RCA Parts and Accessories

In 1964, Parts and Accessories assumed a more important role within RCA. The operation moved into a new building in Deptford; the first computerized controls were instituted; the first marketing and sales force was added; and accessory products were introduced as an important part of the business.

Long range forecasts made in 1964 indicated that solid-state technology would have a negative impact on the replacement parts business by reducing the number of discrete components that would be required as replacement parts. Although this would adversely affect sales volume, it would not eliminate the necessity of maintaining an organization to provide parts for product support.

To improve expense liquidation and to take advantage of the profit potential offered, a line of accessory products was added to the business. It was at this point that engineering effort was initiated. During the years, the business has grown and at the same time the engineering department has grown, both in numbers and in breadth of capability and experience.

Over the ten year period, products have become diversified so that they now include indoor and outdoor tv receiving antennas, a unique miniature antenna, antenna rotators, small master antenna tv systems, car stereo radios and tape players, specialty calculators, color tv test jigs, and a variety of other products. During the same period, the engineering capability has expanded from a specialized antenna design center to a broad-based effort. The continued growth of the business is dependent on the timely introduction of new products, and engineering innovation is the key to new product development.

By corporate standards, Parts and Accessories is a small business. Specialized capability is used, but its application is in a broad business sense since the interaction among people is so close that each specialist becomes a broad-based businessman as well. Parts and Accessories is by all standards a successful enterprise. It has become a diversified business within a diversified corporation.

Paul B. Garver
Division Vice President
and General Manager
Parts and Accessories
Deptford, N.J.

Our cover

...shows the Engineering Department at RCA Parts and Accessories and some of the products they develop. Clockwise from lower left:
- Bruce Buckley — antenna rotators
- Bill Bachman (p.9) — Mini-State antenna
- Pete Mikulich (p.22) — outdoor antennas
- Chazz Rearick (p.26) — car stereo
- Dave Callaghan (p.6) — Chief Engineer
- John Fox — color test jig
- Frank DiMeo (p.9) — indoor antenna
- Bob Wilson — tv reception aids

The Deptford, N.J., plant is in the background.

Photo credit: John Semonish, EC Commercial Engineering, Clark, N.J.

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RCA Engineer

• 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.

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Emphasis — Parts and Accessories

RCA Parts and Accessories —an entrepreneurial effort

P. R. Slaninka

Over the past ten years, RCA Parts and Accessories has developed a unique "small business" role within the Corporate structure. When people think of RCA they naturally think of the major segments of the Corporation such as Consumer Electronics, Commercial Systems, Phonograph Records and Tapes, Hertz Corp. etc., each of which contributes an average of several hundreds of millions of dollars in sales annually. By contrast, RCA Parts and Accessories has developed several successful small businesses over the past ten years under the heading of "Accessories", and none of these businesses has a sales volume exceeding $10 million.

UNTIL 1964, the basic purpose of RCA Parts and Accessories was to provide replacement-parts support for the Consumer and Commercial equipment sold by the Product Divisions of RCA. At that time, little emphasis was placed on "marketing" replacement parts. The main effort of the organization was directed toward making certain that the right replacement parts were stocked, that parts were purchased at the best price, at the right time, and in the right quantity, and also that an efficient system was employed in handling customer's orders. RCA Parts and Accessories customers were "users" of Broadcast, Mobile and Computer equipment; distributors that sold replacement parts to servicing dealers involved in repairing RCA television, radio, phonograph and tape products; and the RCA Service Company which was directly involved in servicing RCA products.

Advances in technology however — notably in solid-state devices and modularized construction — were increasing the reliability of the product, resulting in a natural decline in replacement-parts sales. For Parts and Accessories, such a decline would result in a high level of fixed cost that could not be absorbed at the resulting reduced sales volume. Since a parts operation was still needed, expensive or not, it was concluded that future growth and profitability as a Division would depend on the ability to expand into additional product-oriented businesses. In considering such a move, it was recognized that the base of skills of the organization, which at the time was specifically limited to the replacement-parts business, would have to be broadened. This required the addition of Marketing, Engineering, and — over the long term — a Manufacturing capability.

Limits on business expansion

RCA Parts and Accessories, as a Corporate service, is responsible for controlling the costs and expenses involving replacement parts support for designated equipment; however, all replacement parts sales, costs, expenses and profits associated with a particular line of equipment are reported back to the Corporation through the Product Division that originally sold the equipment. This means that the financial resources needed to support any business expansions have to be charged to an existing RCA Product Division. Since this would have a direct impact on their profit and loss, their approval had to be obtained before any commitment was made. For these reasons, "out of pocket" expenses could not be incurred, and RCA Parts and Accessories would have to finance its growth on a "pay as you go" basis. In other words, the additional cost and expense of entering into any new businesses could not exceed the amount of gross margin generated by the sales from the new products. These "constraints" placed a practical limitation on the choice of product businesses that could be entered. A business would be considered only if it could effectively utilize the existing network of distributors that were currently supplying replacement parts for Home Entertainment products. The selection of business was further limited to product areas that did not overlap the province of existing RCA product divisions.

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TV antennas —the initial thrust

Following a study of possible product businesses that met the above criteria, Parts and Accessories decided initially to enter the tv antenna business. The tv antenna industry is made up of two major segments — one involves indoor antennas that are placed on top of the tv set and the other segment involves the larger antennas conventionally erected on rooftops. Indoor antennas are sold through the same type of retail stores that sell tv sets. In contrast, the large majority of outdoor antennas are sold to servicemen who install tv antenna systems and to a lesser extent, to the "do-it-yourselfer" through retail outlets. Total annual industry sales, at distributor prices, of both indoor and outdoor antennas were substantially less than the total sales volume of the smallest RCA Product Division.

In entering the antenna industry, it was realized that market share would have to be taken from competition who had become well established in the antenna business ever since the formation of the tv industry in the early 1940's. This meant that a line of RCA antenna products would have to be developed which could compete successfully in the marketplace in performance, price, and promotional support and would thus represent a better business opportunity to the distributors and their dealers.

Indoor antennas

To get a feel for the indoor antenna market, three "look alike" models were purchased from the leading competitor in the industry and the RCA logo was placed on these units. In the course of selling these products, it was observed that there had been practically no change of any significance in the performance and appearance of indoor antennas over the years. Thus the opportunity was presented for developing and marketing a partial line of *unique* RCA indoor antennas.

In the fall of 1964, two basic RCA indoor antenna models were introduced — one was a vhf-only model and the other was a combination vhf/uhf model. There were two versions of each model—one in a "gold" metal finish and the other a "step-up" model in a "chrome" metal finish. The use of chrome finish in this case was a "first" in the industry. Another important breakthrough was made in the overall appearance of indoor antennas by developing new cabinet styles made of high impact plastic and using new colors and configurations that blended with, and complemented, prevailing tv cabinet styles. Not only did the RCA antennas look better, but they also worked better. By providing superior value in product performance, reliability and appearance, a high volume of sales was obtained at a price level which permitted the recovery of the initial investment over a short term, and thus provided the base for an effective entry into the indoor antenna business. This performance was particularly significant in that the four units involved did not represent a full line of indoor products meeting all the critical price points, nor did the supporting promotional and advertising program match those of major competitors who had already paid for their basic investment in facilities, tooling, and organization.

The high level of sales and gross margin that was obtained provided the means for the development of several additional models so that all the critical price points and features required in a *full* line of indoor antenna products was now met. The philosophy of providing superior value in performance, quality, and appearance proved successful.

It is a basic premise that an enterprise "begins" and "will continue to grow" on the strength of its organization's ability to offer progressive innovation in product features and designs that are cost effective. Since the greatest sales volume and larger gross margins came from the higher priced products, the development effort was addressed to creating new products that would open up a new and higher segment of the antenna market. At the time, the leader in the market, with well over 50% of the industry sales, had a significant cost and price advantage in lower priced models due to "economies of scale" associated with market shares of that magnitude. Due mainly to these circumstances it was decided that the best route was to continue to lead in creating products at the higher end of the line having recognizable advancements of sufficient degree to attract the consumers dollars. Since the top model in the RCA line at that time was sold at a suggested retail price of $9.95, it was decided to undertake the development of a new model which would sell in high volume at $14.95. High sales volume is needed to pay for the high tooling costs associated with molded plastic parts and cabinets. For this model, a new concept was developed that involved a rotatable uhf antenna controlled by a special knob on the antenna cabinet. This feature did not exist on any other antenna on the market at that time. New styling trends were also evolving in tv cabinet design and these could also be incorporated in a new antenna. A target retail price of $14.95 was set for this model with a significantly higher gross margin than existed on the $9.95 antenna. This seemed like an impossible objective at the time as it demanded a level of design skill and expertise seen only in the more sophisticated plastic-parts industries.

The fact that the development and production of this new model was achieved at the targeted price and gross margin opened a whole new market — not only for RCA, but for the industry as well. The successful introduction of this new model strengthened RCA's position with its distributors, established a new threshold of sales, and increased market share by several points. The high sales volume that followed justified the development of more new models that would sell at suggested retail prices of $19.95 and $24.95 respectively. These were both introduced in 1970 and, not surprisingly, the $24.95 model has proven, in terms of sales income and gross margin, to be the most successful indoor antenna of all.

Outdoor antennas

The initial success achieved by the indoor antenna business led to the decision to enter the outdoor antenna market. This posed a problem of much greater magnitude from an engineering stand-

The Engineer and the Corporation

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point. Although RCA had developed some original designs in the early days of tv, the art had progressed well beyond that point and the field had become well covered by competitors' designs. Again, the same approach was taken as with indoor antennas. The initial entry into the market consisted of four "look-alike" models, obtained from a major competitor and sold under the RCA label. The next step was to undertake the development of a more complete and distinctive antenna line. Initially, the component parts that our source was using in his own outdoor antenna line were utilized. The configuration, however, was later designed by RCA Parts and Accessories engineering for superior electrical performance. In fact, the superior electrical performance of the RCA line over that of the "source-competitor" justified a price high enough to provide respectable gross margins to the source and to RCA. Here again, the high level of sales that resulted indicated that RCA could compete successfully in the outdoor antenna market.

A new development program was then undertaken with the final objective of achieving complete independence of design. This would result in a distinctive line of products that would compete effectively in performance and price against major competitors and could be manufactured by either a noncompetitive source or by RCA.[1] This objective became very critical because, as RCA gained market share, its full potential for increasing sales volume was being limited by cost increases from the manufacturer. At the same time, antenna distributors were well aware of the fact that RCA was buying its product from a leading competitor. The source, furthermore, was using this fact to his advantage in promoting his own line of products to the same distributors RCA was selling to. In addition, certain novel features of the RCA design that were important factors in improving the efficiency and performance of the RCA-labeled line of antennas were subsequently being incorporated in the supplier's own antenna line, thereby improving his advantage. In the final analysis, it was difficult to deny the supplier use of these features since RCA was benefiting from several construction details and unusual features which he had made available to RCA.

Another very important reason for gaining independence from a competitive source was to convince distributors that RCA was fully committed to the antenna business and had complete control over product design, cost, availability, and quality. It is indeed difficult to convince a distributor to take on a new line when that line is not manufactured independently of competition, and the company involved is not completely integrated from an engineering and manufacturing standpoint. Even if a distributor would be willing to buy another company brand on this basis, he still has major negatives to overcome in convincing his dealers to go along.

The successful development of a line of outdoor tv antennas, with a number of new and unique features, established RCA as an important competitor in the outdoor antenna industry. Some very demanding design criteria in terms of performance, durability, reliability, ease of assembly and installation, compactness and appearance had been set. All of these criteria were met successfully and have resulted in what is considered by many to be the best antenna "pound for pound" on the market. With the development of the "Permacolor" outdoor antenna line,[2] all necessary tooling was purchased outright so that all integral parts could be fabricated and the finished product assembled in RCA Parts and Accessories' own manufacturing facility.

With full entry into the antenna business established, and with significant performance and features built into the product line, a substantial increase in market share was realized. Many distributors completelv replaced competitive product lines with RCA "Permacolor" products. By having control of manufacturing, it has been possible to realize significant improvements in quality and to reduce substantially the cost of product. With the high level of product performance and features offered by the RCA "Permacolor" antennas, it was possible to price the product at a level that paid for the investmest in engineering, tooling, manufacturing, and marketing and produced a profit in a minimal period of time.

Mini-State antenna

RCA's latest tv antenna product innovation is a subminiature antenna that represents a revolutionary new concept in outdoor antennas.[3] The all-channel vhf/uhf antenna is housed in a round radome 22-in. in diameter and 7-in deep. It is highly directional, can be remotely rotated 360° and is very easy to install. This antenna is designed to perform very effectively at a distance of up to 35 miles from the tv station; a radius which encompasses 75% of the total tv households in the U.S.

The antenna satisfies the demand for a less obstrusive structure and is in keeping with the increasing sales trend toward "do-it-yourself" type products.

Antenna rotators

As RCA became fully involved in the outdoor antenna market, an interest was developed in antenna rotators. Since it is estimated that about 24% of outdoor antenna installations include an antenna rotator, this product would be a natural supplement to the line of outdoor antenna products. The leader in this industry, who was not involved in the antenna business, accounted for an estimated 60% of total industry sales volume. This supplier, however, had contributed little in the way of design or performance improvements since the first introduction of his product to the market in the late forties. Since the promotion of rotators could be tied in with antennas, it was clear that entry into this business represented another opportunity to RCA Parts and Accessories. Rotators, it appeared, would not only result in substantial sales of the product itself, but, having this product to sell would result in increased outdoor antenna sales.

An antenna rotator is a complex electromechanical device, and here again the engineers were faced with the unusually difficult challenge to develop a competitive design in the face of well established products that had been refined over the years. While searching for an independent source to manufacture the product, contact was made with a firm in West Germany. Subsequently a joint program was undertaken that resulted in the development of a product line consisting of three rotators having several basic innovations in design and performance. Some of the superior features of the product design included:

- A v-shaped shaft-clamping construction that provides positive clamping pressure to the antenna mast over a wide range of pipe diameters thus preventing the antenna from swiveling out of orientation under high winds.

- A greater use of high tensile aluminum which makes the drive unit 20% lighter in weight.
- A clutching arrangement which allows for a limited mechanical free play in the motor drive before engaging the main gear which is effective in breaking loose the gear mechanism under freezing weather conditions.
- A servo system between the control box indicator and the drive unit on the roof which assures complete synchronization between the control-box indication and the drive-unit direction.
- A finer control resolution that permits more accurate positioning of the antenna.
- A styling design of the control box that is far more compatible with tv cabinet styles.

RCA's entry into this business was quite successful. It resulted in an additional volume of sales equal to 50% of its total outdoor antenna sales and also served to strengthen its position in the outdoor antenna market.

Related tv products

During the course of developing these three businesses, the engineering base at Parts and Accessories was broadened to develop several related peripheral product lines. These consisted of the following:

- A line of devices to enhance tv reception and provide distribution of signals to a series of tv sets.
- A line of servicing devices to facilitate the bench servicing of tv chassis.
- A line of antenna installation hardware.
- A line of chemicals used in the servicing of tv sets.
- A line of "universal" replacement portable tv antenna rods that apply to all makes of tv sets.

Car stereo

As a result of a continuing search for new businesses, Parts and Accessories entered the car stereo "after-market" in the fall of 1970 with a stereo cassette tape player, a stereo cassette tape player with recording capability, and a Stereo-8 cartridge player.[4] Since the great majority of all after-market players were manufactured in Japan, it was decided to source these products in Japan as well. However, in so doing, it was necessary to be certain that a high quality manufacturer was selected who was well resourced in engineering capability and not active in the U.S. market. A preliminary study of this market indicated that a large number of brands were being sold on the market and that the realiability of many of the products was quite low by RCA standards. For this reason, it was decided that the market condition here was right for a product with the RCA reputation for high quality.

These initial products were very well received and actual sales substantially exceeded sales forecasts. This initial success has stimulated the expansion of the line of car-stereo products to the point where it now consists of a comprehensive line of nine models covering cassette, Stereo-8, Quad-8, and tape/radio combinations. To complement the full capability of the tape playing equipment for high quality sound, a high quality loudspeaker system was also developed. This system produces a level of audio performance that was not commonly matched in the industry.[5] In the continuing effort to develop a high degree of performance and reliability in the car stereo system, RCA was the first to introduce a completely integrated-circuit system. This was a very important innovation and had a substantial impact on sales volume in that it was responsive to the demand of the consumer for better quality, higher reliability, and a more compact size. With the trend in compactness of design, the "after market" car stereo industry has moved from providing product for strictly under-dash installation to providing tape/radio equipment combinations that can be readily installed "in-dash". Only about 4% of the cars shipped from Detroit include tape players as a built-in accessory. A factory-installed unit is much higher-priced than the equivalent product that is available in the custom after-market.

An interesting facet of this industry, that has been learned from a continuing market research program initiated several years ago, is that 65% of car stereo buyers are below the age of 25 and that over 69% of the installations are actually done by the buyer. This information, along with other data resulting from market and engineering research programs, is fully utilized in planning the continuing product development program at RCA Parts and Accessories. The entry into the car stereo market has resulted in a substantial increase in total sales volume to the point where sales of this product line alone have grown to nearly equal the combined sales of both indoor and outdoor antennas and, equally important, has given RCA Parts and Accessories further diversification into a larger and faster growing market.

Commercial organization

The development of RCA Parts and Accessories Commercial organization began in the spring of 1964 with the addition of four salesmen. Later that same year, a marketing research specialist was added to identify potential markets and the first engineer was brought into the organization to spearhead the technical development of new products. The assistance of a design group at Consumer Electronics was obtained to develop the design configuration of the new products as required. As sales volume grew and styling needs increased, an outside consultant was employed to assist us in this area. The "pay as you go" requirement, established as a necessary fact of life in regard to the development of the new business effort, has placed an unusual degree of discipline on the organization. It assures that the organization and its assets are always utilized in a balanced and effective manner.

Today, Parts and Accessories has a full-fledged highly integrated product business system that includes manufacturing, merchandising, advertising, sales promotion, market research, sales, distribution, and engineering resources. This system has proven to be very effective in successfully developing and managing a variety of small businesses. The development of this capability is a most valuable asset in that it assures:

- The continued growth of RCA Parts and Accessories.
- Improved replacement parts service in support of RCA Product Division.
- The continued contribution to the Corporation sales and profit objectives.

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Engineering at RCA Parts and Accessories

J. D. Callaghan

RCA Parts and Accessories decided to put meaning into the "accessories" portion of its name ten years ago. This required that accessory products be designed and developed to augment and the marketing and sales force that was already deemed necessary to make the "parts" portion of the business profitable. To accomplish this goal, an Engineering Department was established on a somewhat different basis than that usually employed in a large corporation when starting a new product activity. However, since no corporate investment was available for this activity, product development was to be done on a pay-as-you-go basis.

UNDOUBTEDLY, the newly established Engineering Department at Parts and Accessories was the smallest one within the Corporation; it consisted of one man who functioned as manager, mechanical engineer, electrical engineer, draftsman, and model maker. This may seem strange to those who are accustomed to the extensive staffing and organizing associated with new product development within the larger division. However, only low-cost, medium-volume consumer-type products were being considered, and these have historically been marketed most successfully by low overhead manufacturers often referred to as "loft" operators. Previously, attempts by RCA to compete in this type of business were without notable success. The key seemed to be to structure the business in a fashion similar to the competition and then to grow as profits would allow. While this structure is not completely possible within the corporate framework, there are, fortunately, advantages as well as disadvantages to being a part of a large organization. Obviously, the negatives must be kept from outweighing the positives.

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Product selection

A number of limitations became immediately apparent regarding product consideration. First, the product had to be readily saleable by the established RCA electronic parts distributors. Second, the products could not be those for which a charter already existed in other RCA Divisions. Third, the product had to be relatively simple and low in cost. Fourth, it would be highly desirable for these products to augment those of other divisions so that the RCA image of a complete source for consumer items in the electronics business would be enhanced.

With this in mind, a product philosophy was developed. The most important criterion was price competitiveness in the marketplace. Innovation was necessary both from a technical standpoint and from that of customer appeal and convenience. The products had to be well stvled to make them readily acceptable, and be of a quality consistent with RCA's reputation.

Considering these criteria, an approach to product development was selected. It was clear that RCA manufactured almost everything in the television entertainment system: cameras, studio equipment, transmitters, broadcast antennas, television receivers, and picture tubes. The only gap in the chain was receiving antennas, and necessary supplementary accessories. This product area of television receiving antennas could satisfy all of the listed conditions and would make RCA the only manufacturer in the world who supplied everything from the tv camera to the picture in the living room.

Indoor tv antennas

The first product selected was an indoor antenna because it was simple enough to permit the entire design to be done by the one-man Engineering Department. Plenty of competition existed in this field but much of the product was poorly styled and of mediocre construction and performance. Considerable engineering work was done to develop a simple selector switch which would alter the directional characteristics of the dipole rods in a manner that would improve reflected signal rejection. A small innovation was made that allowed the uhf loop to be rotated by a knob control so that the user's hand did not detune the antenna during adjustment. An industrial design consultant was used to develop better styling, and higher quality materials were selected for the construction of the antenna. Some unique mechanical design and assembly techniques were also developed to partially offset the increased costs of the above items. Thus, having fulfilled the design philosophy requirements, mechanical and styling models were built and approved, drawings were made, tools were built, and the product was sourced out to manufacturers on a competitive bid basis.

After the usual trials and tribulations inherent in the design process, our first product was brought to the marketplace where it established RCA as a factor in this highly competitive business. This unit, in a slightly modified form, is still being marketed as our Model 10X280. Its innovation, while small, established a definite trend in the indoor antenna market. It has been widely copied and almost every manufacturer now features indoor antennas with rotating components, improved styling and quality. The indoor antenna line has been subsequently expanded and today consists of eleven models ranging in retail price from $2.75 to $30.95.

As sales dollars increased, it became possible to expand the engineering function. The first addition to the staff was a designer-draftsman who doubled as mechanical engineer. This allowed the engineering manager to devote a little more time to sales and marketing support as well as to speeding up the design cycle on more indoor antenna models.

