (assigned to U.S. government)

H. Honda
In-line coax-to-waveguide transistor using dipole—4011566 (assigned to U.S. government)

N. Hovagimyan| J.M. Link
Elastic buffer for serial data—4056851

E.M. Sutphin, Jr.
Testing compression in engines from starter motor current waveform—4062232 (assigned to U.S. government)

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C.A. Clark, Jr.
CRT display with truncated rho-theta presentation—4059785

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Radio frequency pulse width amplitude modulation system—4063199

D.M. Schneider| L.J. Bazin
Constant pulse width sync regenerator—4064541

H.G. Seer, Jr.
Apparatus for automatic color balancing of color television signals—4064529

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Horizontal deflection circuit with timing correction—4063133

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Bias circuit for avalanche diodes—4058776

V.S. Ban| S.L. Gilbert
Apparatus for chemical vapor deposition—4062318

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Semiconductor device having a body of amorphous silicon—4064521

D.E. Carlson| C.E. Tracy
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Patent Operations

A.L. Limberg
Current sensing circuit—4057743

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Cathode support structure for color picture tube guns to equalize cutoff relation during warm-up—4063128

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Distributor and Special Products

Sterner, J.F.	NJ-15008
Stonaker, W.M.	NJ-11275

Globcom

Correard, L.P.	NY-41632
Ginters, F.	NY-47848
Hoffman, L.	NY-39507
Martin, J.	NY-38519
Stackhouse, D.R.	CA-, HI-

Electro Optics and Devices

Adams, B.B.	PA-9293E
Byram, R.E.	PA-10707E
Cox, R.W.	PA-ME6212E
Eshelman, J.A.	PA-21434
Fanale, J.R.	PA-79E
Fleckenstein, E.D.	NJ-10197E
Forman, J.M.	PA-11347
Gote, J.T.	PA-9748E
Hamilton, G.A.	PA-7435E
Hammersand, F.G.	PA-10163E
Helvy, F.A.	PA-11131E
Hensley, J.W.	IN-10912
Jasinski, J.P.	PA-21435E
Licht, H.W.	PA-7627
McDonie, A.F.	PA-10693
Nekut, A.G.	Pa-10276
Nierenberg, M.J.	PA-12291E
Palmquist, D.W.	PA-7925E
Paul, W.H.	PA-10304
Romero, E.L.	MA-19979 PA-10301E
Seidman, N.	PA-10014E
Shannon, A.W.	PA-13209
Smith, C.P.	PA-9714E
Tomcavage, J.R.	PA-21428E
Trout, D.R.	PA-21431E
Villanyi, S.T.	Canada
Walton, H.B.	PA-5063E
Werntz, H.J.	PA-21436E

Government Communications Systems

Allen, R.W.	NJ-7826
Ames, M.E.	PA-8695E
Anzalone, P.	NJ-11837
Black, A.L.	NJ-13820 PA-10368E
Brill, H.A.	NJ-24489
Bucher, T.T.	NJ-14341
Buck, R.A.	NJ-13521
Chapman, H.H.	OH-EE2079
Comninos, D.A.	NJ-10857
Daigle, E.J. Jr.	NJ-16322
Henter, C.	NJ-14241
Herman, S.H.	PA-1855E
Houck, R.D.	NJ-22536
Jellinek, E.	NY-22650
Jobbe, I.	NJ-17347
Jones, A.G.	PA-9735E
Kaufman, J.W.	NJ-16069 PA-4572E
Knoll, J.	PA-10430
Kozak, M.J.	NJ-12050
Livingston, H.N.	PA-1505E
Mack, A.	NJ-20598
Magasiny, I.P.	PA-10422E
McCauley, E.S.	PA-11153E
Meer, M.E.	NJ-12191 NY-36986
Merson, L.N.	NJ-12497
Nahay, L.P.	NY-35259
Nasto, S.N.	NJ-13493
Nossen, E.J.	NJ-20601
Parker, D.J.	NJ-21110
Risse, R.A.	NY-37050
Rostrom, R.W.	NJ-19578
Sass, E.J.	NJ-17217

Sokolov, H.	CT-3938 PA-3507E
Steinberg, N.	NJ-16531
Tannenbaum, D.A.	NJ-20154
Thompson, A.C.	NJ-18272
Ubben, R.C.	MD-5366
Vallette, C.N.	PA-2811E
Vallorani, A.A.	PA-14955
Wezner, F.S.	NJ-20115

Governments Systems Division Staff

Coben, P.W.	PA-9004E
Hilibrand, J.	NY-37383
Keller, M.A.	NJ-15007
Shore, D.	NJ-16176
Wilkinson, D.A.	DC-2865
Wright, P.E.	NJ-17027

International Licensing

Romero, E.L.	PA-10301E MA-19979
Shotliff, L.A.	NY-40390

Laboratories

Haldane, H.R.	NJ-15158
Hellman, H.I.	NY-22392E
Lile, W.R.	NJ-17467
Mackey, D.	NJ-13627
Mawhinney, D.D.	NJ-13246
Rosen, A.	Canada
Schell, R.E.	NJ-13629
Zollers, S.M.	NJ-13695

Missile and Surface Radar

Abbott, S.L.	PA-10084
Adams, F.G.	NJ-13504 PA-9007E
Aron, S.	NJ-15447
Bachinsky, R.D.	PA-11162E NJ-14872
Baker, H.F.	NJ-8113
Baron, A.S.	MD-3183
Beadle, P.R.	Britain
Beckett, W.	NJ-23495
Berkowitz, H.	NY-23101
Bernard, W.	NJ-8878
Boertzel, R.L.	NJ-14398
Bogner, B.F.	NJ-19875
Breese, M.E.	NY-39719 OH-E22759
Brown, H.W.	NJ-14672
Burke, T.J.	NJ-16533
Caplan, L.A.	VA-00039
Clarke, T.L.	NJ-10274
Copestakes, J.E.	NJ-13471
Daut, Jr., S.E.	DE-15569Y
DeFelice, R.F.	NJ-21673
Dorman, M.L.	NJ-24379 WA-8949
Duffin, J.D.	NJ-8653
Eble, F.A.	DC-3664Str PA-4161E
Felheimer, C.	AL-1617
Field, G.R.	NJ-13595
Freedman, D.D.	NJ-11641
Galbiati, L.J.	OH-23069
Gallager, J.B.	NJ-14525
Groman, E.M.	NJ-11557
Grossman, H.B.	PA-11840
Hobson, J.F.	PA-2115E
Hopper, A.G.	MA-21322 NY-41722 PA-1540E
Howery, R.W.	NJ-9518
Johnson, M.C.	NJ-11645
Karch, M.A.	NJ-21862
Kay, F.T.	NJ-11053
Kooperstein, R.	NY-3382
Korsen, M.	NJ-16593
Kruger, I.D.	NJ-6262
Lesser, D.	CA-0447
Levi, P.	NY-37438
Liston, J.	PA-12087E
Lurcott, E.G.	NJ-14641
Lyndon, D.L.	CA-9164
Magun, J.	NJ-13002
McCord, M.	OH-E20813
Melody, J.V.	NJ-17589
Metzger, G.V.	NJ-14170 PA-01866
Moll, A.P.	NJ-19338
Molz, K.F.	NJ-16906 MD-3001
Moncher, R.	NY-35248 PA-009158E
Nessler, T.G.	NJ-13187
Nessmith, J.T.	NJ-10285
O'Brien, J.F.	PA-4879E
Paglee, M.R.	NJ-17679
Patterson, P.	Ontario
Petri, W.H.	PA-8986E NJ-24156
Pschunder, R.J.	NJ-13141
Raciti, S.A.	NY-39124
Ray, P.	FL-4922 NJ-14403
Robinson, A.S.	NJ-14026 NY-29222
Rogers, Jr., A.	PA-01343
Rogers, G.J.	NJ-15073
Rubin, M.	NY-30763
Russell, H.	MA-21504
Scarpulla, G.	NY-30772
Schnorr, D.P.	PA-12703E
Scott, E.N.	NJ-8853
Scott, I.	PA-ME14398
Scull, Jr., W.E.	NJ-15283
Senior, G.A.	NJ-9330
Simonetti, J.A.	PA-15380E NJ-18826
Smith, J.N.	MA-20965
Stadnyk, P.J.	NJ-10497
Strip, J.	NJ-14083
Tillwick, F.H.	NJ-12856 OH-E22556
Urkowitz, H.	NJ-21564
Volpe, J.C.	NJ-22449
Weiss, H.R.	PA-14637E MA-9920
Weiss, M.	PA-4796E
Wells, W.D.	NJ-13185
Wick, R.H.	NJ-17490 PA-18637E
Widmann, F.W.	NJ-8131
Wilsher, R.A.	Britain Canada
Yanis, E.M.	NJ-13476 VA-8947