Outdoor tv antennas

The step-by-step progress of product development has been well covered elsewhere in this issue,[1] so it will only be mentioned briefly here. Outdoor antennas were considered next, since this business, with factory sales in excess of $50 million annually, appeared to be a fertile field in which to apply our philosophy. The outdoor antenna business, dominated by three large, well established manufacturers, was highly competitive. The assets possessed by RCA were a strong engineering background in antenna development and a respected reputation in the tv and related electronics field. One of the liabilities consisted of the fact that RCA had already been in and out of this business several times. Consequently, the distributors felt that once again the project would be dropped when it was found that it could not be competitive.

Television antennas are not easy to manufacture as they are very awkward for an assembly line and require a fair amount of specialized equipment, much of which is uncommon to other industries. Having no suitable manufacturing facility and no component parts, it was necessary to go to those already established in the business to get started. The first antenna models were slightly modified stock units of a major manufacturer. For the next generation, however, the stated philosophy of innovation was applied. The result was a new antenna design which successfully integrated a broadband uhf and vhf section into a single antenna structure.[2]

This integration had previously been tried by several manufacturers with poor results. The new design used, for the most part, the suppliers standard components and required only a few newly tooled parts. This unit was well received in the market place and it was not long until comparable improvements were made in uhf/vhf combination antennas by most other manufacturers.

Further expansion

Having opened the door to the outdoor antenna market, it was now time to expand the engineering operation to a full vertically integrated organization; one that could provide the necessary innovation to continue the momentum which had been generated. Until this time, the two-man operation had been carried out from an office plus a small room with a drafting table with the part-time assistance of a secretary and some contracted design work done at MSRD. The expansion was started by obtaining the services of a recognized expert in the field of antennas, Donald W. Peterson (now retired). Mr. Peterson's first responsibility was to establish an antenna test range and laboratory in a short period of time.

The Deptford location possessed a large amount of land, but suitable bulding facilities were lacking. To accelerate the program, a piece of land was set aside for the range and a 40-foot stripped house trailer was rented and put into place beside the proposed building site.

Within a reasonably short time, a mechanical engineer and a model maker were employed, in addition to Mr. Peterson, through transfer from the Corporate Antenna Skill Center at Moorestown, The trailer was equipped with desks, work benches, and a reasonably complete model shop. This may have been the only mobile trailer ever to be equipped with a milling machine; and, until some reinforcing was done, there was some question as to whether it would survive.

Simultaneously, three parallel efforts were started: first, to develop additional unique electrical features for a complete line of outdoor antennas; second, to design a mechanical components and hardware package that would meet the previously stated product criteria; and third, to design a suitable building to both house the antenna test facility and provide a small lab for associated electronic equipment design.

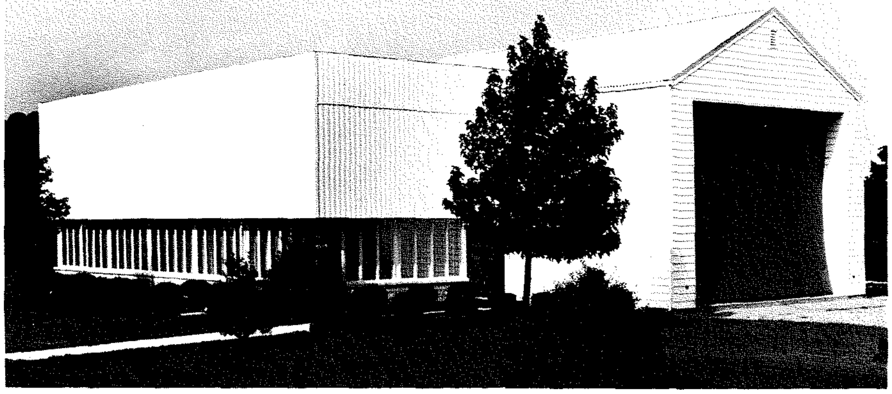
While most people think of an antenna as primarily an electrical design project, those in the field will recognize that the mechanical aspects often present an even more formidable challenge. Upon investigating all available television receiving antennas, it was concluded that some worthwhile electrical innovation could still be done and the area of new mechanical construction appeared to be extremely fertile. The complete story of the first full-scale outdoor antenna development and the construction of the antenna test facility at Deptford was covered in a previous issue of the *RCA Engineer*.[3]

As the laboratory building was being constructed, efforts were launched to fully utilize this facility to obtain a maximum return on the investment. An additional electrical engineer was obtained by transfer to commence work on a line of antenna system accessories consisting of rf amplifiers, matching transformers, multiple-set couplers, etc. Work was also started on the development of an antenna rotator which required the attention of a second mechanical engineer. Over a period of several years, the organization was stressed to its utmost, requiring long hours of hard work from all concerned. In addition to the product development going on, considerable engineering time was devoted to helping facilitate an RCA factory for the manufacture of antennas, to the development of suitable suppliers for the electronic accessories and rotator products, and to the procurement of the many necessary tools and dies.

During this time of rapid expansion, a full-time secretary, two wireman/technicians, another model maker, and a draftsman were added to the organization. This expansion now allowed full utilization of the new building from which came a stream of products that provided the RCA sales representatives with a great opportunity for growth.

As the tv-accessory products became a reality, the Marketing group at Parts and Accessories decided to move into the automotive audio products business. This required the attention of another

J. D. Callaghan, Mgr., Engineering, RCA Parts and Accessories, Deptford, N.J., was employed by RCA in 1946 as a member of the RCA Service Company Home Instruments Engineering Department. His responsibilities included the development and approval of TV receiving antennas and antenna systems. He also engaged in the development of color tv test equipment, TV technician training and liaison between the TV service activity and Consumer Electronics Engineering. In addition, he received the RCA Award of Merit in 1951. In 1959 he joined the RCA Service Company BMEWS project where he became Engineering Manager with responsibility for on-site installation check-out and test of all BMEWS equipment. Mr. Callaghan came to RCA Parts and Accessories in 1964 and organized the present Engineering group which develops accessory products such as TV antennas, rotators, signal distribution systems, color TV test jigs, and automobile stereo tape players. During the course of his employment with RCA, Mr. Callaghan has been granted thirteen U.S. patents.



Present engineering laboratory at RCA Parts and Accessories at Deptford.

engineer. Somehow this activity was squeezed into the existing facility, although it seemed at times that the technician had to sit on the engineer's lap in order to find work space.

In this area also, the basic criteria was applied. Innovations in the radio/tape player field are hard to come by, as the competitive nature of the business required that the basic mechanism be obtained from offshore sources. By careful attention to vendor selection, specifications, and quality control, the basic mechanism could be relied upon to deliver excellent performance. The area of quality loudspeakers, however, was found to have been neglected by the competition. By matching the acoustical characteristics of the loudspeaker to both the interior requirements of a car and to the electronics, the slight but necessary edge in total performance was obtained.[4]

Present organization

The Engineering group now consists of a total of fourteen people, and the building has been expanded to provide excellent working conditions. While small, it is a well-balanced organization for the type of business in which Parts and Accessories is engaged, and only occasionally is it necessary to send work outside. The only major function lacking is the ability to do sufficient R&D. Fortunately, excellent skills exist within other parts of the corporation which can be solicited whenever necessary. This help has certainly contributed considerably to our success. An example is the recent development of a miniature antenna system in cooperation with RCA Laboratories.[5]

A primary concern is to develop and maintain broad basic skills in the consumer products areas and to maintain great flexibility to move quickly from one area to another. The lack of this flexibility usually results in the inability of a large corporation to compete in a business of this nature. This ability to react quickly must also extend throughout the organization and requires a high level of cooperation between the Engineering, Sales, Merchandising, Advertising, and Purchasing functions.

Within Engineering at Parts and Accessories, the whole departmental structure is somewhat unusual and is almost impossible to show on a conventional organization chart. The technical personnel, besides fulfilling their normal classification duties, are assigned item or project responsibilities in accordance with their individual skills and abilities. Thus, each person with an assigned project, reports directly to the Engineering Manager as it concerns that project. At the same time, he may also be responsible for providing support on another project. This gives everyone a feeling of both participation and responsibility while applying the total intellectual ability of the group to almost every project. It certainly goes a long way to eliminate the frustration often experienced by engineers in large organizations who feel they are only a cog in the machine and seldom or never realize the complete satisfaction of project accomplishment.

One indicator of the work accomplished under this system is that P&A Engineering is currently responsible for 430 items of accessory products in the following categories:

Product line	*Items*
Outdoor tv antennas	47
Indoor tv antennas	11
TV antenna rotators	2
Antenna system accessories	49
Antenna installation hardware	127
Automobile radio/tape	16
Stereo headphones	6
TV servicing aids (color test jigs, universal service adaptors, spray chemicals, *etc.*)	172

Some of these items are standard units, purchased to specifications, and may have required only a few hours test and evaluation while others have taken over two years of engineering team development work. Over half the listed items are of proprietary design and require the use of 208 tools and dies for their production. The specification and approval of all these tools as well as the cost estimating on new products are also functions of Engineering. The first engineering assistant, who started as a designer/draftsman, now has this responsibility.

Future

Continuing the expected flow of new products without sharply rising engineering cost is the challenge of the future. Today's world of rising prices, material shortages, and continuing surge of new consumer protection requirements appears as a bottomless pit into which ever increasing engineering effort must flow to support current products. Methods of moving some of this sustaining engineering over to new product development must be a major concern of engineering management everywhere. Solutions to this challenge now appear to be even more vital than the solutions of technological problems which were the challenge of the past decade.

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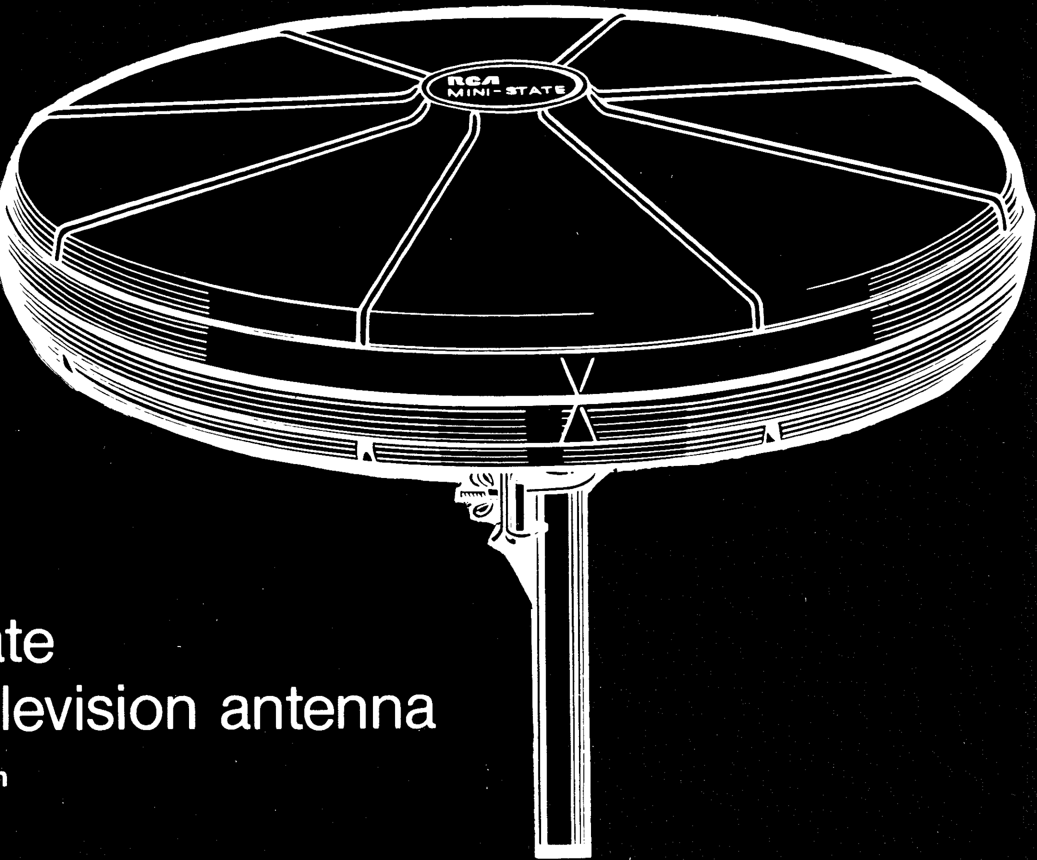

The Mini-State — a small television antenna

J. J. Gibson | R. M. Wilson

The RCA Mini-State is a completely new type of tv antenna system designed for suburban and metropolitan reception areas, where "ghosts" are more of a problem than "snow," and where a small-size indoor-outdoor antenna is very desirable. The antenna diameter is only 21 inches — 1/10 of the longest tv wavelength. Under average conditions this rotatable, all-band, active antenna system provides excellent reception within 35 miles of the tv transmitter — a range which presently includes most homes receiving broadcast television signals. The first part of this paper discusses the principles of small antennas in general and the Mini-State in particular. The second part deals with the design and performance of the Mini-State system.

WHY are tv antennas so large? A typical all-band television antenna for home reception is about nine feet wide and nine feet long. Mounted on a mast with a rotator, the antenna requires a turning radius of more than six feet. The size is dictated by the half wavelength at channel 2 (54 MHz), which is about nine feet. Typically, such an antenna has a gain of 3 or 4 dB above a half-wave dipole at channel 2. In weak signal areas, an antenna of this size is indeed required to overcome random noise, commonly referred to as "snow".

Clearly the size of a standard antenna is awkward and, in many homes, there just is not the space available to install it, particularly with a rotator. Furthermore, most homes today are located in the strong signal areas of their principal tv stations, where there is usually no need for large antennas to overcome "snow".

At some locations, clear pictures may be received from some stations with "rabbit ears" or even with hardly any antenna at all. However, a rotatable unidirectional antenna is often needed to overcome interferences other than "snow". Such interferences are:

1) "Ghosts" due to multipath transmission
2) Man-made noise
3) Co-channel and adjacent channel interference.

"Rabbit ears" type indoor antennas are not unidirectional, require frequent adjustment, are sensitive to the location of people in the room, take up a fair amount of living space, and are usually located where the quality of reception is particularly poor.

Thus, between standard outdoor and indoor antennas there is a need for a small "urban" type tv antenna which has unidirectional characteristics, can be rotated for best picture quality, and can be easily installed indoors or outdoors.

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Small receiving antennas

Passive antennas

It is a remarkable fact that the available power from a small lossless dipole is independent of its size. Unfortunately, the relative bandwidth ($1/Q$) of a small dipole becomes rapidly very narrow as the length of the dipole is reduced. To obtain a useful bandwidth, the dipole must be mismatched with a loss of efficiency as a consequence. The product of the power transfer efficiency and the relative bandwidth of a small dipole of length l is $s(\pi l/\lambda)^3$ where λ is the wavelength and s is a factor of the order of magnitude of unity which depends on the shape of the dipole elements.[1,2] For example, if $l/\lambda = 0.1$ the efficiency-bandwidth product is roughly 3% or −15 dB. Small antennas with more directive radiation patterns than dipoles or loops, so called supergain antennas, have efficiency-bandwidth products varying even more rapidly with antenna size.[1,2] Remote tuning of an antenna can indeed improve the efficiency at the expense of bandwidth, but it is technically complicated and inconvenient for the user.

The relations betweeen directivity, efficiency, and bandwidth of passive antennas are by now reasonably well established, and violations of these "laws" are not to be expected.

Active antennas

Is it possible to do better with an active antenna? Work on "small integrated antennas" (SIA) was initiated by H.H. Meinke in Germany in 1967, who demonstrated that the integration of active devices in the structure of a small antenna could improve the bandwidth and the matching conditions.[3] Although some results for specific antenna geometries and transistor circuits have since been obtained,[4,5,11] general relations governing the performance of small active receiving antennas are, however, not yet well established In addition to bandwidth and directivity, a criterion of performance of active antennas is not the "efficiency" but the dynamic range — limited at weak signals by noise and at strong signals by distortion.

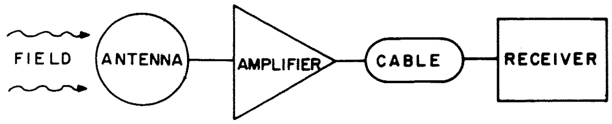


Fig. 1 — Block diagram of an active antenna system.

Noise, distortion, directivity, size, and costs

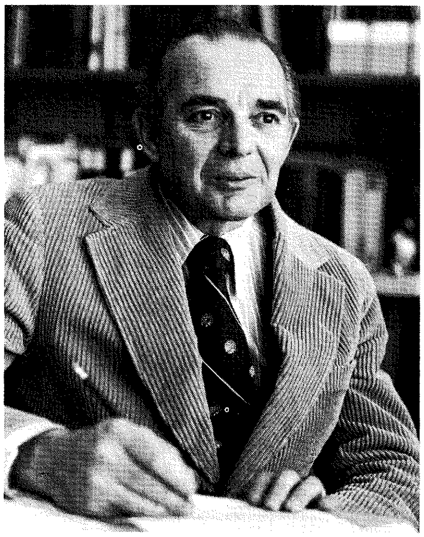
A reception system with an "active" antenna (Fig. 1) consists of a "source", which is the electromagnetic field, an antenna, an amplifier, a cable, and a receiver. All these components inject random noise into the system. A figure of merit can be defined as the signal-to-noise ratio of the system (S/N) relative to the signal-to-noise ratio (S_o/N_o) of a specified reference system located in an identical signal field. For television signals, it is convenient to assume a reference system consisting of a noise-free receiver and a lossless half-wave dipole having a radiation resistance with a noise temperature $T_o = 290°K = 62.3°F$. The figure of merit is then

$$M = \frac{S/N}{S_o/N_o} = \frac{S/S_o}{N/N_o} = \frac{D}{T/T_o} \quad (1)$$

where D is the directivity of the antenna relative to a $\lambda/2$ dipole and T is system temperature. [The system temperature is discussed in Appendix B.] Directivity D depends only on the shape of the radiation pattern. The system temperature T is an equivalent noise temperature assigned to the radiation resistance, representing *all* the noise injected into the system. It is seen that M also means the ratio of signal gain (S/S_o) to noise gain (N/N_o), both of which are measurable parameters. Assuming that all passive components are at a temperature T_o and the noise in the field (cosmic, solar, atmospheric, etc.) also has a temperature T_o, as assumed for the reference antenna, the figure of merit can be expressed as

$$M = DK/F \quad (2)$$

where K is antenna efficiency (*radiation resistance/total antenna resistance*) and F is the equivalent noise figure of the amplifier-cable-receiver combination. If the gain of the amplifier is sufficiently large, the noise of the amplifier will, even after attenuation in the cable, dominate over the receiver noise. In this case, F is



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Robert M. Wilson, Mgr., Product Development Engineering, RCA Parts and Accessories Division, Deptford, N.J., received the BSEE from Tri-State College in 1956 and has done graduate work at Drexel Institute of Technology. Mr. Wilson joined RCA's Surface Communication Division in 1956 where he participated in the rf transistor circuit design of various military communication equipments. In 1959, he transferred to the Microwave Antenna Group at the Missile and Surface Radar Division in Moorestown, N.J. Here he participated in the design of several large radar antennas, including BMEWS and Tradex, and numerous spacecraft antennas including Relay, SERT, and Lunar Orbiter. In 1968 Mr. Wilson transferred to the Engineering group at Parts and Accessories, where he has been involved in the design and development of numerous consumer electronic products, including the Mini-State antenna system and a line of antenna system accessories. In 1973, Mr. Wilson was promoted to Manager, Product Development Engineering.

identical to the noise figure of the amplifier.

Noise figure, however, strongly depends on antenna impedance $Z = R + iX$:

$$F = F_{min} + |1 - Z/Z_{opt}|^2 (R_n/R) \quad (3)$$

where F_{min} is the minimum noise figure which occurs when $Z = Z_{opt}$ and R_n is the so-called noise resistance of the amplifier.[7] If Z departs very much from Z_{opt}, as would be the case for a small lossless antenna, the noise figure becomes very large. For a small dipole length l, the radiation resistance R is proportional to l^2 and the reactance X is inversely proportional to l; consequently, according to Eq. 3, the noise figure would tend to be inversely proportional to l^4. Hence, the high-Q impedance of a small lossless antenna differs greatly from the low-Q source impedance that active devices require for a low noise figure, but at the expense of bandwidth. Antenna losses will also improve the noise figure and the bandwidth and may in fact even improve the figure of merit KD/F, even though the antenna gain KD is reduced. The Mini-State system consists of a very lossy antenna followed by an amplifier with a good noise figure.

From these general considerations and other more detailed analyses, it appears unlikely that integration of active elements in a small antenna could improve the signal-to-noise ratio by orders of magnitude.

An amplifier at the location of the antenna, however, will improve the signal-to-noise ratio to some extent, if the cable loss is large and/or if the receiver is very noisy. The coupling between a small antenna and an amplifier may also have a larger bandwidth than a passive coupling network between a small antenna and a cable.

Another very important function of the amplifier is to bring the weak signals picked up by a low-gain small antenna to a level sufficiently high to override the signals which are picked up directly by the cable and the receiver. These disturbing signals degrade the radiation pattern and are usually quite contaminated with man-made noise. A fairly costly amplifier may be required, however, to provide a high output level with acceptable distortion. The trade-offs between noise, distortion, directivity, size, and cost must be considered in the context of the electromagnetic environment in which the system is to operate. Appendix A summarizes the environment of tv receiving antennas.

Trade-offs and design goals

What are the minimum requirements for a small "urban" tv antenna? An average signal-to-noise ratio of at least 40 dB (considered excellent by 50% of the viewers[12]) at a distance of 40 miles from the transmitter was set as a goal. To achieve this, a minimum figure of merit of −22.5 dB is required at channel 2 (see Appendix A). It must be emphasized that a "range of 40 miles" has meaning only as a statistical average; precise definitions of "signal-to-noise ratio" and "range" are given in Appendix A.

A one-foot-long dipole is only 1/18 of a wavelength at channel 2 and would have an efficiency bandwidth product of roughly $(\pi/18)^3$ or −23 dB. Considering that a dipole is not directive and that an all-band vhf-tv antenna requires a 4:1 frequency band, the prospects for a one-foot antenna are not too good. However, increasing the diameter to 1.5-ft improves the signal-to-noise ratio by roughly $(1.5)^3$ or 5.5 dB. With this improvement, the prospects of reaching acceptable trade-offs between signal-to-noise ratio, directivity, and bandwidth are substantially enhanced.