Mobile Communications Systems

Bullock, J.B.	NJ-8639
Hanway, W.F.	PA-8956E
Neidlinger, J.R.	OH-E40301
Risko, A.J.	PA-7334E
Seymour, J.W.	AZ-8340 NJ-14609 PA-12479E
Springer, C.J.	PA-61992E
Stewig, W.G.	PA-17736-E

NBC

Meany, Jr., M.H.	NY-46233
Polak, H.L.	NY-42746
Siebert, J.L. (Cons)	CA-4732EE

Patent Operations

DeCamillis, M.	MI-12131 NJ-11692
Emanuel, P.M.	MA-25622

Picture Tube Division

Alleman, R.A.	PA-2750E
Blust, H.L.	NJ-
Bumke, J.R.	IN-7550
Chemelewski, D.	PA-17727E
Class, J.S.	PA-6583E
Clutter, L.M.	IN-11632
D'Augustine, F.T.	PA-9312E
Davis, J.H.	PA-
Dymock, L.P.	PA-7417E
Gadbois, G.S.	PA-10538E
Goldberger, R.S.	NJ-7943 PA-1696E
Gruber, L.L.	PA-10316E
Hall, L.B.	IN-7084
Handel, R.R.	PA-9317E
Henderson, W.G.	PA-5323E
Hensel, V.B.	PA-
Hughes, R.H.	PA-12678
Hummer, A.P.	IL-17848
Kimbrough, L.B.	PA-19026
Konrad, R.J.	IN-
Kuzminski, H.W.	PA-8736E
Loser, T.C.	PA-9246E
Maddox, W.J.	PA-11173E
Mengle, L.I.	PA-3778E
Miknis, W.D.	PA-
Ottos, J.G.	PA-
Pederson, W.E.	PA-10017E
Porath, A.C.	IN-11030
Price, D.O.	PA-ME6203E
Royce, M.R.	PA-10005E
Savleter, R.E.	IN-7373
Scearce, K.D.	IN-10967
Swope, H.H.	PA-21426E
Weingarten, M.R.	PA-ME01206
Wolverton, P.W.	IN-5548

RCA Ltd., England

Pickering, J.	MIEE

RCA Service Co.

Cox, H.C.	FL-10778
Dombrosky, R.M.	NJ-14495

Records

Chang, B.J.	IN-16479
Devarajan, A.	IN-15114
Fuller, R.E.	IN-16697
Martin, M.K.	IN-16685
Mattson, G.A.	PA-7155E
Nelson, G.	IN-15343 NJ-19613
Weaver, C.A.	IN-17205

Research and Engineering

Clark, J.F.	NJ-24517
Jenny, H.K.	NJ-19775
Lauffer, W.D.	DE-5243

SelectaVision

Liddle, S.W.	IN-7671

Solid State Division

Ahmed, A.H.	NJ-19596
Bartlett, S.P.	PA-26487
Baugher, D.M.	NJ-17921
Bennet, W.P.	NJ-18910 PA-9249E
Blattner, D.J.	NJ-16183
Campbell, L.R.	NJ-12958
DiMassimo, D.V.	NJ-14264
DiMauro, J.	NJ-A9989 PA-18056
Greenberg, L.S.	MA-11061
Gubitose, N.F.	PA-8511
Jetter, E.	NY-36913
Keller, J.P.	NJ-19400
Lindsley, C.	NJ-13355
Meisel, H.R.	NJ-20307
Mendelson, R.	NY-27175
Moyer, J.H.	PA-8784E
Nash, T.E.	PA-6951
Puotinen, D.A.	NJ-14276
Scaran, E.D.	PA-26505E
Waas, G.J.	NY-31494
Waltke, H.C.	NJ-14483
Williams, C.C. Jr.	IN-14914 OH-14667
Wilson, R.L.	NJ-12968

Two RCA engineers elected IEEE Fellows

The membership grade of Fellow is the highest attaintainable in the Institute of Electrical and Electronic Engineers. The IEEE annually recognizes as Fellows those members who have made outstanding contributions to the field of electronics.

Anthony H. Lind

"for technical leadership in the design and product development of video tape recorders and color television cameras."

Tony Lind has been with Broadcast Systems since 1946, and has been an Engineering Manager since 1951. His engineering organizations have designed and developed many broadcast studio products—cameras, tv tape recorders, projectors, switchers, and terminal equipment. He has participated in many industry technical committees and is presently on the Board of Governors of the SMPTE.

Walter W. Weinstock

"for contributions to radar systems and for leadership in development of modern air defense systems."

Walt Weinstock is a Senior Staff Scientist at Missile and Surface Radar; he has been with RCA since 1949. Most of his work has been in systems engineering and definition of air defense systems, such as BMEWS, ASMS, and AEGIS. His earlier work in extending the area of radar target modeling brought him international recognition through the "Weinstock Cases," now cited in a number of books on radar.

Henderson named Outstanding Young Electrical Engineer of 1977

Each year, Eta Kappa Nu, the national electrical engineering honor society, recognizes a young engineer who has "outstanding professional achievements, civic and social activities, and cultural pursuits." Nominees must be no more than 35 years old, with a BSEE degree, or equivalent, held no more than 10 years.

John G.N. Henderson

"for original contributions to the advancement of television technology and for his participation in civic and cultural affairs."

John Henderson has been with RCA Laboratories since receiving his BSEE in 1967. His work has included projects in i.f. filter design procedures, electronic tuner control systems, and surface acoustic wave filters. He is also an instructor in RCA's Minorities in Engineering Program, working with high-school students from minority groups to help them receive supplemental technical education and experience as preparation for engineering careers.

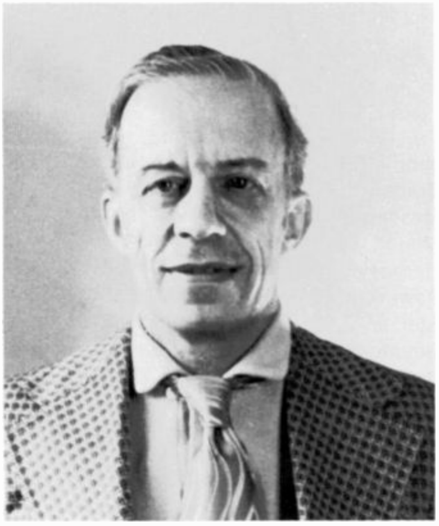
Good company

RCA's two new IEEE fellows join a select group—starting with David Sarnoff, RCA has produced 147 Fellows over the years. The list includes some famous names in RCA's past as well as prominent ones in RCA's present.