Noise figures of medium-priced transistors are about 3.5 ± 1 dB at channel 2. Thus, the gain DK of the antenna proper relative to a half-wave dipole must be about −19 dB at channel 2. According to appendix A, direct pick up by the receiver and the cable dictates an amplifier output level of about 3 dB above the reference dipole level. This implies an amplifier gain of 19 + 3 = 22 dB at channel 2, tapering off at higher frequencies as the gain of the antenna proper increases. A requirement for good tv reception is that the gain variation over a 6-MHz tv channel is less than 1 dB. An amplifier with these gain requirements can be designed with a single transistor.

An amplifier output level of 3 dB above the dipole level could, in some locations with extremely strong signals, yield an output level of 400 mV into a 75-ohm load (see Appendix A). A fairly expensive rf power transistor would be required to provide this level with less than −40 dB cross modulation — a form of third-order distortion which is particularly disturbing. Cross modulation of −40 dB is considered "visible but not disturbing". With a more reasonable goal of −40 dB cross modulation at 250 mV over 75 ohm, the prospects of using a medium price transistor are quite good. With this design goal, there is some probability of visible cross modulation at some locations. As indicated in appendix A, second-order distortion is only a problem if there are strong local fm broadcast stations. This problem can be solved with an fm trap in the amplifier input circuit.

A design goal for the uhf antenna is a passive structure within a 1.5-ft diameter, having a gain of about 3 dB. With cable losses of about 4 dB and a receiver noise figure of 12 dB, the figure of merit for the uhf antenna would be −13 dB, which is 9 dB better than the vhf antenna at channel 2.

Thus, our preliminary studies showed that a 1.5-ft uhf-vhf tv receiving antenna was feasible, within the performance goals outlined above. Further design goals were that the antenna would be weatherproof, easy to install, rotatable from remote locations, and small enough to mount indoors as well as outdoors.

In 1971, RCA initiated a program to develop an antenna meeting these design goals. The resulting product has been named the "RCA Mini-State TV Antenna System".

Evolution and basic principles

Among the antenna structures explored in the early phases of the project, one using two dipoles appeared very attractive because it had good radiation patterns over the entire vhf band and had the required figure of merit at channel 2. There were, however, problems in coupling the antenna to an amplifier over the required band. Adjustments and component tolerances were also "touchy".

Better success was achieved with a very lossy antena having the basic geometry shown in Fig. 2. This antenna, which we refer to as a two-port loop, was invented by H.H. Beverage of RCA.[9] When operating in a transmitting mode, it behaves as a terminated radiating transmission line. The radiation patterns, the efficiency K, and the directivity D can be calculated under the assumption that a current propagates unattenuated along the circumference of the antenna with the

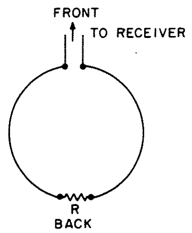

Fig. 2 — A two-port loop antenna.

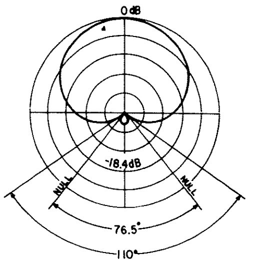

Fig. 3 — Basic radiation pattern for a two-port loop.

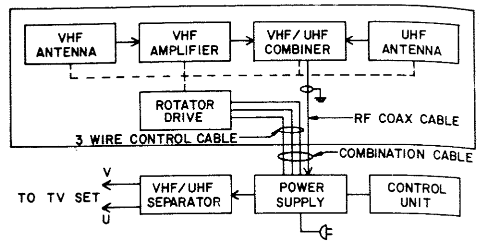

Fig. 5 — Block diagram of the Mini-State antenna system.

velocity of light in vacuum. The results obtained under these assumptions agree quite well with experiments.

When the diameter is much smaller than half a wavelength, the radiated field strength in the horizontal plane has a cardioid-shaped pattern of the form

$$E = E_{max}\,(\pi + 4\cos\phi)/(\pi + 4)$$

where ϕ is the angle with respect to the front direction.

The pattern is shown in Fig. 3. Note that the front direction is toward the feed point. The small backlobe is 18.4 dB down from the front lobe. The nulls are at ±38.25 from the back direction. Within ±55° from the back direction, reception is 18.4 dB below front reception. At higher frequencies, the pattern tends to become flatter in the front direction.

The efficiency at low frequencies is

$$K = 513\,(\pi d/\lambda)^4/Z_o$$

where d is the diameter, and Z_o is the characteristic impedance.

Clearly, it is desirable to make Z_o small. Thus, it is better to make the loop out of a thick, flat band of sheet metal than out of thin wire. When the width of the band is 2-in. and the diameter of the loop is 18-in., the characteristic impedance is about 350 ohms and does not seem to reduce from there very much with increased width of the band. The problem is the same as that of making a free-space balanced transmission line of low characteristic impedance. The directivity is $D = 1.8$ (2.5 dB) and the gain for $Z_o =$ 350 ohms is

$$GK = 2.3\,(\pi d/\lambda)^4$$

For an 18-in. loop at 55 MHz, $d/\lambda = 0.0838$, and the gain is $DK = 0.0127$ or -19 dB, which meets the design goals and is in agreement with measurements.

The resistive termination yields a broadband, essentially resistive, impedance at the input port. This, in turn, is conducive to a low noise figure and has the practical advantage that the antenna and the amplifier can be developed as separate units, rather than together as an "active integrated antenna". In the development of the amplifier, bipolar as well as MOS transistors were explored. For the specific requirements on gain, noise figure, output level, frequency response, and distortion, a bipolar transistor at the time of the investigation was clearly the best choice.

The antenna impedance is essentially equal to the characteristic impedance, Z_o. This impedance, and consequently also the noise figure of the amplifier, is independent of antenna size. The figure of merit, therefore, varies with antenna size in the same way as the figure of merit of a system, which consists of an amplifier fed by a lossless dipole (*i.e.*, in proportion to the 4th order of the linear dimension of the antenna structure). However, in a system with the lossless dipole, the gain is constant and the noise figure varies, while it is the other way around for the very lossy two-port loop.

The radiation pattern of the antenna can be optimized by varying the terminating

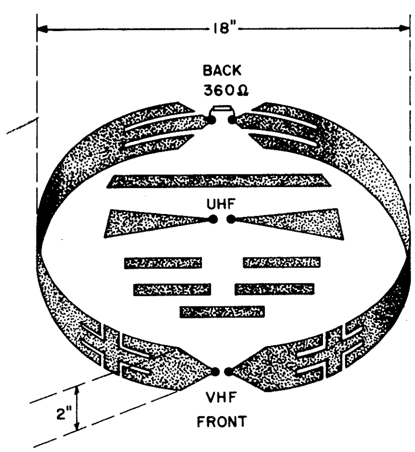

Fig. 4 — Basic elements of the Mini-State antenna.

resistance and adding a reactance in series with the resistance. Of particular significance for ghost rejection is the ability of this type of antenna to obtain a small backlobe between deep nulls. The two-port loop with an 18-in. diameter can be used for the entire vhf band, ranging from 54 to 216 MHz.

A separate uhf antenna, consisting of a dipole, a reflector, and a few directors, has been inserted inside the loop as shown in Fig. 4.[10] It turned out that the uhf antenna had practically no effect on the vhf antenna, partly because the vhf antenna is terminated at both ports to form a low-impedance structure. The effect of the loop on the uhf antenna was reduced by inserting uhf bandstop filters in the loop and at the vhf terminals.

System description

The RCA Mini-state antenna system (Model 5MS440) consists of eight functional units interconnected as shown in Fig. 5. The antennas, amplifier, combiner, and rotator drive units are completely enclosed in a weatherproof plastic radome (Fig. 6). These units are electrically connected to the power supply by a special rf-coaxial/3-wire-control cable developed by Parts and Accessories especially for the Mini-State. The power supply also serves as a junction box for interconnecting the control unit and the vhf/uhf band separator to the radome units.

There is also a non-rotating antenna (Model 5MS330) which is identical to Model 5MS440 except that it does not include a rotator drive or control unit. The power supply is also modified slightly to eliminate the terminals for the rotator control wires.

VHF/UHF antenna

The vhf and uhf antennas, both of which are fabricated from sheet aluminum stampings, are mounted on an 18-in.-

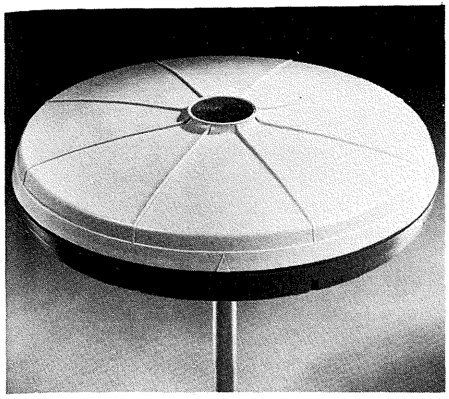

Fig. 6 — Weatherproof antenna radome.

diameter circular plastic foam platform, as illustrated in Fig. 7.

The broadband vhf antenna consists of two semi-circular aluminum bands wrapped around the outer rim of the foam platform. The bands are joined at the rear of the antenna by a terminating impedance and at the front by an output terminal board. A width of 2-in. was chosen experimentally as a compromise between efficiency and practical size. This width yields a characteristic impedance to the traveling wave structure of about 350 ohms. As previously discussed, the optimum terminating impedance for best radiation patterns and impedance characteristics was found to be a complex value. The required resistive component is 360 ohms. The required reactance component is provided by two parallel sets of short-circuited transmission-line stubs located on each side of the 360-ohm resistor. Physically, the stubs are constructed from slots stamped out of the two semi-circular bands.[13]

A yagi-type uhf antenna, consisting of a wideband driven dipole, a reflector, and five directors fits into recessed pockets molded into the top surface of the foam platform. These are fastened in place with adhesive. Since the vhf semi-circular aluminum bands completely surround the uhf elements, it was necessary to provide a "window" through the bands to keep them from blocking the uhf reception. This was accomplished by cutting four slotted stubs into the front side of the vhf bands effectively making them look like additional uhf directors. Since these stubs are electrically very short at the vhf frequencies, they have negligible effect on the vhf reception.

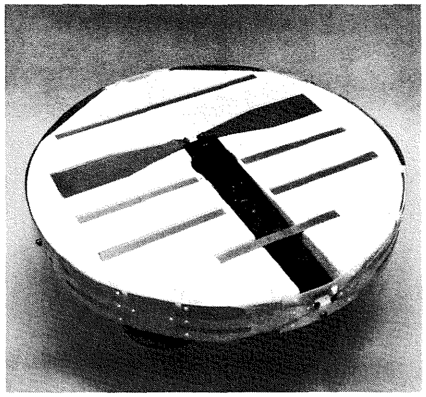

Fig. 7 — Rotating foam plastic platform with antenna and amplifier.

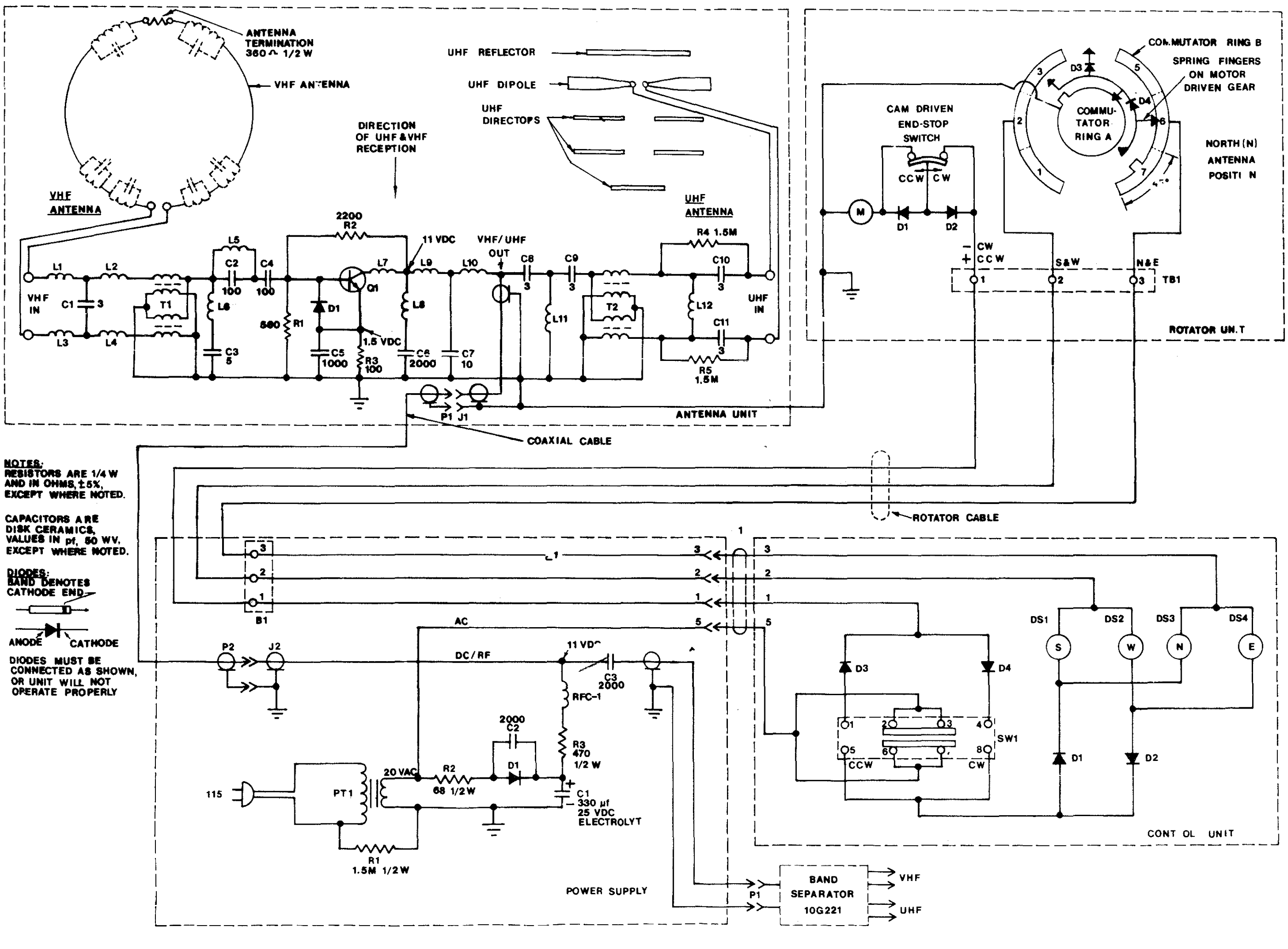

Fig. 8 — Antenna system schematic.

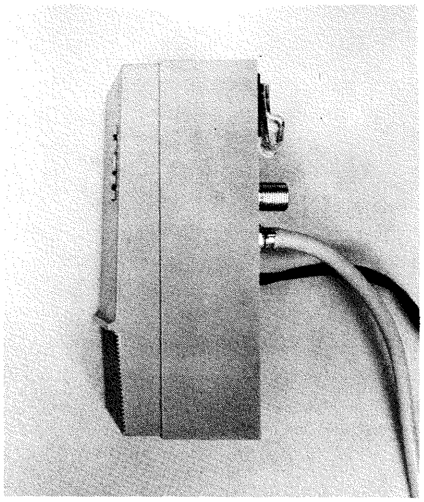

Fig. 9 — Power supply unit mounting.

Fig. 10 — Control unit.

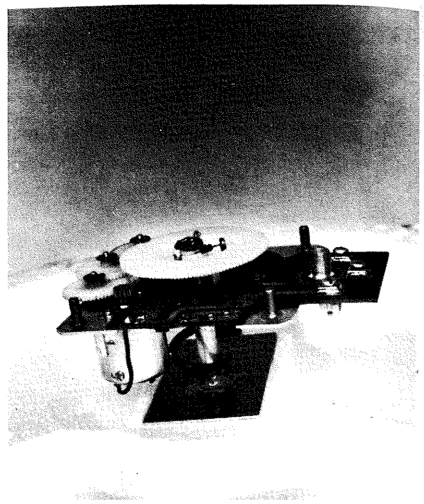

Fig. 11 — Antenna rotator-motor assembly.

Amplifier

A high-gain low-noise vhf amplifier is provided at the antenna to improve the vhf signal-to-noise ratio and to reduce interference from direct pick-up by the transmission line and the receiver. The uhf antenna gain is several dB higher than a dipole; therefore, uhf preamplification is not essential.

The vhf amplifier uses one bipolar transistor, which has been carefully selected to minimize noise, crossmodulation, and costs. It operates in a grounded-emitter configuration with some emitter and collector feedback to control gain, output impedance, noise, and crossmodulation characteristics. The amplifier circuit (Fig. 8) includes an fm trap, a diode lightning protector for the transistor, and bandstop filters to segregate the vhf and uhf circuits.

The vhf and uhf signals enter opposite ends of the amplifier board. After passing through low-pass vhf filter L9, L10, C7 and high-pass uhf filter C8, C9, L11, the signals combine and leave the amplifier board together via a short length of flexible 75-ohm coaxial cable. To allow rotation of the antenna and amplifier assembly, this cable is spiraled concentrically around the rotator unit's antenna drive shaft. The output end of the spiraled cable is connected to an rf output connector mounted on the bottom side of the antenna radome. The amplifier board proper was made long and narrow to fit in the space between the vhf and uhf antenna terminals (Fig. 7).

Power supply

The power supply unit can be mounted on either a wall or the back surface of a tv set as illustrated in Fig. 9. The power supply provides all necessary voltages to operate the system and also serves as a junction box to interconnect the functional units in the radome with the control unit and band separator.

Control unit

The hand-held control unit shown in Fig. 10 remotely controls the rotation of the vhf/uhf antennas inside the radome. Clockwise or counterclockwise rotation is initiated by a thumb-operated rocker switch mounted on the top side of the unit. The switch is spring loaded to return to the center off position when the operator removes his thumb.

The control unit contains a novel illuminated indicator dial designed to indicate any one of eight 45° directional segments. For example, when the antenna is pointing within ±22.5° of north, the N dial segment will be illuminated. When the antenna is rotated clockwide to a pointing direction which is within ±22.5° of northeast, both the N and E dial segments will be illuminated. More precise directional indications would serve no practical purpose for the Mini-State for two reasons. First, the antenna's forward pattern is very broad so that the viewer would be unlikely to notice any change in the picture for small rotational changes — unless multipath ghosts are present. Second, if multipath ghosting effects are present, the viewer can pinpoint the best antenna pointing direction by watching the reception changes directly on the tv screen. The ±22.5° accuracy of the control unit indicators enables the viewer to point the antenna in the best general direction based on past experience — and then to "fine tune" the rotation by watching the tv screen.

The control circuitry to accomplish drive unit rotation and indicator illumination is shown schematically in Fig. 8. The motor and lamp circuits operate on half-wave rectified ac current. In the indicator lamp circuit, alternate half-wave voltage is essential to polarize/match diode pairs to activate the four lamps either singly or in pairs. This technique allows eight different direction indications using only two control wires with one common ground return.

VHF/UHF band separator

The vhf/uhf band separator is a small low-pass/high-pass filter device designed to separate the vhf and uhf signals that were originally combined in the amplifier. The unit also contains a 75-ohm to 300-ohm transformation circuit to provide the proper impedance match between the 75-ohm coaxial input cable and the 300-ohm terminals on the tv set. The vhf and uhf output leads of the band separator are used to mount the unit directly to the input terminals of the tv set.

Combination cable

The combination rf-coaxial/3-wire control cable was designed especially for the Mini-State antenna system to minimize the work required for installing the rf and control cables between the antenna/rotator units and the power supply unit. This combination design also provides for a neater installation — which is especially important for the exposed interior portions of the cable run.

Construction

The vhf and uhf antennas are constructed from 0.016-in.-gage aluminum stamping mounted on a circular plastic foam platform, as shown in Fig. 7. The platform proper is molded from polystyrene-bead foam material chosen for its high strength-to-weight ratio and low dielectric constant.[14] Special adhesive is used to fasten the uhf yagi-type antenna elements to the top surface of the platform. The vhf antenna is held in place around the periphery of the foam platform by special plastic mounting brackets and screws.

The antenna and platform assembly is mounted directly to the rotator motor-gear assembly as shown in Fig. 11. The small sub-fractional horsepower motor is designed for 12 Vdc operation. In the Mini-State system, however, the power for the rotator motor is obtained from the 20 Vac secondary winding of power transformer PT1 (see Fig. 8). Half-wave rectification of the 20 Vac results in an effective rms voltage of 0.707×20 or 14.14 V. Extensive testing has shown that the 12 Vdc motor can operate safely at 14.14 V without overheating. The only significant effect of the increased voltage is a slight increase in motor speed.

The motor drives a gear-train designed to reduce the rotating speed of the antenna drive shaft to approximately 2.4 r/min., or one rotation in 25 seconds. The drive shaft, in addition to driving the antenna foam platform, also drives the beryllium-copper contact fingers associated with commutator rings A and B. The commutator rings, portions of the end-stop switch, and the associated wiring are all printed on a single pc board.

The motor-gear-commutator assembly is fastened securely to the bottom half of the radome housing with four special bolts. These bolts have additional threaded interiors to allow a second set of four bolts to be secured to them for fastening an exterior mast-type mounting bracket. This arrangement rigidly secures the mast mounting bracket directly to the rotator motor gear assembly. The bottom wall of the radome housing is then, in effect, sandwiched between the mast mounting bracket and the motor-gear assembly — thereby freeing the radome from any support function.

The radome is molded in two halves from high-density polyethylene plastic and the two halves are fastened together by eight screws, spaced evenly around the periphery of the radome. The bottom half has a protruding lip around its outer rim which fits into a mating recess in the top half to seal out rain and snow. The top half of the radome is molded in a light gray color to reduce heat absorption. Test results have supported earlier calculations indicating that the maximum temperature rise on a 100° summer day is limited to approximately 150° F.

The housing for the control unit is molded in two halves from high-impact styrene plastic. The small size and contoured styling of the control unit allows the viewer to hold and operate the unit with one hand. All electrical components are mounted on a pc board located within the housing. The four indicator lamps which are located directly below their respective colored indicating lens segment are rated to operate at the system rms voltage of 14 V. To eliminate light leakage to adjacent indicator segments, each lamp is mounted within a light-tight molded plastic compartment.