Name	Awarded
Sarnoff, David	1917
Batsel, Max C.	1927
Beverage, Harold H.	1928
Jolliffe, Charles B.	1930
Wilmotte, Raymond M.	1938
Zworykin, Vladimir K.	1938
Engstrom, Elmer W.	1940
Brown, George H.	1941
Hanson, O.B.	1941
Peterson, Harold O.	1941
Wolff, Irving G.	1942
North, Dwight O.	1943
Hansell, Clarence W.	1945
Beers, George L.	1947
Kell, Ray D.	1947
Coleman, John B.	1948
Herold, E.W.	1948
Lindenblad, Nils E.	1948
Rose, Albert	1948
Carlson, Wendell L.	1949
Olson, Harry F.	1949
Bedford, Alda V.	1950
Hirsch, Charles J.	1951
Knox, James B.	1951
Landon, Vernon D.	1951
Luck, David G.C.	1951
Morton, George A.	1951
Schade, Otto H.	1951
Schmit, Dominic F.	1951
Siling, Philip F.	1951
Epstein, David W.	1951
Holmes, Ralph S.	1952
Law, Harold B.	1952
Nergaard, Leon S.	1952
Headrick, Lewis B.	1953
Laport, Edmund A.	1953
Rajchman, Jan A.	1953
Trevor, Bertran A.	1953
Young, Charles J.	1953
Anderson, Earl I.	1954
Bond, Donald S.	1954
Byrnes, Irving F.	1954
Corrington, Murlan S.	1954
Ewing, Douglas H.	1954
Gunther, Clarence A.	1954
Koch, Winfield R.	1954
Schrader, Harold J.	1954
Schroeder, Alfred C.	1954
Shaw, George R.	1954
Speakman, Edwin A.	1954
Fredendall, Gordon L.	1955
Harris, William A.	1955
Janes, Robert B.	1955
Linder, Ernest G.	1955
Ramberg, Edward G.	1955
Roys, Henry E.	1955
Sinnett, Chester M.	1955
Weimer, Paul K.	1955
Barton, Loy E.	1956
Glover, Alan M.	1956
Korman, N.I.	1956
Leverenz, H.W.	1956
McElrath, G.	1956
Poch, Waldemar J.	1956
Spitzer, Edwin E.	1956
Tolson, W.A.	1956
Ankenbrandt, F.L.	1957
Avins, Jack	1957
Barco, Allen A.	1957
Flory, Leslie E.	1957
Hillier, James	1957
Schairer, Otto S.	1957
Thompson, Leland E.	1957
Tuska, Clarence D.	1957
Pan, Wen Y.	1958
Peter, R.W.	1958
Van Duesen, G.L.	1958
Brustman, J.A.	1959
Mueller, Charles W.	1959
Simpson, LeRoy C.	1959
Curtiss, Arthur N.	1960
Johnson, Edward O.	1960
Johnson, Harwick	1960
Moore, John B.	1960
Rau, David S.	1960
Smith, Philip T.	1960
Sommer, Alfred H.	1960
Spencer, Roy C.	1960
Webster, Wm. M.	1960
Nicoll, Frederick H.	1961
Smith, Theodore A.	1961
Wickizer, Gilbert S.	1961
Kihn, Harry	1962
Kozanowski, Henry N.	1962
Sonnenfeldt, R.W.	1962
Woll, Harry J.	1962
Cimorelli, J.T.	1963
Metzger, S.	1963
Kirkwood, L.R.	1964
Leyton, E.	1964
Morrison, W.C.	1964
Wallmark, J.T.	1964
Pankove, J.	1965
Forgue, S.V.	1965
Guenther, R.	1965
Isom, W.R.	1965
Mason, W.	1965
Seelen, H.R.	1965
Herzog, G.B.	1966
Wege, H.R.	1966
Jenny, H.K.	1966
Bradburd, E.M.	1967
Mesner, M.H.	1967
Muller, J.H.	1967
Hernqvist, K.G.	1968
Powers, K.H.	1969
Sterzer, F.	1968
Rappaport, P.	1969
Robinson, A S.	1969
Woodward, J.G.	1969
Becken, E.D.	1970
Gluyas, T.M.	1970
Jones, Loren F.	1970
Parker, D.J.	1970
Shahbender, R.A.	1970
Smith, C.P.	1970
Vollmer, J.	1970
Lohman, R.D.	1971
Simon, R.E.	1971
Heilmeier, G.H.	1972
Kreuzer, Barton	1972
Sobol, Harold	1972
Urkowitz, Harry	1972
Hershenov, Bernard	1973
Kressel, Henry	1973
Luther, Arch C., Jr.	1973
Behrend, William L.	1974
Belohoubek, Erwin F.	1974
Zaininger, Karl H.	1974
Kosonocky, Walter F.	1975
Sherman, Samuel M.	1975
Bachynski, Morrel P.	1976
Lechner, Bernard J.	1976
Nessmith, Josh T., Jr.	1976
Winder, Robert O.	1976
Lind, Anthony H.	1977
Weinstock, Walter W.	1977

Engineering News and Highlights

New Technical Publications Administrators and *RCA Engineer* Representatives



Francis Holt at Consumer Electronics

Francis Holt is the Ed Rep at Consumer Electronics in Indianapolis, Ind., where he reports to **Clyde Hoyt,** TPA and Manager of Product Safety and External Technical Relations. Francis has been with RCA for nineteen years and was previously the Ed Rep for the SelectaVision Project where he was also a Senior Member of the Engineering Staff. Prior to his work in SelectaVision, he was in Advanced Development at Consumer Electronics.

Maucie Miller at RCA Laboratories

Maucie Miller takes over as TPA and Editorial Representative for RCA Laboratories, replacing **Chester W. Sall** who retired. Maucie was previously the TPA and Ed Rep for RCA Americom at Piscataway, N.J. Throughout his career at RCA, Maucie has been involved in technical communications.

Bob Moore at SelectaVision

Robert Moore is the Ed Rep for the SelectaVision Project at Rockville Road, Ind., replacing **Francis Holt.** Dr. Moore has been with RCA for twelve years with assignments at RCA Laboratories, Corporate Product and Market Planning, and SelectaVision. He currently reports to the Staff Vice President, SelectaVision Videodisc Operations in Indianapolis.

Promotions

Solid State Division

Robert VanAsselt from Member Technical Staff to Leader Technical Staff.

Robert Nestel from Member Technical Staff to Leader Technical Staff.

Picture Tube Division

Don M. Trobaugh from Member, Technical Staff, Manufacturing to Manager, Tube Processing, Quality and Reliability Assurance (Marion Plant).

Astro-Electronics

Yvonne C. Brill from Senior Engineer to Manager, (Spec.) Engineering.

William V. Fuldner from Staff Systems Scientist to Manager, (Spec.) Engineering.

Missile and Surface Radar

R. Morgan from Senior Member, Engineering Staff, to Unit Manager, D&D Engineers.

N. Salzberg from Principal Member, Engineering Staff, to Unit Manager, Systems Engineering.

Staff Announcements

Solid State Division

Bernard V. Vonderschmitt, Vice President and General Manager, appointed **Edward M. Troy,** Division Vice President, Solid State Power Devices, and **Carl R. Turner,** Division Vice President, Solid State Integrated Circuits. In this newly established position, Mr. Turner will be responsible for MOS and Bipolar Integrated Circuits, High-Speed Bipolar Integrated Circuits, and Offshore and Integrated Circuits Manufacturing Operations.

Carl R. Turner, Division Vice President, Integrated Circuits, announced the organization of Integrated Circuits as follows: **Marvin B. Alexander,** Project Manager, Business Systems; **Stanley Rosenberg,** Director, High Speed Bipolar IC Operations; **Richard L. Sanquini,** Director, Bipolar IC Operations; **Philip R. Thomas,** Division Vice President, IC Manufacturing Operations; and **Carl R. Turner,** (Acting) Division Vice President, MOS IC Products.

Fred G. Block, Manager, Central Engineering, appointed **William B. Hall** Manager, Manufacturing Systems Engineering.

Picture Tube Division

Joseph H. Colgrove, Division Vice President and General Manager, appointed **Charles W. Thierfelder** Division Vice President, Product Safety, Quality and Reliability.

Charles W. Thierfelder, Division Vice President, Product Safety, Quality and Reliability, appointed **Wellesley J. Dodds** Director, Technical Publications Administrators (TPAs) are responsible for reviewing and approving technical papers; for coordinating the technical reporting program; and for promoting the preparation of technical papers and presentations.

Editorial Representatives (Ed Reps) assist authors by stimulating, planning, and coordinating appropriate papers for the *RCA Engineer*. They also keep the editors informed of new developments as well as professional activities, awards, publications, and promotions in their areas.

J.R. Reece at Picture Tube Division, Marion

J. R. Reece is the new Ed Rep for the Picture Tube Division Plant at Marion, Ind. Mr. Reece has worked at RCA for nineteen years and is presently a Leader, Technical Staff, in the Applications, Reliability, and Safety Laboratory with responsibility for facilitation and maintenance. He also handles applications liaison with the Consumer Electronics plant in Bloomington.

Murray Rosenthal at Americom

Murray Rosenthal becomes the TPA and Ed Rep at Americom in Piscataway, N.J. replacing **Maucie Miller**. Murray has been with RCA for eighteen years in administrative and technical publications activities. He is now Manager for administration of the Technical Operations Department at Americom.

Chet Sall retires

Chester W. Sall, Technical Publications Administrator, RCA Laboratories, retired after 35 years with RCA, most of that time with RCA Laboratories. Chet has been an active and prolific *RCA Engineer* Editorial Representative over the past twenty years and has also been a frequent contributor to the pages of the journal.

Chet is a Senior Member of IEEE, a charter member of the Group on Professional Communications, and a past chairman of that group. For the past twenty years, he has also served as Editor of the *IEEE Transactions on Consumer Electronics*.

Quality and Reliability Assurance Operations Analysis.

Richard H. Hynicka, Director, Mask and Mount Operations and Lancaster Manufacturing, appointed **Richard L. Spalding** Manager, Production Engineering, and **Jack J. Spencer** Manager, Quality and Reliability Assurance—Lancaster.