The plastic housing for the power supply unit was available from RCA's TV Antenna System Accessories product line, developed by Parts and Accessories Division in 1970. U.L. approved power transformer PT1 was also available from the same line. The availability of these two items considerably reduced the cost and design effort required for the power supply unit. All other power supply components, with the exception of the metal chassis, are standard items available from vendor sources.

The complete band separator unit was also available from RCA's TV Antenna System Accessories product line.

The Mini-State Antennas are manufactured at the Parts and Accessories manufacturing facility at Swannanoa,

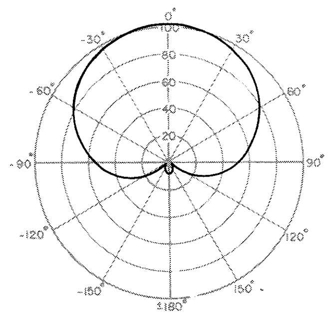

Fig. 12 — Typical low-vhf antenna pattern.

North Carolina. Production was started in early 1973.

Performance

The Mini-State antenna system design successfully meets all the original design goals. The following performance results are typical for all production units tested to date.

Antenna patterns

Although the forward pattern is very broad, the large front-to-back ratio and deep nulls in the rear hemisphere allow the antenna to effectively minimize multipath ghosting (see Fig. 12). As the vhf frequency is increased, the patterns tend to become broader, but they retain their good front-to-back ratio and deep nulls in the rear hemisphere (see Fig. 13).

In the uhf band, the yagi-type antenna produces the typical pattern shown in Fig. 14. As would be expected, the pattern for this electrically larger antenna has a beamwidth which is considerably narrower than that obtained from the vhf antenna.

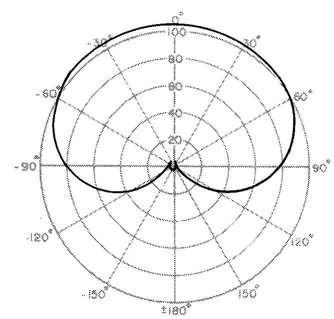

Fig. 13 — Typical high-vhf antenna pattern.

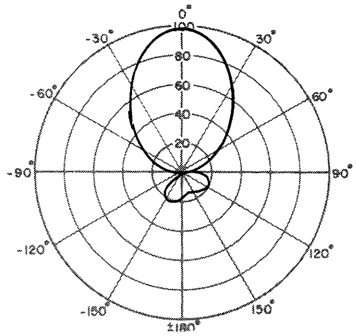

Fig. 14 — Typical uhf antenna pattern.

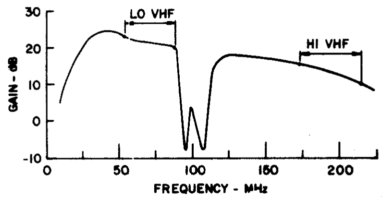

Fig. 15 — VHF amplifier gain.

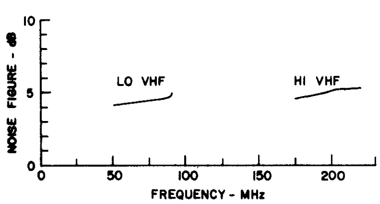

Fig. 16 — Amplifier noise figure.

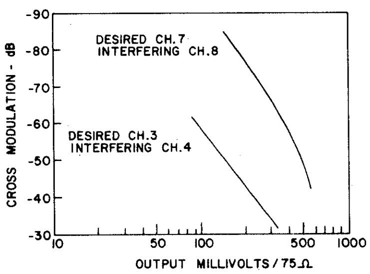

Fig. 17 — Cross modulation *vs.* output voltage.

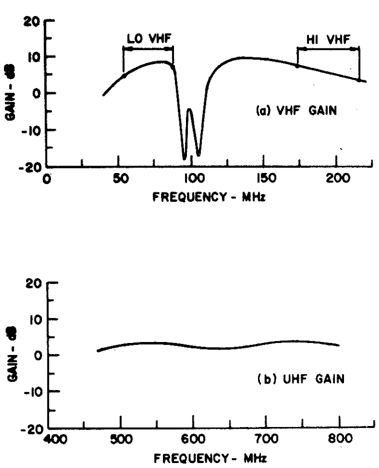

Fig. 18 — Antenna gain (relative to half-wave dipole).

VHF amplifier gain

As can be seen in Fig. 15, the gain falls off at a fairly even rate as the frequency increases from 54 to 216 MHz. This is desirable to compensate for the opposite gain slope of the vhf antenna. Ideally, the amplifier gain should fall off sharply below 54 MHz, between 88 to 174 MHz, and above 216 MHz to avoid amplification of frequencies outside the tv band. However, except for the fm broadcast band, radio services at these frequencies do not usually cause intermodulation or cross-modulation problems due to their relatively low power and low geographical density. Therefore, the cost of adding filters to attenuate these frequencies is not justified. On the other hand, the numerous high-power fm broadcast stations found in many areas often cause severe intermodulation problems in wideband amplifiers. For this reason, a two-section fm trap (to attenuate frequencies between 88 and 108 MHz) is included in the amplifier. The addition of a third section to the fm trap circuitry would reduce the slight peak shown at 98 MHz. However, testing to date has not indicated that this is necessary.

Noise figure

The noise figure of the vhf amplifier is plotted in Fig. 16. The 2SC1424 transistor itself has a minimum noise figure of 2.5 dB when biased for a collector current of 3 mA. The Mini-State amplifier, however, is biased for a collector current of 14 mA to minimize cross modulation. At this current, the transistor noise figure increases to approximately 3.25 dB. This higher collector current, plus losses between the amplifier input terminals and transistor base, cause the amplifier noise figure to be slightly higher than the minimum noise figure of the transistor itself.

Cross modulation

The cross modulation betweeen two tv channels is shown in Fig. 17. The cross modulation of channel 4 onto channel 3 is seen to be −40 dB or better up to 230 mV rf output. As the frequency of the interfering channel increases, the cross modulation tends to improve. For example, the cross modulation of channel 8 onto channel 7 remains better than −40 dB for rf outputs up to 550mV.

Multiple-channel synchronous-signal cross-modulation measurements were not taken since the results are very difficult to correlate with the actual cross modulation that would result from the reception of multiple tv channels in any representative area.

Extensive field testing of the Mini-State system in various high-signal-density areas of Philadelphia and New York City showed no evidence of cross modulation.

System gain

The vhf and uhf system gain is shown in Fig. 18. The vhf system gain includes the gain of the antenna and the amplifier. The gain of both the low and high vhf bands is flat within ±2 dB with an average gain of approximatley 6 dB above that of a $\lambda/2$ dipole. The uhf gain is flat within ±1 dB with an average gain of approximately 2.5 dB. The resultant gain variation over anyone vhf or uhf channel is less than 1 dB.

Figure of merit

The figure of merit, as defined in Eq. 1, is the ratio of the signal gain to the noise gain. Signal gain (S/S_o) relative to a half-wave dipole is measured in a conventional manner while the noise gain (N/N_0) is measured by comparing the output noise of the antenna enclosed in a screen room (which is practical for small antennas) with that of a calibrated noise source. In these measurements, the amplifier is loaded with the system reference impedance, which is usually the characteristic impedance of the cable which connects the antenna to the receiver.

The −21dB figure of merit of the Mini-State meets the required design goal for a "40-mile antenna". It must be emphasized, however, that the 40-mile range is based on statistical propagation averages (see Appendix A), and therefore it should not be assumed that excellent pictures will always be obtained at 40 miles in all areas. Although actual field tests have shown that the Mini-State antenna does indeed receive excellent pictures at 40 miles in many areas, the Mini-State is conservatively advertised to

Specifications and performance summary

Power requirements

Voltage (ac)	105 to 130
Frequency (Hz)	50 to 60
Power (W)	5 (operating)/10 (rotating)

RF specifications

	Low vhf	*High vhf*	*uhf*
Frequency (MHz)	54 to 88	174 to 216	470 to 800
Antenna			
Polarization	Horiz.	Horiz.	Horiz.
Beamwidth (deg.)	±74	±103	±32
Front-to-back ratio (dB)	19	19	14
Null depth (dB)	30	30	30
Amplifier			
Gain (dB)	24 to 20	15 to 11	—
Noise figure (dB)	4.5	5.5	—
System			
Gain (dB)	4 to 8	4 to 8	1.5 to 3.5
Figure of merit (dB)	>−21	>−12	—
Impedance (ohms)	75	75	75
Maximum range (miles)	35	35	35

Mechanical specifications

Power Supply	
Size (in.)	2 × 3 × 5
Mounting	Bracket on wall or rear of tv
Antenna	
Radome size (in.)	21 × 7
Radome weight (lb)	5.5
Wind load (lb. at 80 mi/hr)	9.0
Rotation speed (r/min) (120 Vac, 60 Hz, 60°F)	2.4
Mast size (in.)	1 to 1.5
Mounting	Mast clamp or tri-pin legs
Control unit	
Size (in.)	2 × 3 × 5¼
Mounting	Hand-held
Band separator	
Size (in.)	1 × 1¾ × 2
Mounting	Connects directly to 300-ohm terminals of tv set
Combination cable* (two cables in single jacket)	
RF cable	RG-59/U type 75-ohm foam dielectric-aluminum foil/braid jacket
Rotator control cable	3-wire solid #22 AWG
Temperature range	−40°F to +150°F

*60 ft. cable packed with each system. Additional length (30,50,80 ft.) available.

have a *maximum* range of 35 miles.

Conclusions

The Mini-State antenna system was designed and developed through the cooperative efforts of the Parts and Accessories Division and RCA Laboratories to offer a high-quality economical alternative to large, bulky outdoor antennas and lower quality indoor antennas. The final system is a compact, rugged package suitable for indoor or outdoor installation, which meets or surpasses all performance and design goals established early in the development cycle.

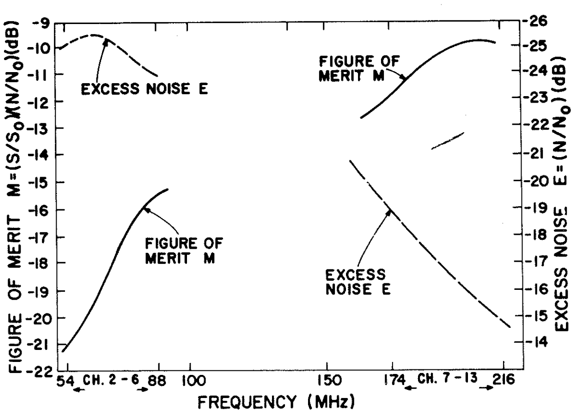

Fig. 19 — Excess noise and figure of merit for vhf antenna system.

Acknowledgments

The authors acknowledge the contributions of their colleagues who participated in the design and development of the Mini-State antenna system. In particular, J.D. Callaghan who had overall responsibility for coordination of the design effort; D. W. Peterson whose extensive experience in antenna design was invaluable; W. J. Bachman, who was responsible for mechanical engineering design; F.R. DiMeo who was responsible for mechanical design details; and R. Kaysen who did the product styling. A.P. DiDonato's participation as draftsman is greatly appreciated. We also thank P.J. Smalser for his contributions to the antenna design and testing program and J.E. Joy for his work in testing the amplifier, power supply, and control unit prototypes. Final testing of the prototype and preproduction models was performed by P.J. Mikulich. All model shop machine and fabrication work was done by J. H. Carr and J. W. Maull.

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Appendix A — Electromagnetic environment of a television receiving antenna

The spectrum of radiated tv and fm signals is shown in Fig. A-1. There are three bands: the low vhf (Ch 2-6; 54-88 MHz), the high vhf (Ch 7-13; 174-216 MHz), and the uhf (Ch 14-69; 470-806 MHz). The fm broadcast stations in the 88-to-108-MHz band may also expose a tv antenna to strong signals.

The voltage that a half-wave dipole can deliver to a 75-ohm load is

$$V = 48.5\ (E/f)$$

where E is the field strength in volts/meter and f is the frequency in MHz. The free-space field (E) at a distance d meters from a transmitter is

$$E = (30P)^{1/2}/d$$

where P is the effective radiated power in W (input power × antenna gain).

For example, for d = 10 miles and P = 100 kW, the field would theoretically be about 100 mV/meter as shown in Fig. A-2. Due to various propagation phenomena, the actual field is in general substantially weaker than the free-space field. This is particularly true at large distances and high frequencies. The Federal Communiations Commission has developed field strength curves, the so called FCC (50,50) curves, which are experimentally determined statistical averages of the field strength as a function of the distance. These are shown in Fig. A-2 for a transmitting antenna height of 1000 ft, a receiving antenna height of 30 ft, and for the maximum permitted effective radiated peak power which is 100 kW in the low-vhf band, 316 kW in the high-vhf band, and 5 MW in the uhf band. It should be noted that the field strength is approximately proportional to the height of the receiving antenna, so that at, say, 15 ft, the field strength is 6 dB less than indicated in Fig. A-2.

It must be strongly emphasized that the FCC (50,50) field strength curves shown in Fig. A-2 are statistical averages (50% of the locations, 50% of the time). To say, as is commonly done in advertising, that an antenna has a certain "range" is correct only in the sense that a specified signal-to-noise ratio may be obtained "on the average" at that range, assuming a "normal" receiver.

The close range maximum field strength and the average field strength at 40 miles is summarized in Table A-1. At distances from 30 to 60 miles, the field strength varies by about 7 dB for every 10 miles (see Fig. A-2).

Also shown in Table A-1 is the voltage that a matched half-wave dipole 30 ft above ground can deliver to a 75-ohm load. This signal level is expressed in decibels referenced to one microvolt, $dB_{\mu V}$. It should be noted that the 0 dB reference, *i.e.* 1 μV over 75 ohms, corresponds to thermal noise in a bandwidth of 3.33 MHz. Thus, the signal level shown in Table A-1 is also the reference signal-to-noise ratio, which would be obtained with a noise-free receiver and a dipole in a space of 290° K. In the so-called TASO definition[12] of television signal-to-noise ratio, 6 MHz rather than a 3.33-MHz noise bandwidth has been used. Thus, thermal noise at 75 ohms according to the TASO definition is at a level of $+2.5 dB_{\mu V}$. Signal voltages are defined as the rms voltages of the carrier at the peak of the waveform — *i.e.*, at the peak of sync.

It is seen that the maximum permitted radiated power has been carefully chosen to make the signal level on all channels about the same. Channel 2, which is the most critical channel for a small $\lambda/2$ dipole antenna yields a signal of 65 $dB_{\mu V}$ at 40 miles, *i.e.*, a level 62.5-dB above thermal noise in a 6-MHz bandwidth. If the receiving system has a figure of merit of −22.5 dB, the resulting TASO signal-to-noise ratio would be 40 dB, which is considered "excellent" by 50% of the viewers.[12] An antenna system with a figure of merit of −22.5 dB would thus have a "range" of 40 miles in the sense that with such an antenna 30 ft above ground, 50% of the viewers located on a radius of 40 miles from the transmitter will, at 50% of the locations, find channel 2 to be excellent 50% of the time, assuming no impairments other than random noise. This obviously leaves a number of users on the 40-mile radius with less than excellent reception of channel 2. Within the 40 mile radius, however, the vast majority of the users are likely to be satisfied with the reception.

In strong signal areas, intermodulation (IM) distortion in the antenna amplifier may impair the picture. To maintain good radiation patterns, the output signal level from the amplifier must be at least 25 dB higher than the level of signals picked up directly by the cable and the receiver.

Table A-1 — Television signal intensities having the transmitter antenna at a height of 1000 ft and a receiving antenna at a height of 30 ft.

		Low vhf		*High vhf*		*uhf*	
	Effective radiated peak power	100 kW		316 kW		5 MW	
	Channel No.	2	6	7	13	14	69
	(MHz) channel freq.	55	83	175	211	471	801
40 mile average signal	Field strength dB (μV/m)	66	66	74	74	82	82
	Input signal over 75 Ω from dipole $dB_{\mu V}$	65	61	63	61	62	58
close-range max signal	Field strength dB (μV/m)	110	110	115	115	120	120
	Input signal over 75 Ω from dipole ($dB_{\mu V}$)	109	105	104	102	100	96

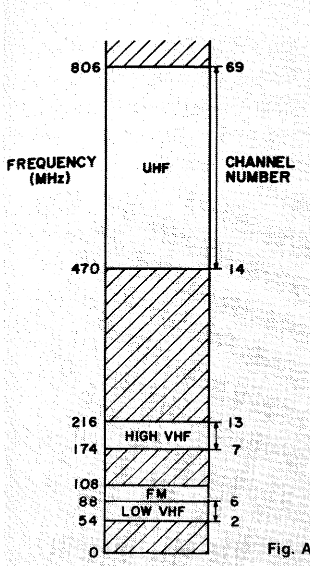


Fig. A-1 — The television and fm broadcast spectrum.

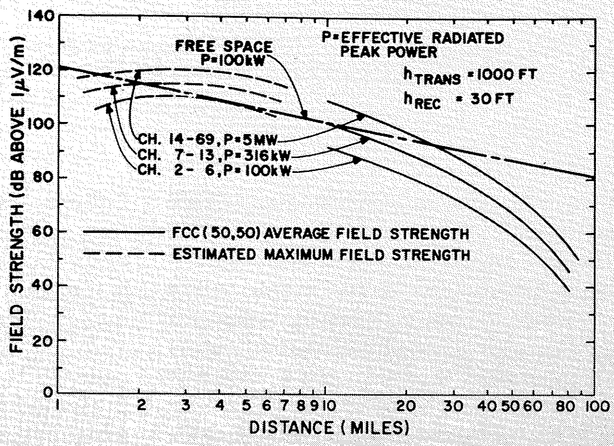


Fig. A-2 — Average and maximum field strength *vs.* distance.

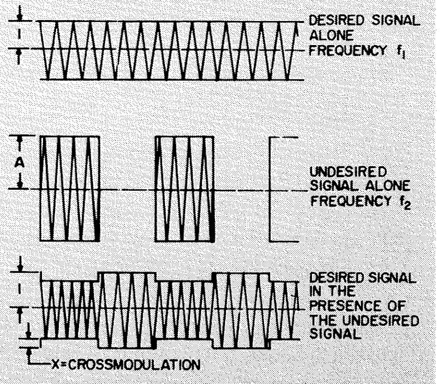


Fig. A-3 — A definition of crossmodulation.

It has been found experimentally that a "typical" television receiver with a 300-ohm twin-line, a 300-to-75-ohm balun, and 50 ft of 75-ohm coaxial cable (RG 59/U) picks up a signal which may reach a level 25 dB below the signal level picked up by a dipole at the same location. For this reason, the output level of the amplifier should be at least equal to dipole-level. This is also a good choice of signal level to overcome cable losses and receiver noise.

Due to the beam shape of transmitting antennas, the field strength reaches a maximum a few miles from the transmitter. Assuming a free-space field and a typical transmitting antenna, a maximum field strength has been estimated, as shown by the dotted lines in Fig. A-2. The field strength could, at some places, be 6 dB higher than shown in Fig. A-2 due to reflections. Table A-1 shows that estimated maximum signals received by a dipole could be of the order of 109 $dB_{\mu V}$ over 75 ohm, or about 280 mV. Fortunately, as can be seen in Fig. A-1, the tv spectrum has been so carefully planned that second order IM products of tv signals fall outside the tv spectrum. However, as can also be seen from Fig. A-1, second harmonics of fm signals, as well as second-order intermodulation products between fm and tv signals can fall in the tv band. At some locations, an fm signal may also be much stronger than the tv signals. For these reasons, it is necessary to insert a passive filter before a wideband antenna amplifier to trap the fm signals.

Third-order intermodulation products, which tend to increase in proportion to the output power of the amplifier, can, however, not be avoided. When the number of signals is small, the most disturbing form of third-order IM-distortion is crossmodulation, *i.e.*, the transfer of modulation from one carrier to another. Figure A-3 shows a definition of a measure of crossmodulation commonly used in the cable television industry. A crossmodulation of −40dB according to this definition is considered "visible but not disturbing".

Appendix B — System temperature

In the system shown in Fig. 1, we shall make the simplifying assumption that all passive components are at a reference ambient temperature $T_o = 290°K$. With this assumption, the relative system temperature can be shown to be

$$T/T_o = (T_A - T_o)/T_o + F/K$$

where

T_A is the actual antenna temperature (noise temperature of the field)

K is the antenna efficiency = (radiation resistance/total resistance).

F is the effective noise figure of antenna-cable-receiver combination.

The effective noise figure can in turn be expressed as:

$$F = F_G + \eta_c(F_R - 1)/\eta_A GC$$

where

F_G is the noise figure of amplifier-cable combination.

F_R is the noise figure of receiver.

G is the amplifier gain $\geqslant 1$.

C is the cable gain $\leqslant 1$.

η_A is the match efficiency of the antenna output impedance.

η_C is the match efficiency of the cable output impedance.

The match efficiency η of a source with an impedance $R + iX$ is the efficiency with which the available power can be transferred to a reference "normalization" resistance R_o,

$$\eta = 4\,RR_o/[(R + R_o)^2 + X^2_o]$$

The normalization resistance R_o can be chosen arbitrarily, but the most convenient choice is the characteristic impedance of the cable. In television systems, this is usually 75 ohms. The gain of the amplifier (or cable) is defined as P_A/P_S, where P_A is the power that the amplifier (or cable) can deliver to a load resistance R_o, and P_s is the power that the source which drives the amplifier (or cable) can deliver directly to R_o. The noise figure of the amplifier (or receiver) is defined for a reference temperature T_o and for the actual impedance of the source which drives the amplifier (or receiver). The antenna temperature T_A, which depends on atmospheric, cosmic, solar, and man-made noise, varies with frequency and time, as well as with radiation pattern and antenna orientation. There is substantial atmospheric noise below 30 MHz, at which frequencies T_A is an important factor. In the high-vhf and uhf television bands, the noise temperature of the radio sky is equal to or less than $T_o = 290°K$. In the low-vhf band (54-86 MHz) the temperature of the radio sky is, according to various sources[8], anywhere from 1500° K to 10000° K. However, the effects of cosmic and solar noise on low-vhf tv reception are likely to be variable and unpredictable and have not been verified with typical tv antennas. For these reasons, the performance of the Mini-State antenna relative to conventional antennas is assessed under the "pessimistic" assumption that $T_A = T_O$.

Foam plastic as a structural component

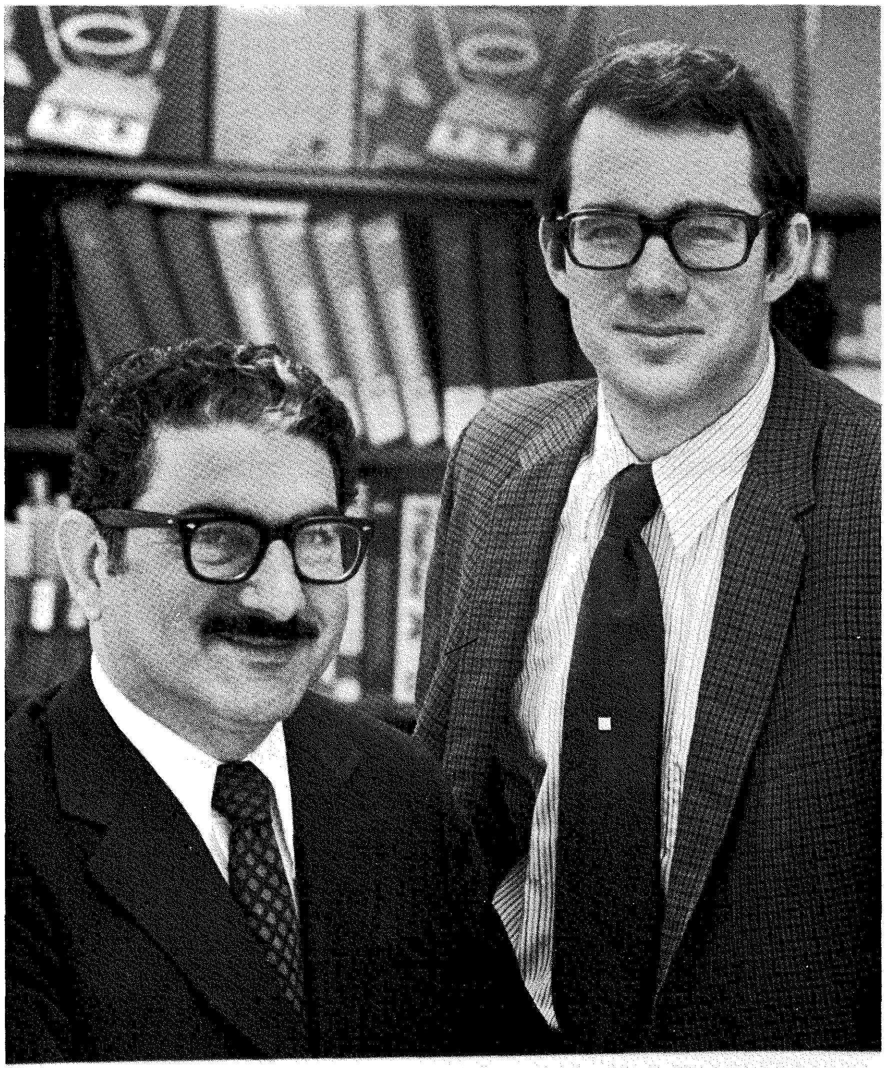
W.J. Bachman, Jr.| F.R. DiMeo

The RCA Mini-State antenna is a compact, readily installed consumer antenna system. This electronically innovative system provided many mechanical design challenges. All the rf components are mounted on a support platform, which, in turn, mounts on the output shaft of a drive unit. This drive unit rotates the platform a full 360° in order to take advantage of the directional properties of the antenna. In most instances, the application of standard materials used in straightforward design approaches proved to be best, but the design of the support platform allowed for innovation, especially in the choice ol material—polystyrene expanded bead foam; this material is commonly found in packaging applications and in products which utilize its thermal insulation properties such as the familiar styrene picnic cooler.

William J. Bachman received the BSME in 1966 from Lehigh University. He joined RCA Parts and Accessories in 1969 after working at General Electric, where he was involved in the design and devleopment of mechanical test equipment. His major responsibility at RCA has been the mechanical design and development of indoor and outdoor tv antennas.

Franklin R. DiMeo, Product Development Specialist, Engineering, Parts and Accessories, Deptford, N.J., received a certificate in Mechanical Design Technology at Temple University in 1958. Mr. DiMeo joined the ITE Circuit Breaker Company in 1951 where he gained experience in the design of large electro-mechanical systems. In 1956 he joined RCA in Camden, N.J., as a senior designer in the Airborne Fire Control Group. He continued as a designer in several other departments where he participated in the equipment design of several large military projects, including the original Minuteman missile launching system. In 1965, Mr. DiMeo joined the Parts and Accessories Division at Deptford to participate in RCA's new antenna development program where he is presently responsible for design and drafting. He holds five patents for RCA.

Authors DiMeo (left) and Bachman.



Editor's note: RCA Parts and Accessories received the Gold Award of the Society of the Plastic Industry in the Fourth Annual National Expandable Polystyrene Competition in 1973. This award, given for excellence in design and quality, was presented to RCA "for unique use of expandable polystyrene for structural use."

EXTREMELY LOW MASS and excellent low-loss rf characteristics, makes polystyrene foam an ideal choice for mounting antenna elements. Such materials are commonly used in rf radomes for communication antennas since, at vhf frequencies, the material has negligible effect on gain, beamwidth, back-lobe level, and other pattern characteristics.

Mechanically, the material is attractive because of its low density and ease of fabrication. The low density of only 2 lb/ft^3 minimizes both the load on the drive unit and the weight of the overall product.

During the early design stages of the antenna configuration, sample pieces were readily fabricated into prototype models and necessary changes could be effected with little more than sharp knife. These handmade models closely simulated final manufactured parts both mechanically and electrically. This similarity made possible the early establishment of rf electrical performance characteristics and structural configurations. In addition, the effectiveness of fastening methods could also be evaluated.

Assembly considerations

In the design of those parts which interface with the platform, there were two major considerations dependent on material properties. The first involved establishing adequate and economical fastening methods for parts mounted to the platform. The uhf elements were designed as flat metal stampings to be bonded to the platform with adhesive.

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The photograph of the platform in Fig. 1 shows how pockets were molded into the top surface in order to accurately position the elements. A pressure-sensitive adhesive applied to the metal components during their fabrication holds them in position. The vhf elements were designed as flat metal stampings which, when staked to molded plastic connectors, form a closed belt. This belt is slipped down around the outer periphery of the platform and accurately positioned by matching tabs on plastic connectors with recesses in the top of the platform. Self tapping screws driven through the belt and into the platform prevent dislocation of the belt. A photograph of the final assembly is shown in Fig. 2.

Secondly, consideration had to be given to dimensional variations characteristic of foam molded parts. In the case of the platform, a potential variation of ±0.125 in. in the 18-in. diameter had to be allowed for. This was accomplished by designing the vhf belt and platform interface so that sufficient controlled flexing of the belt would automatically occur during assembly to make up for any dimensional differences from one platform to another.

Economic considerations

Major economic advantages were also gained by using the polystyrene bead foam in this application. When compared to an equivalent injection molded plastic part, the tooling costs are considerably less— in this case nearly 90% lower. In addition, delivery time for tooling is about 75% less. The chief reason for these reductions in cost and time is that the molding of this material is done at far lower pressures and temperatures and, therefore, does not require expensive high strength tool steel molds. The mold for the platform was an aluminum sand casting. The wooden pattern built to produce the casting could be used repeatedly, thus lowering the tooling cost of a multi-cavity mold and insuring similarity and uniformity between cavities. In addition, design changes, should they be necessary, are easily implemented in this type of tooling.

There are two chief factors which tend to determine the piece-price of molded parts: material cost and fabrication cost. The latter is determined primarily by the molding cycle time. Foam molding cycles are usually longer than injection molding cycles; therefore, in the case of small parts where the differences in material costs are slight, foam molded parts are not usually cost competitive. However, on large items, it is often possible to design a foam-molded part which is structurally equivalent to an injection-molded part but with significantly less material by weight. In such cases, the foam-molded part may be more economical. In the case of the Mini-State antenna platform, which is 18 in. in diameter and 2 in. high, this proved to be true.

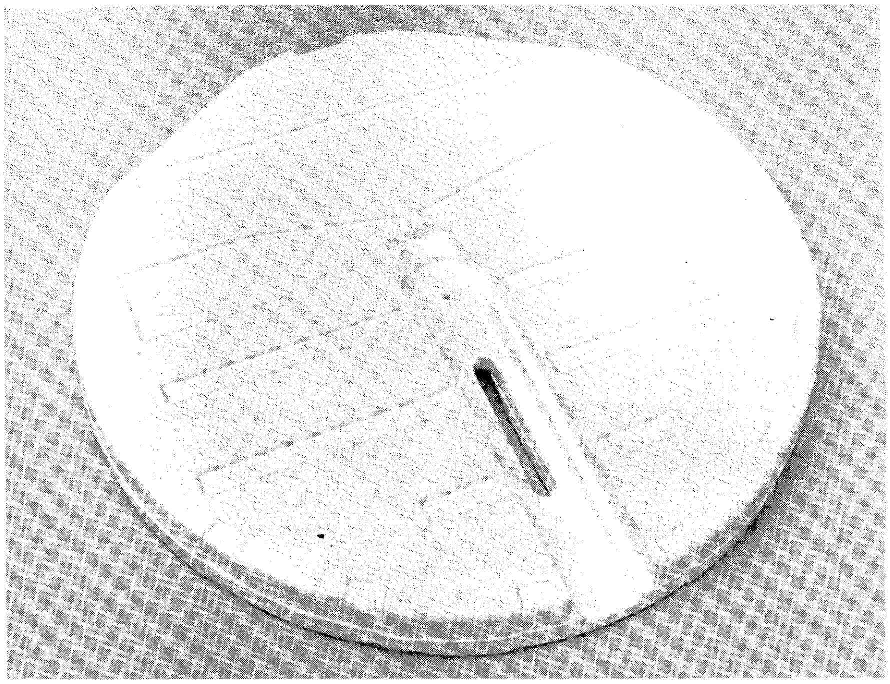

Fig. 1 — Molded foam plastic structure.

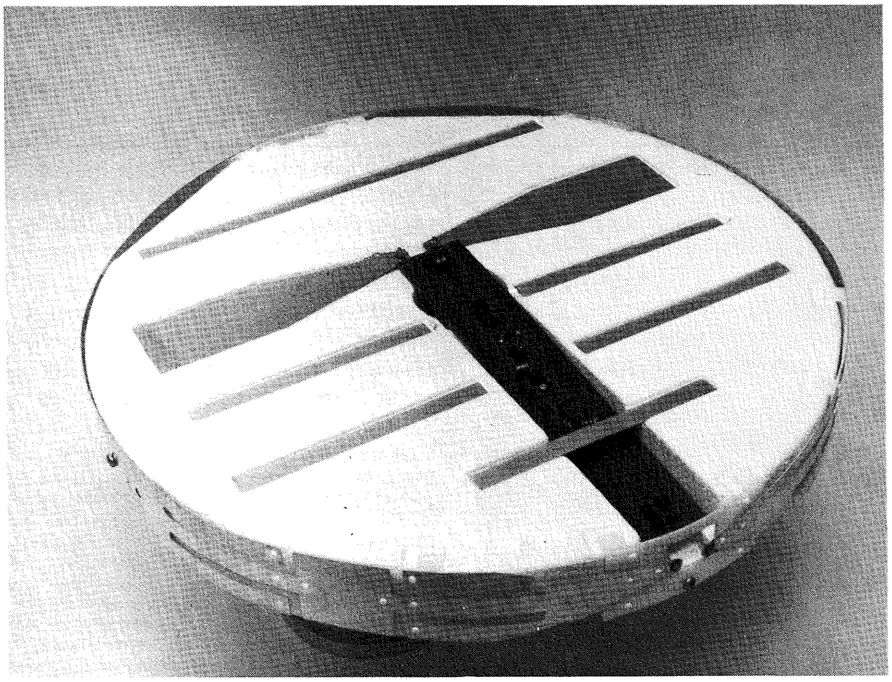

Fig. 2 — Final assembly showing position of vhf belt around the foam platform and the uhf elements inside.

Conclusions

Testing of production units has shown that all design parameters specified in terms of the prototypes were met by the production units. The objective of a good commercial product design is reliable performance at minimum cost. Field performance of the Mini-State antenna system to date has shown that the choice of polystyrene foam for the platform application meets these objectives.

New indoor uhf tv antenna

P.J. Mikulich

Slot antenna concepts have been well documented for a number of years [Refs. 1,2,3]. Recently, RCA has applied the slot concept to indoor television antennas for uhf reception. This paper reviews the slot-antenna concept, describes two applications of this concept to uhf indoor tv antennas, and compares these antennas to existing indoor uhf types.

OVER the past ten years, RCA Parts and Accessories has developed a complete line of indoor (top-of-receiver) antennas, including vhf, uhf, and combination antennas.

Today, the indoor tv antenna market consists of vhf-expanding dipole elements (rabbit ears) and uhf loops. Some variations of the bowtie and multi-element yagi are still available for uhf reception, but few have been successful products.

One of the best performing uhf indoor antennas on the market today is the RCA loop with patented parasitic director/reflector elements. These parasitic elements increase the directivity and improve ghost-rejection capability.

Recently, RCA has developed a new slot-tuned uhf indoor antenna. It is a radical change from the previous designs with increased performance and a new look in styling. Two variations of the slot-tuned antenna can be seen in the combination vhf/uhf antennas shown in Figs. 1a and 1b.

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Fig. 1a shows the larger version which consists of a common tunable vhf telescopic dipole and a tunable uhf slot. The slot antenna is essentially a flat sheet of metal with a vertical slot opened at one end. The sheet of metal itself may be square, rectangular, circular, diamond, etc.; the only limiting criterion is that the sheet of metal must not be small in terms of operating wavelength. The twin 300-ohm feed line is connected at a point near the center of the vertical slot. A slide tuner is positioned at the open end. This tuner is a capacitively coupled short circuit and consists of a small metallic slider separated from the sheet by a thin piece of dielectric material. The position of this slider tunes the slot to a specific frequency. Since the slide tuner has no metal-to-metal contacts, rf noise is not present on the picture while tuning. Director and/or reflector elements can be added to this configuration for increased directivity.

Fig. 1b shows the smaller version which consists of a vhf telescopic dipole and a fixed-tuned uhf slot. The slot antenna consists of a curved metallic sheet with a narrow vertical slot. Near the top and bottom of the vertical slot are intersecting horizontal slots. These slots act as end-loading elements and make the vertical slot appear longer. The feed line is connected to the metal sheet near the center of the vertical slot.

Existing antenna designs

Over 90% of the indoor tv uhf antennas today are of the loop configuration. Many of these are designed so that the styling additions actually degrade the antenna's performance.

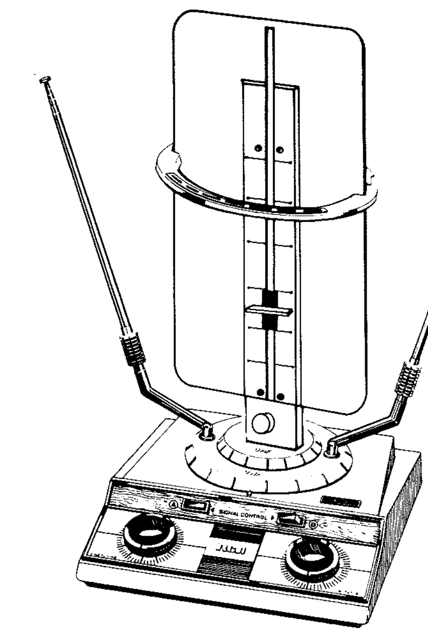

Fig. 1a — This indoor television antenna consists of a vhf telescopic dipole and a tunable uhf slot antenna.

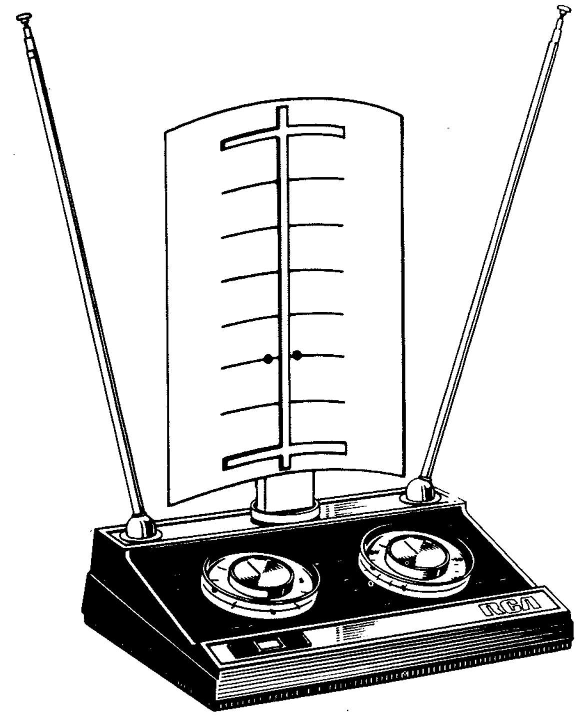

Fig. 1b — This indoor television antenna consists of a vhf telescopic dipole and a fixed-tuned uhf slot antenna.

A loop oriented in the vertical plane and receiving horizontal polarization should be approximately one wavelength in circumference to operate efficiently. The antenna pattern that it generates is a "figure-8" with maximum lobes perpendicular to the plane of the loop and deep nulls in the plane of the loop. Any additional loops, such as an inner and outer loop, create resonant nulls in the response unless the loop is a multi-wound type or the additonal loops are specifically designed to eliminate the resonant nulls.

A fairly standard-size uhf loop is designed to operate in the lower middle portion of the uhf band. Since the loop is never more than 1.5 to 2.0 wavelengths in circumference, multiple lobes and extra deep nulls which accompany a loop of larger circumference are avoided. A loop that is much smaller than a wavelength in circumference has significantly different radiation patterns; that is, the maximums occur in the plane of the loop, and nulls are perpendicular to the loop (assuming uniform current distribution).

So, to maintain an efficient vertical loop antenna with a "figure 8" type pattern across the uhf band, the loop size must be maintained between 0.8 to 1.8 wavelengths in circumference. With this size loop, the current maximums occur at the feed point and approximately every 90° around the loop. The phase, however is such that the top and bottom maximums (which produce horizontal polarization) reinforce one another and the side maximums (vertical polarization) cancel each other at the feed point. The directivity of this loop is equal to, or better than, that of a standard dipole for a good portion of the uhf band. Increased directivity can be attained by the use of RCA patented director/reflector configuration. This configuration uses parasitic elements, which derive currents from the nearby driven antenna, to increase directivity of the newly formed array.

The remainder of the indoor uhf antennas in the industry are made up of mainly "bowtie" types and a small percentage of miniature yagis, butterfly dipole, etc.; none of these have had much market success. However, a few words may be in order for the bowtie at this point.

The bowtie uhf antenna is essentially a triangular dipole. The middle can be cut out (wire form) or solid. The flare angle helps to broaden the bandwidth of the antenna and match it to the feed line. The length (total length) is usually a wavelength at the high end of the uhf band. It is easily made and has equal front and back gain and deep nulls. This type of uhf antenna is usually very popular with portable tv receivers. It also may be found used in a stacked orientation, two bowties one above the other in front of a reflector to improve gain and directivity.

Slot design and development

In keeping with RCA tradition of setting the trend in new indoor antennas with improved performance and modern styling, a revolutionary new uhf design has evolved. The goals set for this new design were simple: improved performance over the standard loop antenna and different than loop styling. Styling considerations pointed toward something with more mass such as a sheet of metal which could be shaped and styled. Therefore, the slot in a sheet of metal was chosen for evaluation. The basic slot antenna as shown in Fig. 2 is a very efficient radiator.

The antenna consists of a $\lambda/2$ slot having a width of much less than a wavelength cut in a flat metal sheet; the currents are not confined to the slot but spread out over the sheet. This is a simple type of slot antenna, and it radiates equally from

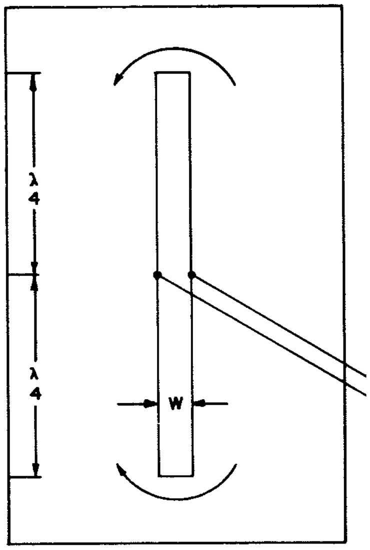

Fig. 2 — Basic slot antenna.

both sides of the sheet. The slot, when oriented vertically (as shown in Fig. 2), radiates or receives horizontal polarization normal to the sheet.

The radiation pattern of a $\lambda/2$ slot antenna of slot width W in a flat sheet of infinite extent is the same as that of a complementary dipole of a flat strip W but with two differences: 1) the electric and magnetic fields are interchanged and 2) the component of the electric field of the slot normal to the sheet is discontinuous from one side of the sheet to the other, the direction of the field reversing. (Refer to Fig. 3.) When the slot is oriented in the vertical position, as shown in Fig. 4, the radiation pattern is everywhere horizontally polarized.

Referring to Fig. 4, the electric field has only an E_ϕ component. If the slot is very thin ($W << \lambda$) and 1/2 wavelength long ($L = \lambda/2$), the variation of the E_ϕ as a function of the vertical angle, θ is

$$E_\phi = \cos[(\pi/2)\cos\theta]/\sin\theta \qquad (1)$$

Also, if the assumptions are made that the sheet is infinite and a perfect conductor, then the magnitude of the E_ϕ as a function of ϕ for any value of θ is constant

$$E_\phi(\phi) = constant \qquad (2)$$

Now consider the situation where the slot is cut in a sheet of finite extent as illustrated by the dashed lines in Fig. 4. This configuration has relatively little effect on the $E_\phi(\theta)$ pattern. There is, however, a drastic change in the $E_\phi(\phi)$ pattern since the electric field radiated from the two sides of the sheets are equal in magnitude but opposite in phase so that they cancel. Hence, there is a null in all directions in the plane of the sheet which gives a "figure-8" shape to the $E_\phi(\phi)$ pattern, as shown in Fig. 5.