Clifford E. Shedd, Manager, Equipment Development, announced that the activity of Equipment Engineering—PTC is transferred to the staff of the Manager, Equipment Development. **Keith D. Scearce** is appointed Manager, Equipment Engineering—PTC, and will report to the Manager, Equipment Development.

Mobile Communications Systems

Lee F. Crowley, Manager, Engineering and Technical Services, appointed **Albert R. Allen,** Manager, Technical Services.

Advanced Technology Laboratories

Fred E. Shashoua, Director, Advanced Technology Laboratories, has appointed **Harold E. Haynes,** Manager, Programs and Planning, for ATL.

Commercial Communications Systems Division

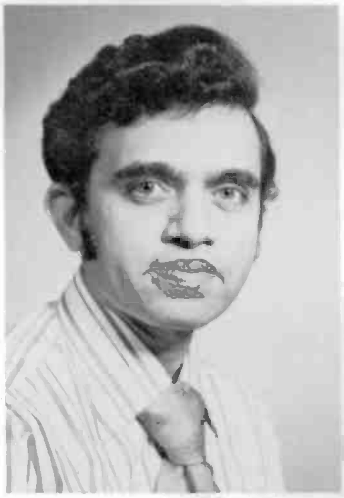
Irving K. Kessler, Group Vice President, announced that the Commercial Communications Systems Division will assume responsibility for the Electronic Industrial Engineering organization. **Henry Duszak,** General Manager, Electronic Industrial Engineering, will report to **Neil Vander Dussen,** Division Vice President and General Manager, Commercial Communications Systems Division.

Kleinberg ends four-year term on ANSI Board

Harry Kleinberg (right) RCA's Manager of Corporate Standards Engineering, accepts a certificate of appreciation from **John W. Landis,** President of the American National Standards Institute at the Board of Directors meeting in New York. Mr. Kleinberg served two successive two-year terms as a Director on the ANSI Board.

Awards

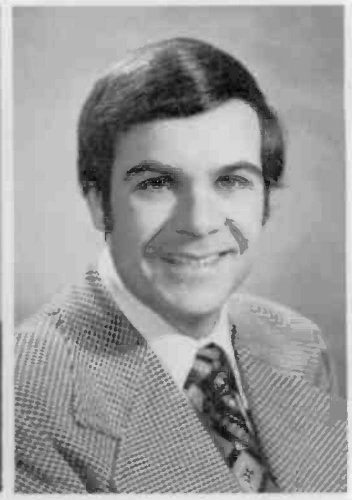
Four technical excellence award winners at Moorestown



Hatim Bharmal—for special contributions in the program design of the AEGIS ORTS Data Base Generation System, particularly for his pioneering use of special structured programming development techniques.

Andrew Moll—for definition and design of combined hardware-software configuration for a complex signal/data processing system, applying cost-effective mini- and micro-computer techniques.

Murray Rubin—for technical and task-team leadership in the design and construction of the Combat System Engineering Development (CSED) facility.



Arthur Simons—for outstanding achievements in defining data processing algorithms and man-machine interfaces, and translating complex system operational concepts into specific computer software requirements.

First and second prizes awarded in COSMAC contest

John Kowalchik (second from left) of Solid State Division, Mountaintop, Pa., accepts his COSMAC Evaluation Kit and Microterminal from **Don Carley,** Manager of Custom System Design at Solid State Division. John was the first-prize winner in the COSMAC Applications Contest for his COSMAC-based autopatch control for amateur repeaters. Also in the photo are **Keith Loofbourrow** (left) Mountaintop Engineering Leader and **John Phillips** (right) Editor of the *RCA Engineer*.

Tom Lenihan (center) of RCA Laboratories, Princeton, N.J., accepts his COSMAC Evaluation Kit from **Don Carley,** Manager of Custom Systems Design at Solid State Division. Tom was the second-prize winner for his A/D-based burglar alarm system (see *RCA Engineer*, Vol. 23, No. 3, p. 72). Also in the photo are **Angelo Marcantonio** (left) and **Paul Russo** (second from right) of RCA Laboratories and **John Phillips** (right), Editor of the *RCA Engineer*.

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RCA Engineer

A technical journal published by Corporate Technical Communications
"by and for the RCA Engineer"

Printed in USA

Form No RE-23-4