If the size of the sheet is kept approximately equal to $\lambda/2$, the "figure-8" pattern will predominate. However, as the sheet gets larger, the $E_\phi(\phi)$ pattern usually exhibits a scalloped or undulating characteristic. The pattern undulations become more numerous as the sheet gets larger, but the magnitude of the undulations decrease so that for very large sheets the pattern conforms to a circular shape.

The impedance of a slot antenna, in a flat metal sheet, which is free to radiate on both sides, can be obtained directly from the impedance of a complementary dipole antenna.

According to Brooker[3], the terminal impedance (Z_s) of a center-fed slot antenna is equal to 1/4 of the square of the intrinsic impedance of the surrounding medium divided by the terminal impedance (Z_d) of the complementary dipole antenna.

For free space $Z_0 = 376.7\Omega$

$$Z_s = Z_o^2/4Z_d = 35\,476/Z_d$$

the impedance of the slot is proportional to the admittance of the dipole or vice versa. Since Z_d may be complex

$$Z_s = 35\,476/(R_d + jX_d)$$

$$= \{35\,476/(R_d^2 + X_d^2)\}\,(R_d - jX_d)$$

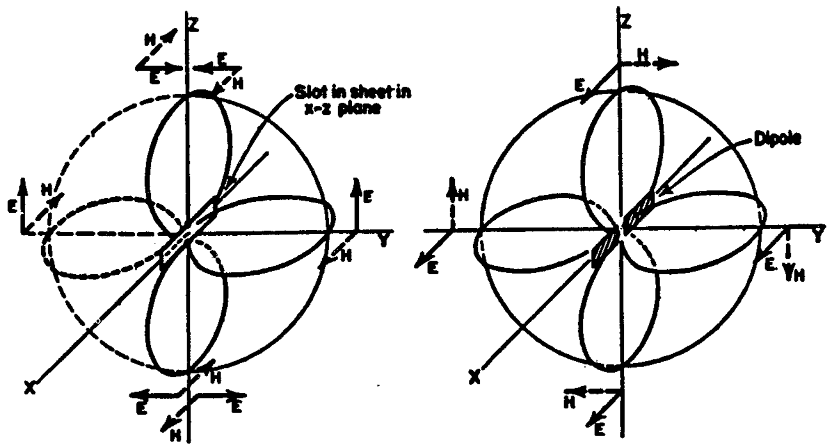

Fig. 3 — Radiation field patterns of slot in infinite sheet (a) and of complementary dipole antenna (b). (From *Antennas* by J.D. Kraus. Copyright 1950; McGraw-Hill Book Co.; New York. Used with permission of McGraw-Hill Book Company.)

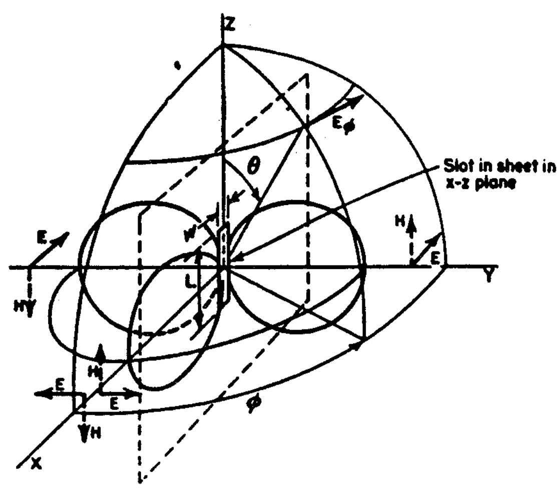

Fig. 4 — Radiation pattern of vertical slot in infinite flat sheet. (From *Antennas* by J.D. Kraus. Copyright 1950; McGraw-Hill Book Co.; New York. Used with permission of McGraw-Hill Book Company.)

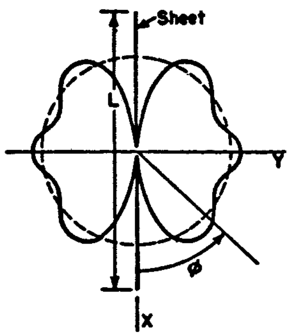

Fig. 5 — Solid curves show patterns in *x-y* plane for slot in finite sheet. Slot is open on both sides. (From *Antennas* by J.D. Kraus, Copyright 1950; McGraw-Hill Book Co.; New York. Used with permission of McGraw-Hill Book Company.)

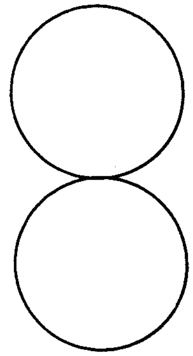

Fig. 6 — Slot antenna pattern in the horizontal plane without director/reflector ring.

where R_d and X_d are the resistive and reactive components of the dipole terminal impedance Z_d. Thus, if the dipole antenna is inductive, the slot is capacitive, and vice versa. The above discussion on impedance applies to slots in sheets of infinite extent. If the sheet is finite, the impedance values are substantially the same if the sheet is fairly large in size in terms of wavelength. The slot impedance is also sensitive to the configuration of the terminal connections and care must be taken in the design of this area.

The RCA slot design is based on the previous section with certain modifications incorporated to adapt the slot for a tv table-top receiving antenna.

The slot antenna was evaluated to determine what the minimum size and shape must be to still have better performance than a loop and not be too massive in design. Fig. 1a shows the tunable model which was developed at P&A. Typical patterns in the horizontal plane, without a director reflector ring, are shown in Fig. 6. As noted, the pattern has equal front and rear lobes with deep nulls in the plane of the sheet. Fig. 7 shows the effect of the addition of a director/reflector ring (developed for, and used on, the RCA 10X808 loop design); also shown is the increase in directivity that is attained by the addition of this ring.

The greatest innovation in this design over a simple slot antenna is the tunable slot. The uhf band covers 470 MHz to 900 MHz — an extremely large bandwidth. The tunable slot antenna is designed to be a resonant half wave at 470 MHz. At higher frequencies, if tuning were not available, the antenna would be progressively greater than a half wave and become an inefficient radiator. The tuning tab adjusts the slot length to be approximately a half wave in length at the higher frequencies. The impedance characteristics through this technique are greatly improved.

The tab itself acts as a short circuit. Originally, the tab was metal which made contact with the sheet causing a short; however, this caused rf noise on the tv screen when tuning. The tab was then changed to a capacitive type, using a thin piece of dielectric placed between the metal tab and the metal sheet. This eliminated the rf noise, and allowed the tab to slide much easier. The size of the metal tab and the thickness of the dielectric, however, are critical to the proper tuning of the antenna.

It should be noted at this point that the antenna terminals are not exactly on center of the vertical slot. This is because the terminal resistance at the center of a resonant one-half wavelength slot in a large sheet is about 500 ohms, and the characteristic impedance of the twin line is 300 ohms. By using a slightly off-center feed configuration, a better impedance match across the uhf frequency range results.

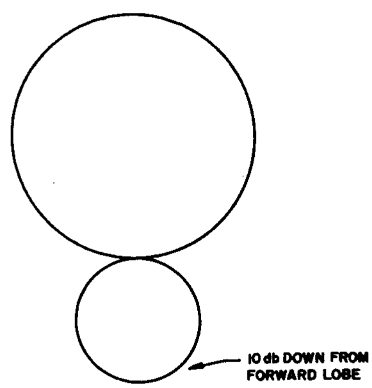

Fig. 7 — Horizontal pattern after addition of director/reflector ring.

The second model developed by RCA is much shorter, as shown in Fig. 1b. RCA's innovation here is horizontal slots at the top and bottom of the vertical slot. The vertical slot is much shorter than 1/2 wavelength at the low end of uhf. If a dipole is very short compared to a wavelength, the impedance is high and capacitive. To reduce the impedance and give a more uniform current distribution, plates are often added at the ends of the dipole to provide capacitive loading. Now a slot antenna is the complement of the dipole. Therefore, a very short slot is inductive, and short slots added at the ends act as inductive loading. This has the same effect as the capacitive loading plates on the dipole — that is, making it look effectively longer.

Conclusions

The improvement gained by use of the tunable slot over a fixed tuned loop is especially noticeable at the band extremities. The loop is designed for approximate mid-band uhf response; the low and high ends suffer. The tunable slot allows efficient antenna performance across the *entire* uhf band. Actually, this is the first uhf indoor antenna that actually can be tuned by the customer to increase the signal for the particular station he is viewing (vhf rabbit ears have incorporated tuning for years). The slot was designed to obtain better performance than a loop, and this was achieved by as much as 3 dB. Likewise, appearance of the fixed-tuned end-loaded uhf slot antenna is more appealing than the wire loop antenna, and it is equally efficient.

Acknowledgments

J.D. Callaghan was responsible for some of the very important design and development work on these slot antennas. W. J. Bachman and F. R. DiMeo were responsible for the mechanical design and product design of these antennas.

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Stereo tape players for in-car entertainment

C.C. Rearick | J.M. Shuskus

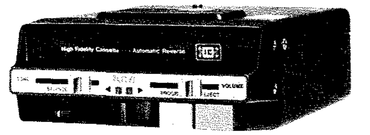
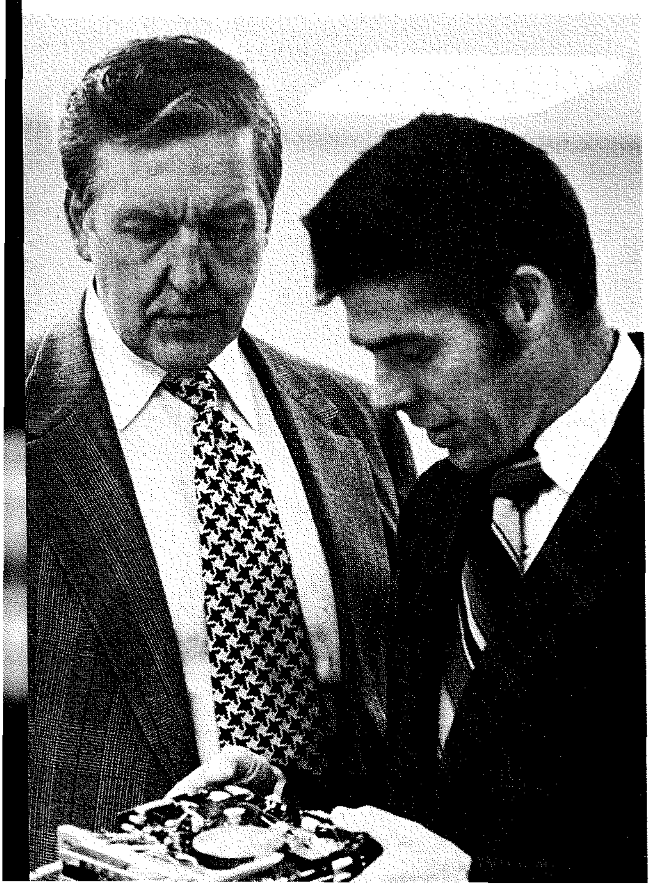


Fig. 1 — The Model 12R150 fully automatic reversing cassette tape player. This unit weighs 4 lbs.; its dimensions are 2⅛ in.(H) X 5½ in. (W) X 6⅝ in. (D).

Success in the car stereo product line has been a result of a set of tradeoffs between the natural limitations of the automotive environment, state-of-the-art of audio product technology, and customer-oriented merchandising features. This paper describes the growth of the RCA car stereo product line and outlines the technical and merchandising constraints.

TODAY, a.m. radio in the automobile has virtually become a "necessity." Broadcasters cater to the driver during the morning and evening rush hours, with detailed traffic reports, weather, and news capsules. "Music to drive by" and related advertising are pointed directly at "the man in a car". Better or more personally satisfying forms of in-car entertainment, especially for those persons who must spend more than 20 to 30 minutes a day in their car is a natural extension of the basic a.m. car radio. For many drivers, the prospect of being able to choose quality programming, even though he has far outdistanced the one radio station which plays "his kind" of music, has a strong appeal. The RCA product line of Car Stereo Tape Players, introduced in November of 1970, and continuously expanded to this day, meets this demand for quality in-car entertainment.

Authors Shuskus (left) and Rearick examing the workings of an a.m./fm/multiplex stereo radio and stereo-8 tape player.



Product line development

Originally, the product line consisted of two stereo cassette models and a lower priced stereo 8-track model. One of the cassette players was a "play-only" version, model 12R100, while the other, model 12R200, was identical except for a monaural recording capability. The stereo 8-track unit, model 12R300 very quickly became the model 12R301 when channel indicator lights were added as an additional feature. With but very few minor improvement modifications, the 12R301 continues, four years later, to be one of the best selling models in our line. The two cassette models have since run their course and been replaced just this past year with the new model 12R150 (Fig. 1), a fully automatic reversing machine, miniaturized to less than half the volume of the original cassette machines and featuring all-integrated-circuit audio amplifiers which will be described later.

The 12R301 picked up a "little brother" about two years ago in the form of the model 12R500, a mini-sized 8-track tape player, featuring for the first time all-integrated-circuit electronics. Shortly thereafter, the product line grew to include both a combination stereo-8/fm multiplex stereo radio receiver, and the ultimate in in-car stereo sound, the 12R800 (Fig. 2) "quad-8" *discrete* 4-channel stereo tape player.

The final acoustic link, the loudspeaker, was not ignored throughout this development; in fact, in conjunction with the development of the first tape players, the model 12R400 (Fig. 3) stereo loudspeaker pair was introduced. This loudspeaker was designed to have low-frequency characteristics especially tailored for ideal operation in the unusual acoustical environment of the interior of an automobile.

Design liberties and constraints

The most obvious constraint imposed upon automotive electrical equipment designs is the 12 Vdc supply voltage limitation. Though quite acceptable for operating the small signal portions of electronic circuits, the power output stage can *only* swing a maximum theoretical ±6 V before peak clipping limits any further output. To realize the audio power output levels necessary for a satisfactory dynamic range inside a noisy car, the amplifier should deliver a minimum of 3.5 W (sinewave continuous power) to each loudspeaker so that a maximum stereo sound field intensity of about 90

Joseph M. Shuskus, Manager, Product Planning, Parts and Accessories, Deptford, New Jersey joined RCA Service Co. in Kearney, New Jersey in 1947. Shortly thereafter, he was assigned to the RCA Teleran Project (Television radar navigation) as a Field Engineer. He was in charge of the Field Engineering activity and upon completion of the project received a commendation from Watson Electronic Laboratories of the Air Materiel Command. Subsequently, he served as RCA Service Company Branch Manager in Brooklyn, and District Manager in Chicago and North Jersey. After a period of years as a principal in an antenna and accessories manufacturing firm, he rejoined RCA at Deptford in 1968. He was Manager, Product Merchandising for tv antennas and car stereo products and presently is responsible for the new product activity.

Charles C. Rearick, Principal Member Engineering Staff, Parts and Accessories, Deptford, N.J., joined RCA in 1956, having graduated that year from the University of Maine with the BSEE. He completed the engineering training program and then served two years of military service as an army lieutenant. He returned to the Home Instrument Division engineering labs at Cherry Hill, where he became responsible for the acoustical and audio performance of the tv product line. After one year with the M&SR Division, he transferred to the Camden plant where he participated in various audio, digital signal processing and magnetic recording projects. He received his MS in Engineering for Graduate Work in Electrical Engineering from the University of Pennsylvania in 1969. As Technical Publications Administrator for Parts and Accessories, Mr. Rearick is also responsible for the review and approval of technical papers; for coordinating the technical reporting program; and for promoting the preparation of papers for the *RCA Engineer* and other journals, both internal and external.

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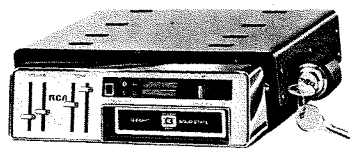

Fig. . — The Model 12R800 "quad-8" discrete four-channel stereo tape player. This unit weighs 4.75 lbs; its dimensions are 2⅝ in. (H) X 10⅛ in. (W) X 7½ in. (D) including quick-release mounting bracket.

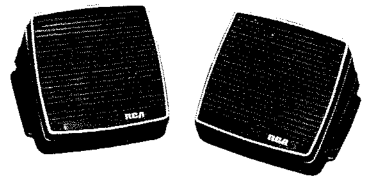

Fig. 3 — The Model 12R400 stereo loudspeaker pair. Each speaker is 5¾ in. in diameter; cabinet size is 6¾ in. (H) X 6½ (W) X 4½ in. (D). The frequency response is 50 to 10000 Hz and sensitivity is 93 dB.

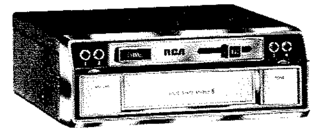

Fig. 4 — First generation. The Model 12R301 stereo-8 tape player. This unit weighs 6.5 lbs; its dimensions are 2⅞ in. (H) X 7¼ in. (W) X 7¾ in. (D).

dB results. If traditional 8-ohm loudspeakers are used (as some competitors specify) the maximum theoretical continuous undistorted output power could only be 2.25 W/stereo channel. By using 3.2-ohm loudspeakers, however, the maximum theoretical continuous undistorted output power becomes 5.6 W/stereo channel. It is obvious that the output transistor impedance at maximum conductance is not going to be zero so the theoretical value cannot be realized. In practice, however, between 3.8 and 4.0 W can be achieved from well-designed class-AB push-pull transistor amplifiers; between 3.5 and 3.8 W from early integrated-circuit power amplifiers; and between 4.5 and 4.8 W from more recent integrated-circuit power amplifiers (presently used in all of the IC amplifier models in the RCA line.) The integrated-circuit amplifiers have an advantage over transistorized amplifiers in that they can be driven harder (to realize the additional power) while their very high open loop gain (60 to 80 dB) is put to work to eliminate the resulting crossover distortion with negative feedback. The large amount of feedback also results in output damping factors in excess of 10:1 at 100 Hz.

The mechanical environment of an automobile interior is also an important limitation on the performance of a stereo tape player. The interior acoustical noise level limits the usable audible dynamic range; and the mechanical vibration, ambient temperature range, and dust and dirt problems far exceed those of conventional commercial home-type audio entertainment products. Thus, more than normal design care must be exercised to insure reliability. Plastic molded parts, such as loudspeaker grills, if exposed to direct sunlight, can reach temperatures as high as 200°F, even in mild climatic areas. Desert proving ground measurements[1] have recorded temperatures as high as 235° F (113°C) at the top of the rear package shelf. Under-dash temperatures (behind the instrument panel) can be expected to reach as high as 178°F (81°C).[2] Low temperature limits are completely uncontrolled, being limited only by the latitude in which the car is operated. There is no attempt made to obtain completely satisfactory operation of a tape player at these extremes of course, but it is absolutely necessary that the unit survive both exposure to, and attempts to operate at, temperatures near these limits. In practice, we assume that the limits of driver comfort should dictate the environmental range over which the unit will perform satisfactorily; these being from around +35°F to around +90°F (1.3 to 32.2°C).

Practical design limitations

Our original premise was that the in-car entertainment system be one of high quality. The home audio industry, under the umbrella of "high fidelity" has trained us to respect certain "standards" as necessary for a system of quality performance. As mentioned earlier, ambient noise restricts the useful audible dynamic range, while the maximum practical record "fidelity" of either 8-track or cassette tape systems restricts the useful output spectrum. These limitations, however, are not really all that bad, especialy when one considers that the driver should be applying his major concentration on the usual problems associated with safe driving. Since a quiet automobile at a 60 mi/h highway speed will sustain an interior noise level of about 75 to 80 dB_a[3], a maximum comfortable (to the ear) peak audio program level of 90 dB_a or so is a far cry from the 50 or 60 dB_a dynamic range available in quality home equipment.

Again, quality home equipment specifications dictate a frequency response of from 40 to 18 000 Hz, while the 8-track and cassette media, as commercially pre-recorded, will do very well to provide more than 70 to 10 000 Hz. Since 70 to 10 000 Hz is about the best that can realistically be reproduced by the loudspeakers that conveniently fit inside either a car door or in the rear package shelf, these design limitations may be comfortably accepted. Actually, the interior of a car, being an enclosed acoustical volume considerably smaller than the typical listening room in a home, reacts to the loudspeaker somewhat differently at low frequencies than does the larger listening room. At frequencies which have wavelengths near those of the interior dimensions of the enclosure, the coupling from loudspeaker to the air improves, resulting in a noticeable improvement in deep-bass response inside a car. This effect can be tested by using a loudspeaker with a slightly lower than normal (for its size) resonance, such as the RCA model 12R400, 401 or 402 mounted either in a door panel or in the rear package shelf (i.e., baffled), and listening to a program containing heavy (clean) deep bass, such as a good organ recording, and then opening the car windows. The loss of bass response with the windows open under these conditions is quite noticeable. We can therefore claim to take advantage of at least one characteristic of the listening environment to realize an improvement which allows the use of loudspeakers as small as 5-3/4 in. in diameter, if properly constructed and specified.

The performance specifications for typical car stereo products have continued to improve along with the state of the commercial electronic and mechanical arts. Table I shows a comparison of the characteristics of one of the earlier products (12R301, Fig. 4) with those of a second generation product (12R500, Fig. 5) and again with those of a most recent third generation product, (12R703, Fig. 6).

Merchandising considerations

To attract buyers, a product must have more associated with it than merely competent engineering design. Attractive packaging, convenient and easily operated controls, ease of installation, good and valid warranty provisions, and of course an affordable price are all

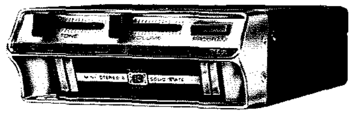

Fig. 5 — Second generation. The Model 12 R500 stereo-8 tape player. This unit weighs 3.7 lbs; its dimensions are 2⅛ in. (H) X 5½ in. (W) X 7¼ in. (D).

additional factors which affect the engineering effort associated with commercial product design and development.

Because of competitive pressures and the continuous innovations in products, engineering and marketing must work closely together in order to remain constantly abreast of market conditions. Sudden market changes and trends must be assessed quickly to maintain a strong competitive posture. Failure to recognize these changes in market requirements can result in immediate loss of sales and reduced opportunities for growth. Two examples of subtle but rapid market changes can be given.

First, when the cassette car player was introduced by the industry four years ago, it was not successful and sales never came up to industry expectations. The general conclusion at that time was that the *cassette* car player was not a viable product. However, over the past four years, the entire cassette industry has changed. High quality pre-recorded cassettes have become readily available and cassette equipment in the home has grown rapidly. Consumers who have built up extensive libraries of cassettes for home use wanted to use them in their cars. Consequently, they began asking for cassette car players. This caused a rapid resurgence in the demand for cassette players. It is estimated that cassette players now represent 25% of total car player sales. Had we not introduced the 12R150 cassette player, this segment of the market would have been missed.

The second example is the growth of the in-dash mounted tape player business. Originally, all car tape players were installed under dash. Many customers, particularly those with current model year cars, were not satisfied with under-dash or "hang-on" units. They wanted equipment that could be installed in the dash and have a custom installed appearance. To meet this need, the model 12R703, in-dash 8-track car tape player with a.m./fm/fm-stereo radio was introduced. It is expected that in-dash units will represent 40% of total sales by mid-1975.

Additional changes will continue to take place at a very fast rate, thus posing a challenge to marketing to clearly identify and evaluate market trends. And, just as important, engineering has the challenge to react quickly and develop the required new products that are vital for continued growth.

Related product areas

As is so often the case, a successful product line also generates a line of related accessories almost as successful as the original line. To provide customers with a reasonable improvement in the security of their car stereo installation, a unique quick-release mounting bracket, model 12R550 was designed, having a key lock. Since this makes the car stereo readily removable (that is the *only* condition for absolute security), the models 12R900 and 12R1000 Home Converter power source and mounting enclosures were designed so that the units could be brought indoors for use as a "home" audio product. The model 12R410 bookshelf loudspeaker stereo pair were then designed[4] to provide an ideal match to the car stereo for inside the home listening. Additional car loudspeaker configurations such as the models 12R401 and 12R402 were designed, using the 12R400 driver for installations which requried a very low profile for flush mounting. Customer demands for larger and heavier loudspeakers have resulted in the introduction of the model 12R404 "big mag" loudspeaker pair with 10-oz magnets, while other customer demands for smaller, more economical loudspeakers resulted in the introduction of the model 12R403 "economy" pair.

Fig. 6 — Third generation. The Model 12R703 a.m./fm/multiplex stereo radio and stereo-8 tape player for use in-dash or under-dash. This unit weighs 5.1 lbs; its dimensions are 2¼ in. (H) X 7⅛ in. (W) X 7⅛ in. (D).

Table I — Performance specifications for three generations of RCA car stereo tape players.

	1st Generation	*2nd Generation*	*3rd Generation*
Frequency response @ ±3 dB (Hz)	50 to 10000	50 to 10000	50 to 10000
Power output @ 8% THD into 4Ω (W/chan)	4	3.5	5
Wow and flutter (% rms)	0.44	0.40	0.30
Damping factor (@ 100 Hz)	1:1	10:1	10:1
Signal-to-noise ratio (dB)	40	42	45

Conclusion

The RCA car stereo tape player product line has succeeded in a very difficult and highly competetive market. This success is a direct result of product design requirements which recognized the natural limitations of the entire set of system parameters and allowed for changes in the engineering state-of-the-art and changing customer likes and dislikes. Significant Merchandising features to stimulate retail sales had to be included, while omitting unnecessary performance requirements to keep pricing competitive. The recognition by Engineering and Marketing of the potential of related accessories, and the rapid introduction of these items, has broadened the product line and increased total sales considerably. Product development is a continuing process; four new car stereo products are scheduled for introduction by June 1975.

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A practical, low-cost home/school microcomputer system

J. Weisbecker

The mention of low-cost computers usually evokes one of two images. Some see a super calculator while others picture a large-data-base processor. However, a more modest machine has been developed that could sell for under $500 in the relatively near future. Prototypes of this low-cost, mass-market, free-standing computer system based on the RCA COSMAC microprocessor architecture have been constructed, programmed, and operated in a home environment over the past several years.

WHILE stored-program computers have been one of man's greatest achievements, the majority of people are denied direct contact with these fascinating machines. Why can't thousands enjoy computers as a rewarding new hobby? Why aren't children who may be tomorrow's social problems having their minds turned on constructively by playing with computers? Why aren't computers used more widely in the area of correcting learning disabilities? Why can't the unique recreational and educational aspects of computers be made available to everyone? Cost is the single answer to these questions. There is no shortage of ideas for using computers, but there are no computers with a mass-market price tag.

For widespread home and school use, the price of a free-standing, self-contained computer system should be well under $500. This is the price level for color tv's, quality audio systems, home-study courses, air hockey games, pool tables, one-week vacations, cheap electronic organs, and encyclopedias.

Does the advent of LSI microprocessor and memory chips signal the availability of low-cost home/school computers in the near future? If we need conventional input, output, and bulk storage devices, the answer is *no*. If our applications are playing chess, printing pages of data, or accessing large on-line digital/video data bases, the answer is also *no*. If we take a more modest applications approach and place reasonable limitations on hardware capability, the answer becomes a resounding *yes*. In fact, prototypes of one such system have been constructed and in use for several years.

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This system is called FRED (flexible recreational and educational device) and is based on the RCA COSMAC microprocessor. The COSMAC architecture is ideally suited to this application and COS/MOS circuitry minimizes power-supply cost. Assuming the availability of 4 x 1024-bit random access memory (RAM) chips and a single-chip microprocessor, a complete system could be built using as few as ten chips. In large-volume production, a selling price under $500 would be achieved easily. The success of products such as calculators, Odyssey, and coin-operated games indicates that the type of home/school computer described herein could achieve wide market acceptance.

Along with a description of the computer and uses of the prototype system, system philosophy is covered in detail since it is a prime factor in achieving low cost.

Application and system overview

In schools, FRED provides a powerful educational tool. It can be used to drill and test students from first grade up. It can be used in educational games, simulation exercises, and reading readiness. It can also be used to teach programming or as an adjunct to math courses, and as an accessible student tool in almost any subject. It lends itself to demonstrations and experiments in a wide variety of areas, such as the area of learning disabilities or for stimulating the development of creative abilities. Cost per student hour is measured in pennies.

In the home, FRED offers an extension of the school uses. It also functions as a sophisticated entertainment center for the whole family.

The low cost of the system is achieved via a combination of techniques. The use of the RCA COSMAC microprocessor is fundamental to minimizing total system cost. A basic memory of only 1,024 bytes keeps RAM cost low.

Since FRED is a stored-program computer, it requires a program to be loaded into memory before use. Program loading is performed with an inexpensive audio cassette player which also gives the computer voice, music, and sound-effect capability.

After being loaded with a program cassette, FRED is operated with a small 16-position keyboard. For a game, the player would press appropriate keys to

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indicate the moves. Overlay cards are provided so that keyboard labeling can be changed for different programs.

FRED is attached to the antenna terminals of any tv set. This provides an inexpensive, flexible, dynamic output display which is ideally suited to home/school use. Numbers, words, or simple pictures can be displayed on the tv screen in the form of dot patterns.

Adding a $25 punched-card reader and $10 manual punch to the basic system enhances its usefulness and provides more sophisticated users with the ability to prepare and save short parameter lists or programs. Adding a module for recording the contents of memory on cassettes converts the basic FRED system into a user-programmable computer for serious hobbyists. Other possible attachments include light guns, extra memory (RAM), pre-stored programs or tables (ROM), and output relays for control uses.

Design considerations

Two different approaches can be taken toward developing an under $500 home/school computer. One approach involves specifying a desired set of system characteristics and then attempting to achieve cost objectives. The danger in this approach is the tendency to overspecify the hardware so that price targets cannot be met. The approach described here involved defining a minimum-cost, non-trivial hardware system that could easily meet a low-price goal, and then testing its usefulness. This approach ensures that applications development effort will not be wasted.

Any free-standing computer must include the following:

1) Central processing unit (CPU)

2) Main memory (RAM)

3) Input device(s)

4) Output device(s)

5) Bulk storage device(s)

The FRED system required the development of a philosophy that was consistent with utilizing minimum cost hardware. This philosophy included asking what we could do with inexpensive devices instead of asking what types of devices we might ideally want. Because of our low-price goal, the system implications of each device choice were magnified in importance.

The area of use is also a consideration involved in developing a minimum-cost system. For mass-market recreation/education use, competitive cost-performance ratios can be largely ignored. Reliability can also be sacrificed to some extent to achieve low cost. This does not mean that permanent system failures can be tolerated but that occasional transient errors during program loading will not be catastrophic. The need for memory and processor parity checking was also felt to be an unaffordable luxury.

Ease of use is a primary requirement. Initital users will be completely naive and frightened off by any apparent complexity. Thus, it was decided that a turn-key system philosophy would be adopted. The user merely loads a program from a library to obtain a desired game or function. He is not expected to program the machine. This approach eliminates the need for program dump/save capability and maximizes ease of use. Also, the need for an expensive control and diagnostic panel is eliminated. In fact, only two switches are required for basic use — LOAD and RUN.

A block diagram of the basic system is shown in Fig. 1. System considerations will be included in the discussion of individual elements.

Central processing unit and memory

The advent of single-chip LSI microprocessors makes the consideration of under $500 systems possible. Suitable microprocessor chips should be available at less than $25 within the next several years. The choice of a microprocessor has a large influence on total system chip count and cost. This influence is an important consideration since the microprocessor itself is only a small part of a total system cost. For this reason the home/school computer described here was based on the RCA COSMAC microprocessor architecture.

This architecture immediately eliminates the need for a read-only memory (ROM) in the minimum system. Only one supply voltage is required, and COS/MOS circuits further reduce system power-supply costs. A self-contained direct-memory access (DMA) channel facilitates initial program loading and display refresh. A single-phase clock is consistent with minimum cost. High output drive capability eliminates external buffer circuits.

The 8-bit COSMAC architecture is compatible with the intended uses of the system. The short, single-byte instruction format permits compact programs leading to minimum memory requirements. Since the average user will never see the processor micro-instruction set, ease of programming is secondary to efficient memory utilization.

For the hobbyist, COSMAC provides a simple, easy-to-understand set of micro-instructions. This means that he will not be confused by the subtleties of a complex order code. He can, instead, concentrate on his applications.

A complete description of the COSMAC microprocessor has appeared previously[1,2] and will not be repeated here. This architecture has demonstrated its advantages in prototypes of the low-cost home/school system.

Because of the nature of our application, RAM is required for both program and data storage. It is well known that programs tend to expand to fill available memory space. Providing a 4096-byte

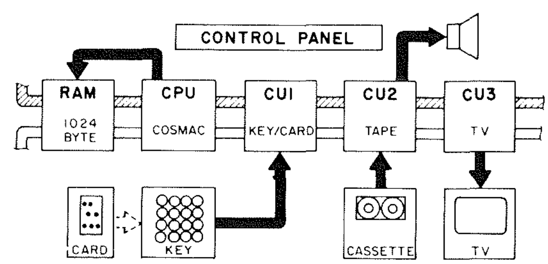

Fig. 1 — Basic system.

memory only ensures that no program will be written requiring a smaller memory. Even projecting a cost of $0.02/byte would yield a cost of $82 for a 4096-byte memory. This size memory would add $200 or more to the selling price of the system. Instead of asking how much RAM we could use, we provide 1024 bytes in the minimum system. This is consistent with keeping memory cost equal to projected microprocessor chip cost. Should LSI memory costs drop below $0.02/byte we can increase minimum system capacity to 2048 bytes or lower the price of the 1024-byte system. Based on current trends, we can safely predict one-microsecond LSI RAM costs of $0.02-$0.03/byte. Dynamic RAM chips are at this cost level now, while static, single-voltage RAM chips are currently available at $0.07 to $0.08/byte.

The challenge of a 1,024-byte memory seems to stimulate cleverness in programming and makes a future 2,048-byte memory seem large by comparison. If we had initially provided a 4,096-byte memory, subsequent size reduction to meet cost targets would have been extremely difficult. The probable availability of 4 x 1024-bit RAM chips within the next several years should result in a minimum system requiring only two chips for memory.

Limiting the minimum system memory to 1024 bytes also provides several system cost advantages. Power-supply cost is reduced, memory-address drivers are eliminated, and printed-circuit board space is saved. A less obvious system implication is the effect of memory size on program loading costs.

In general, the user should be able to load a program in half a minute or so. This coincides with observed user patience factors. An occasional error requiring reload can also be tolerated for short load times. This permits lower reliability loading devices to be used. To load a 1024-byte memory in 30 seconds requires a serial transfer rate of only 300 bits/s. This assumes a parity bit for each byte. For a 4096-byte memory, the required rate jumps to 1200 bits/s. The required transfer rate influences the choice of a program loading technique. Lower rates can generally be translated into lower costs and better reliability.

It is in the area of input, output, and bulk storage that we encounter the major cost problems. The choice of I/O and bulk-storage techniques also has a major effect on the range of possible system applications.

Output display

Fortunately, an ideal, low-cost output device for home/school applications already exists. A standard tv set provides a flexible, dynamic output display device that most users already own. Even if a tv set must be purchased for $50 to $100, this cost can be charged largely to normal viewing use.

The choice of a tv display format involves a number of system considerations. These include types of applications, display-refresh memory requirements, and complexity of control circuits. A low-resolution, black-and-white dot matrix was chosen for maximum flexibility at minimum cost. In this system, an array of white dots is displayed on a black background. The black background avoids potential picture noise problems. Arrays of 32 x 32, 16 x 64, and 32 x 64 dots are provided. Fig. 2 illustrates the flexibility of this format for displaying small game boards, simple pictures, words, numbers, or symbols. Each dot represents the state of a main memory bit. If the bit is "1" the dot is on, if the bit is "0" the dot is off.

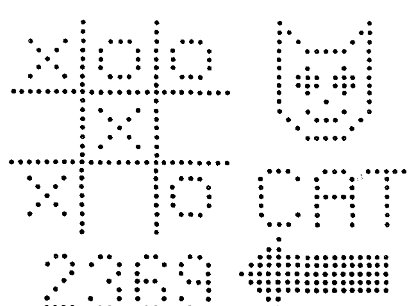

Fig. 2 — Display flexibility.

Simple animation can be achieved by modifying memory bit patterns at appropriate time intervals. Any contiguous 128/256-byte section of memory can be selected for display by setting a microprocessor address pointer. This display pointer can be modified at any point in a program providing the ability to step through various memory display areas at any desired rate. It is easy to flash selected portions of a picture by alternating between two display areas in memory.

For 32 x 32 and 16 x 64 displays only 1024 bits (128 bytes) of memory are required for display refresh. This is only 12.5% of the minimum system memory but provides a larger-area picture when required. It is also useful in expanded memory systems. It should be emphasized that no ROM is required for tv display in the minimum system and that frame refresh storage is provided via main memory.

The tv control unit (CU3 in Fig. 1) contains the circuits for generating tv sync signals and for requesting memory bytes via the COSMAC DMA channel as required for display refresh. The individual bits of each byte are used to generate a video signal. The composite sync and video signal modulates the output of a simple rf oscillator. This modulated rf signal can be applied to the antenna terminals of any standard tv set.

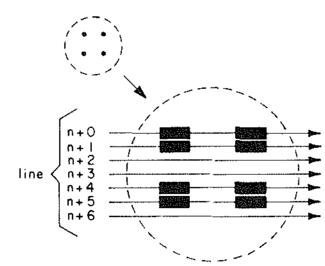

Fig. 3 — TV dot detail.

Fig. 3 illustrates the detailed timing for displaying dots on the tv screen. A magnified view of four dots is shown. Each dot is two horizontal tv lines high with a two-line space between dots. An 8-byte row buffer is provided in the tv control unit. Each tv line time is 65 ns. During the two blank line times, between rows of dots, up to 8 bytes (64 bits) are retrieved from main memory and stored in the row buffer. During the next two tv line times, the bits in the row buffer modulate the tv beam to display the proper dot row pattern. By spreading the dots as shown, the low-resolution display fills up the tv screen, and memory to tv refresh transfer rate is lowered.

The tv control unit also generates a program interrupt signal at the beginning of each tv frame. This interrupt permits the program to initialize the microprocessor display address pointer at the appropriate time. Since tv program interrupt occurs 60 times/s, a free real-time clock exists when needed. This clock capability is useful for timing purposes in a number of applications.

Bulk storage

Program library storage and loading present another major problem area in a low-cost system. The high cost of existing computer devices such as floppy discs and digital tape units immediately rules out their use. Paper tape is awkward and still fairly expensive. Conventional punched-card readers are expensive and inconvenient.

This problem was solved by using another existing, inexpensive consumer device — the audio cassette recorder. Suitable portable units sell for under forty dollars. A built-in unit could be provided for less than $20. Since normal use is not impaired, the cassette recorder cost is spread over normal and computer uses. Several methods for storing bit serial digital data on audio cassettes have been described,[3,4] and others are possible. We developed a proprietary, pulse-counting technique that yields a 50-byte-per-second transfer rate, tolerates missing or extra pulses, and permits tape-speed variations of 30%. This system works well even for cheap portable audio units. To minimize costs, only single-track capability is required in the system.

Since errors can be expected every so often, a parity bit is added to each byte on tape. The cassette control unit checks the parity of input data read from tape and turns on an error light for incorrect parity. Reloading a program when an error occurs is a simple, quick procedure.

Fig. 4 shows the single-track, cassette tape format used. Digital or audio blocks are always framed by 4-Hz stop tones (*T*). The stop-tone detection circuit is designed to respond only to long (0.5 s) continuous tones so that voice or music frames will not falsely trigger it.

Fig. 5 shows how a standard cassette player is used in the system. Most cassette

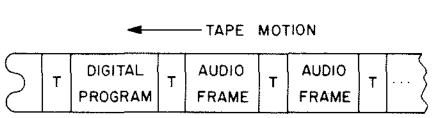

Fig. 4 — Cassette tape format.

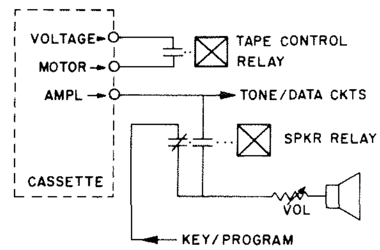

Fig. 5 — Cassette attachment.

recorders provide an external speaker or earphone output jack. This output is connected to the control unit as shown. Stop tones and digital data are detected via this cassette output line. A relay is also provided that permits the cassette output to be connected to a speaker under program control. This allows selected tape frames to be passed inaudibly.

The majority of inexpensive cassette recorders have a remote start-stop control jack. This is designed for use with a microphone or foot switch. For use in our system the cassette remote jack is connected to a program-controlled relay. This gives the computer the ability to start and stop tape, providing the user has previously placed the cassette recorder in its PLAY mode.

The primary-system operating controls comprise two toggle switches ... LOAD and RUN. The LOAD switch activates the cassette control unit (CU2 in Fig. 1). The desired program cassette is selected by the user, rewound, and the recorder set to PLAY. When the first stop tone is encountered the data-reading circuits are automatically turned on. Waiting for this stop tone eliminates possible noise problems at the beginning of the tape. The digital data representing the program is loaded sequentially into memory at 50 bytes/s. The second stop tone automatically stops the tape via the tape-control relay. Turning off the LOAD switch resets the computer. The RUN switch initiates execution of the program just loaded.

During program execution the tape can be automatically restarted so that the user will hear audio frame No. 1 at a desired time. The stop tone following audio frame No. 1 will automatically stop the tape. The program can monitor the state of the control relay to determine when the end of data/audio frames occur. This permits synchronizing audio material on cassettes with a program.

The provision for program-controlled audio segments has an important sytem implication. The ability to provide instructions, questions, or other data in the form of voice frames on tape minimizes the need for a high-resolution, alphanumeric tv display with its attendant requirement for large refresh and backup digital storage capacity.

The speaker provided for use with the cassette recorder provides a useful output device by itself. A flip-flop that can be set and reset by program drives the speaker when it is disconnected from the cassette output. Programs can, therefore, create any audible sequence of tones desired.

Input devices

The primary input device for our system is a 16-position keyboard. A number of $5 to $10 keyboards of this type have been developed for use in pocket calculators. A flat, printed-circuit type was chosen to facilitate an overlay feature. A slight modification of the keyboard permits insertion of a printed card above the switch array. Various cards are provided to relabel the switch array for different programs. Some programs require symbol keys, others letters or numbers. For educational programs, keys can be labeled with colors, pictures, words, or possible answers to questions. For other programs keys might be labeled with colors, pictures, words, or possible answers to questions. For other programs keys might be labeled with direction arrows for manipulation of the tv display. The variable-label keyboard is fundamental to meeting the ease-of-use criterion for this type of system.

Unfortunately, the flat keyboard, which is ideal for variable labeling, has no tactile feel. This objection was overcome by taking a systems approach. Since a speaker already exists, switch depressions need only be coupled into this speaker to provide an audible "click". This has proven to be an adequate substitute for tactile feel. The scanning approach used to decode the switch panel minimizes the cost of this approach. Specific programs can also generate various tones for switch depressions, which again substitute for tactile feel.

The 16-position keyboard normally causes an 8-bit byte to be stored in memory for each key depression. The most significant four bits (digit) are normally 0000. A shift switch pressed in conjunction with a hex key causes the most significant four bits to be 0001. The least significant four bits of a stored byte represents the code for one of the 16 possible hex digits shown in Fig. 6. The hex keyboard in conjunction with a shift switch permits entry of 32 different byte codes.

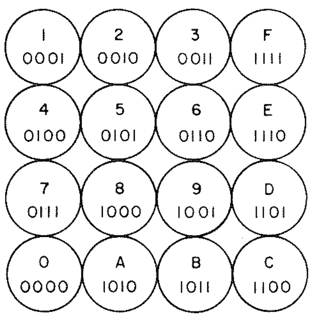

Fig. 6 — Keyboard code.

An alternate mode of keyboard entry is also provided. In this mode two key depressions per byte are required. The first key specifies the most significant hex digit of the byte to be entered. The second key provides the least significant hex digit of the byte. This mode provides the sophisticated user with a convenient way to manually load his own machine-language programs. It is also a useful mode for certain turnkey programs.

The hex keyboard control unit (CU1 in Fig. 10) also supports the addition of an inexpensive card reader to the minimum system. This unique device uses 3-x 5-in. punched cards. Data is punched in the form of rows of holes. Fig. 7 shows four such rows (A,B,C,D) punched on one side of a card (both sides can be punched). Each row represents the 4-bit code for one hex digit, plus a parity bit to make the 5-hole code odd. This means that at least one hole will be punched for each of the possible hex digit codes. Cards are read by dropping them into a 3-in. slot. They fall past a light source and six inexpensive photodiodes. One photodiode senses the

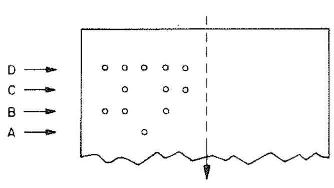

Fig. 7 — Punched card.

presence of the card and conditions the control-unit circuits accordingly. The other five photodiodes read the self-clocking hex digit codes into the system. Hex digits are paired to form bytes before storage in memory.

By limiting the information content of a card to 16 hex digits per side, the mechanical tolerances of the reader are not critical. The reader has no moving parts and photodiodes can drive the COS/MOS control unit circuits directly, eliminating the need for amplifiers. These factors combine to provide a very low-cost input device ($25 or less).

The low-cost card reader can be used to enter short lists of parameters or short user-prepared programs. In a classroom the teacher might use parameter cards to set up the difficulty of test/drill programs. Picture cards used by the student could contain the spelling of the word pictured for checking by the computer. The cards also facilitate certain simulation languages and permit users to save simulation language programs that they develop themselves.

Another low-cost, optional input device is a simple light gun. This device contains a lens system and a photodiode. The computer detects when the gun is pointed at any lighted area of the tv screen. The light gun facilitates various computerized target-shooting games. By alternately flashing portions of the tv display a program can determine the area at which the light gun is pointed. This permits the user to indicate various types of choices by pointing the gun at appropriate portions of the display.

Applications philosophy

The open-ended aspect of a stored-program computer differentiates it from other types of recreational and educational devices. Any number of special-purpose devices such as tv games, shuffleboard tables, electric football games, and educational toys are ideally suited to their intended function. None of these, however, will change their characteristics as user moods or interests change. Many of these special-purpose devices are seldom used after their initial novelty wears off. The stored-program computer is a dynamic general-purpose device. New programs constantly adapt it to changing moods and interests without the expense of new hardware.

The real value of the home/school system described here lies in its ability to stimulate and develop human capabilities that are often ignored or discouraged by conventional recreational and educational device approaches. The computer system provides an environment that stimulates experimentation, analysis, and creativity. Contemporary tv encourages passive viewing. With a computer attached to his tv set the user is encouraged to interact with the tv picture to play games.

For a child, the computer may initially provide arithmetic or spelling drills. Even his memory development can be made more interesting via interaction with the computer. However, the child will eventually begin to wonder about the computer. Programs made available stimulate his curiosity and let him experiment with changing game rules. He can even begin to formulate and develop his own simple programs in a variety of simulation languages. While the initial use of the computer involves memory skills, it eventually encourages experimentation and the development of analysis and synthesis capabilities.

The creation of programs that stimulate the user to develop mentally is a challenging task with a high payoff in terms of satisfaction. We have only begun to explore this area of use for very small, inexpensive, practical computers of the type described here. Even so, the number and richness of uses for this type of system are surprising. After experience with 64,000-byte main memories and large disc files, we are apt to dismiss a 1024-byte memory system as unusable. To dispel this notion, over 80 specific applications of the inexpensive home/school system are listed in Table I. Many of these represent whole classes of programs that could be developed. Types of programs already written are marked with an asterisk.

Four general areas of use are identified in Fig. 8. These areas are discussed individually although there is a high degree of overlap between them. Most of the listed uses require only the basic system. Ref. 18 also describes a number of uses (mostly games) that have been programmed on larger computers with hard-copy output. Many of these are readily adapted to the low-cost computer described here.

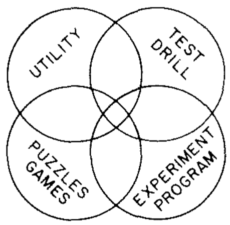

Fig. 8 — Areas of use.

Table I — Typical applications for home/school microprocessor.

Utility

- Four-function decimal calculator*
- Hex/binary calculator
- Game score keeper
- Number base converter*
- Weight/measure converter (metric)
- Secret code computer
- Logic machine (see Ref. 5)
- Classification computer
- Gambling strategy computer
- Other specialized calculations (temp. conversion, interest, etc.)
- Electronic dice
- Random-number generator
- Simulation game computer
- Bar graph
- Interactive audio-visual toy
- TV greeting card*
- Electronic "etch a sketch"*
- TV puppet
- Audio-visual demonstrator*
- Mind-reading computer
- Party compatability computer
- Programmed timer/controller
- Stop watch/game timer
- Simple electronic organ
- Metronome
- Advertising display

Text & drill

- TV arithmetic drill*
- Word spelling drill*
- Word recognition test*
- Pattern recognition (superimposed, complex)*
- Electronic flash cards
- Classroom group games
- Preschool shape/color recognition
- Up-down, left-right discrimination
- Sound-picture matching
- Reading readiness skill drills
- Logical aptitude test (see Ref. 6)
- Number base conversion drill*
- Flap board simulator (see Ref. 7)
- Morse code drill
- Reflex testing
- Logical deduction test (21 questions)*
- Logidex (see Ref. 8)
- Memory training (sobriety test)
- Individual testing & scoring aid
- Change making drill
- X-Y curve plotting drill
- Time sense development

Games & puzzles

- TIC TAC TOE*
- Hexapawn (see Ref. 9)*
- Sliding block puzzles*
- State change games/puzzles (see Ref. 10)*
- Bowling*
- Football (see Ref. 11)
- Minikrieg*
- Target shoot (optional gun)*
- One-armed bandit*
- Network games*
- Twenty-one*
- Cell matching games*
- Maze tracing (invisible, changing)*
- Race games (against time)*
- Space war*
- Bombs away
- Combinational/sequential puzzles (see Ref. 12)
- Dodge games (space ship & asteroids)
- Fish card game
- Moon landing
- NIM games (static/dynamic)*
- Invisible counter board games
- Simulation games (see Ref. 13)
- Game, forms of utility/test/drill programs

Experimentation and Programming

- LIFE (see Ref. 14)*
- Penny Matching computer (see Ref. 15)
- Turing machine (see Ref. 16)
- Tutorial computer*
- Picture computer
- Sound computer
- Machine code programming
- Simulations
- Variable rule games
- Logic simulator
- Learning machines
- Probability & Monte Carlo experiments
- Heuristic program design

Utility applications

This area involves using the computer to achieve some specialized function. These functions might include those listed under "utility applications" in Table I.

A simulated four-function decimal calculator has been implemented on the basic 1024-byte memory system. This capability includes display refresh, digit pattern tables, decimal arithmetic algorithms and 20 digit operand/result capability. A 2048-byte memory would permit a programmable calculator with multi-line display. Optional ROM chips could provide a permanently resident calculator capability if desired.

A variety of specialized calculators can be implemented on the basic system. Programs to provide scorekeeping for card, war, or other commercial games could be provided. Children could have their own secret-code computer. For several years a plastic toy rock-identification computer has been on the market. With this equipment, certain tests are performed (color, hardness, etc.) on a mineral sample. The plastic computer and a set of cards is then used to identify the sample. The basic home/school system could readily be programmed as a classification computer of this type.

Logic machines have held a certain fascination for years.[5] The computer readily simulates a variety of machines of this type. It can also be programmed to simulate gambling algorithms. A pair of dice is easily simulated for use in a number of games. Random-number generating machines find use in various school courses and experiments. Serious war-game fans can use computer-generated battle results and score-keeping to advantage. The leading magazine in the field, *Strategy & Tactics,* has over 20,000 subscribers, indicating a wide interest in this type of activity.

For very young children the computer simulates a variety of interactive, audio-visual toys that make sounds and change tv pictures in response to key depressions. Customized and animated TV greeting cards/decorations for birthdays, Christmas, or Halloween can be provided. Simple, key-operated tv puppets are possible. Also, the ability to step a spot around the screen permits drawing tv pictures.

The ability to synchronize audio-tape frames with programs permits programmed audio-visual tutorials for home and school or eye-catching advertising displays. The basic system realtime clock facilitates key-operated game-timer or stop-watch capability. The program-controlled speaker turns the computer into a simple electronic organ or metronome. TV display can be included with the sound generation.

The basic system can be used for any number of party games including couple compatibility testing. Adding inexpensive, output relays lets you program Christmas tree light sequencing or control other devices.

Test and drill applications

Drills mainly involve the development of memory or conditioned reflexes. Testing can involve a wider range of skills. The infinite patience of a computer makes it ideal for drills. Interactive capability adds interest and motivation. Some specific examples are shown in Table I.

Programs of this type are ideal for individual use to overcome specific weaknesses. The psychological benefit is that the computer does not seem to be making value judgments of a child during a drill as a child might fear a teacher or parent would. The drills can also be made to appear as games with the computer providing added motivation and self-adjusting challenge levels.

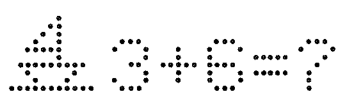

Fig. 9 — Add drill display.

A simple arithmetic drill might appear as shown in Fig. 9. First, addition problems are randomly generated on the tv screen. Next, the child must enter correct answers via the keyboard in time to prevent the boat from completely sinking. The rate at which the boat sinks can be preset by the teacher and changed from session to session to maintain challenge as the child's speed and accuracy improves. The computer displays the child's score when the teacher enters a special code (key/card).

Spelling drills can be implemented in several ways. A cassette voice could ask for the spelling of a word which the student then spells via the keyboard. The tv display and/or audio tone tells him if he is right. The computer again keeps score and times answers. A simple word-recognition drill involves displaying a word on the tv screen and asking for the corresponding picture via keyboard or card input. Patterns can be superimposed on the tv screen and the student asked to identify the components of the picture. Simple preschool shape, color, or sound-recognition programs are possible. Up-down, left-right concepts are readily presented via tape voice and animated tv displays.

The computer can be programmed to momentarily flash a picture, word, pattern or group of symbols on the tv screen to develop perception skills. Reflexes or time sense can be developed by requiring a specific keyboard response following programmed sounds or tv displays. Scoring adds a motivating game element to these types of drills. Morse code is taught by requiring the translation of tape voice passages into key depressions. The computer checks accuracy and gradually increases speed.

Reading-readiness skills include simple shape recognition, word configuration recognition, and maintaining fixation on a moving object. The latter could involve having a child press direction-changing keys to prevent a moving spot on the tv from hitting obstacles.

The computer can easily simulate logical aptitude testing devices[6], existing simple educational aids[7], or games.[8] The dot-array tv display format is ideal for *X-Y* plotting practice. The computer can be used for individual testing and scoring in any subject area and at any grade level. The test questions are provided in printed page or booklet form. The computer specifies which questions are to be answered via tape voice or TV display. Answers can be in the form of multiple choice, numbers, or words which the computer can check against a pre-stored table of correct answers.

The ability to skip audio frames on tape via the program-controlled speaker relay provides added flexibility for test and drill applications. Two sequential voice frames could be provided per question. One frame would "tell" him that his answer was wrong, and why. For each student response the computer "plays" the appropriate frame and inaudibly "skips" the other.

Games and puzzles

Games and puzzles are normally associated with recreation. We have already seen that a number of utility programs have recreational aspects. The educational as well as recreational aspects of games and puzzles are discussed here. Some of the possible uses of the computer in this area are listed in Table I.

One of the most obvious aspects of the list in Table I is that there has been no problem in motivating people to write game programs. TIC TAC TOE, Hexapawn, Twenty-one, and space war are played against the computer. Two-player versions are, of course, possible. Hexapawn[9] was implemented as a learning program. The computer learns to play perfectly only after a number of games have been played. This type of learning program provides the basis for experiments where the user plots games played versus games lost by the computer to establish empirical learning curves.

Bowling displays the pins on the tv screen. A ball spot randomly moves up and down at the opposite end of the alley. Pressing a key at the proper time rolls the ball. Sound effects, scorekeeping, and some random factors are incorporated in this two-player game. A variety of football games are possible. The simplest of these involves simulating commercial varieties of electrical football.[11] Minikrieg is a simplified war game. With the optional light gun a variety of computer-controlled target-shooting games can be devised.

Sliding block puzzles are easily simulated via the tv display. A move counter keeps the puzzle solver honest. Cell matching games involve momentarily flashing an array of cells on the tv screen at the beginning of the game. Each cell contains a symbol. Two players take turns trying to find cell pairs with matching symbols. The most matches wins the game. Network games involve completing a path from one point to another before your opponent. A number of published combinational/sequential puzzles can be easily simulated.[12]

Manipulating a moving spot through a racecourse or maze in the minimum time has proved to be a popular pastime. Spot acceleration and deceleration maximize the challenge. The computer also permits invisible and changing mazes to be easily implemented. NIM type games can have a dynamic aspect included by using the computer. Board games can incorporate invisible counters whose positions must be deduced. Moon landing involves selecting fuel-burning rates so as to avoid crashing. This type of game lends itself to experimentation, since it represents a simple simulation situation.

Experimentation and programming uses

This area might be thought of as primarily educational. There is, however, a recreational aspect as well. Developing programs for your own computer embodies both educational and recreational aspects. Some of the specific experimentation and programming possibilities are listed in Table 1.

A classic example of experimentation via computer is provided by Conway's game of LIFE described in Ref. 14. The hours of bootlegged computer time devoted to this program at computer centers all over the country are a testament to its recreational value. LIFE simulates a succession of generations for a colony of cells. Cell birth, survial, and death are controlled by algorithms in the program. Watching the patterns of cells change for each generation on the tv screen is addicting. The program is extremely rich in experimental possibilities. New starting patterns that yield interesting and sometimes surprising life histories are constantly being discovered.

Heuristic programs for simple games such as Hexapawn and Penny Matching[9, 15] let the user develop experimental learning curves. This approach has been used to add interest to grade-school math even without the availability of a computer.[17] Letting the user modify program behavior via keyboard parameters stimulates more creative and sophisticated experimentation; even TIC TAC TOE becomes a fascinating educational device when the user is allowed to modify the rules that the computer uses to play.

The computer can provide a variety of simple simulations that encourage experimentation. A simple moon-landing game or racecourse game with acceleration and deceleration controls are examples. A logic simulator would permit inexpensive experimention with arrays of logic elements especially, since commercial hardware logic trainers are quite expensive. A random-number generating program facilitates experimental development and understanding of probability curves. Game-theory experiments are a natural application. Yet, none of these uses requires programming ability on the part of the user.

However, the area of programming provides the richest and most valuable recreational and educational experiences. Programming capability can be provided at several levels. A simple set of simulated instructions to move a spot around the tv screen could be provided via card or key symbols. Programming this picture-drawing computer could be introduced as early as second or third grade. The ability to program sequences of audible tones (or music) via a simple simulation language is also easily provided.

At a slightly higher level of sophistication, various tutorial computers can be simulated. A simple fixed-word decimal computer was simulated on the basic 1024-byte system. This included ten instructions, 100 words of user memory, and a simulated control/debug panel. Teenagers were able to write and debug their own programs with as little as one hour of instruction.

Ref. 16 is of particular interest. In this article, the construction of a hardware Turing machine model for educational purposes is described. The authors list several disadvantages inherent in the alternative approach of computer simulation:

1) Computer time is too expensive.

2) Students have to learn how to operate the computer which has nothing to do with the simulation.

3) Graphic output display is expensive and printed output is slow and inconvenient.

The home/school system described here readily overcomes all three objections.

For the sophisticated hobbyist the area of machine-code programming will be of major interest. All that is required is the addition of circuits that permit "writing" on cassette tapes. This is an inexpensive option. The use of a small set of programming conventions together with specialized subroutines permits the sophisticated user to develop, debug, and save his own machine-code programs.

Conclusions

A practical, inexpensive, free-standing computer system based on the RCA COSMAC microprocessor would, for the first time, permit widespread access to computers. Much of the public awe and confusion relative to computers would be dispelled. The creation of a group of home computer hobbyists will stimulate invention and development of new computer devices and applications.

More importantly, educational benefits are unlimited. Computers are considered to be useful tools with which to achieve a specific end result such as processing a payroll or calculating a trajectory. This view of computers has often carried over into educational applications with the computer cast in the role of teacher/tutor. The low-cost home/school system described here is intended as a flexible plaything which encourages experimentation and stimulates a desire to learn. This approach may be more significant than the improvement of teaching methods for unmotivated students.

Acknowledgments

A. R. Marcantonio, C. T. Wu, and B. J. Call have made a number of contributions to the development of this low-cost computer system. A. D. Robbi and P. Russo have provided continuing moral support, ideas, and major assistance in developing and evaluating the system. R. O. Winder deserves most of the credit for making the development of the system possible.

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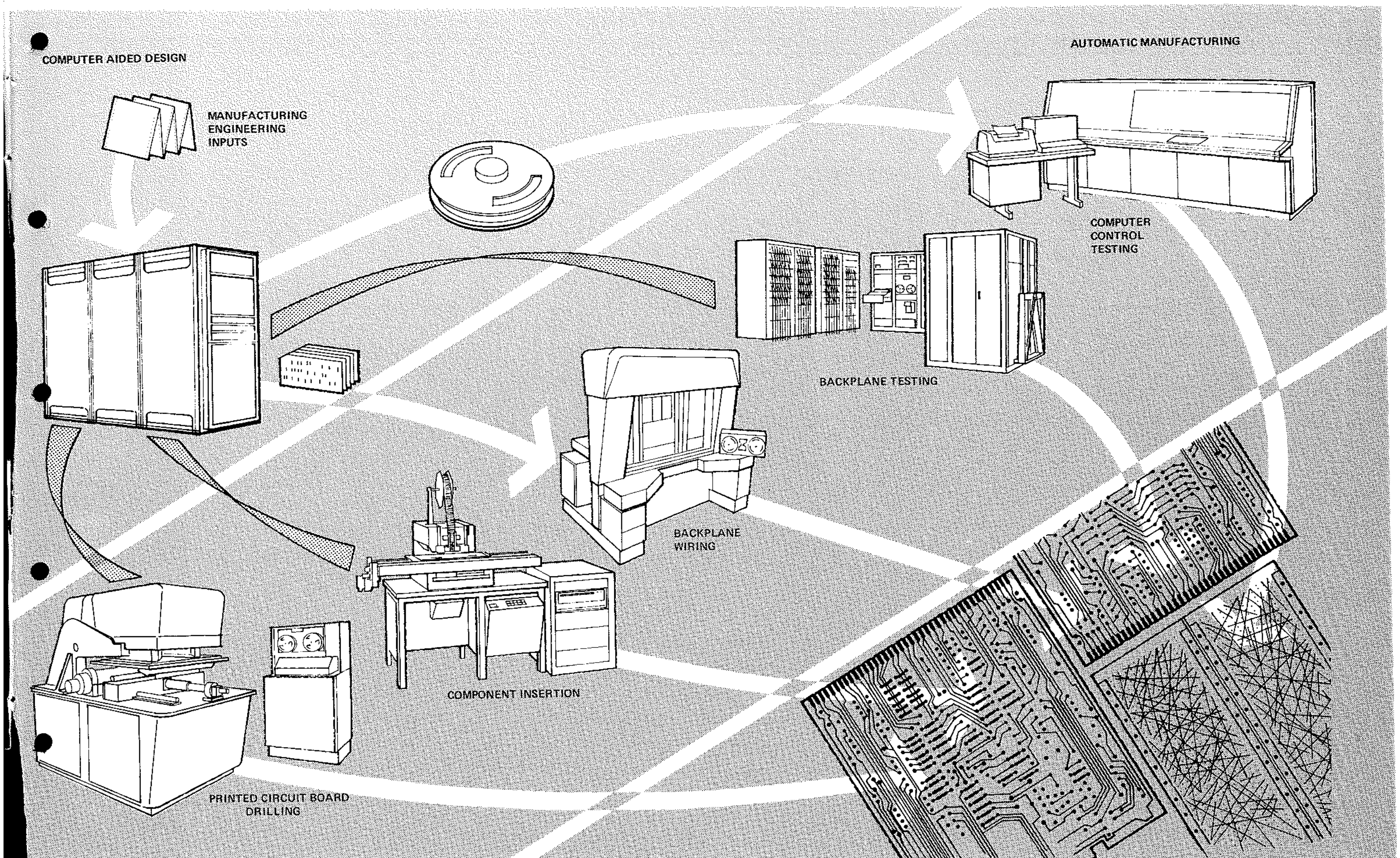

Fig. 1 — System overview showing how CAD aids manufacturing-engineering automated operations.

Interfacing CAD and automated manufacturing

D.H. Mercer

Dramatic forward steps have been made at RCA over the past ten years in automating manufacturing processes. Recently, the automation process has been further stimulated by the close interface between Manufacturing-Engineering and Computer Aided Design groups. Some of the automated manufacturing functions described in this paper are PC-board drilling, automatic component insertion through sequenced tape controlled equipments, automatic backplane wiring and testing (computer controlled). It is predicted that the future will see additional refinements and use of automated manufacturing processes in RCA and other industries.

DRAMATIC, though subtle, changes have occurred within Manufacturing during the past ten years. From PC board drilling to module testing, many of the manufacturing processes are now facilitated for computer control. This evolution generally followed the pattern that the equipment was first paper-tape numerically controlled; next, programmed by the manufacturing engineer; and, then later integrated into the computer aided design (CAD) system. The first generation NC equipment is now being replaced by computer controlled equipment.

From NC to computer control

Numerical control equipment usually employs hardware logic such as relays, with the program information contained in an 8-or 12-bit paper tape. Repetitive reading of the control information is comparitively slow; mechanical positioning functions, if required, are performed with stepping motors.

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Computer control by contrast uses much higher speed computer logic and provides greater flexibility for requirement changes. Mechanical positioning is also improved, frequently, closed loop servo systems employing digital linear (or shaft) encoders assure positioning accuracy. As a result, production rates have improved considerably. For example, in automatic component insertion, a typical rate has increased from 2,000/hour to 7,500/hour.

The move to computer control also permits an easier interface with modern CAD systems.

The change to computer control also complements the shift in our products to the use of integrated circuitry — and a phasing from the use of analog to digital for some circuit functions.

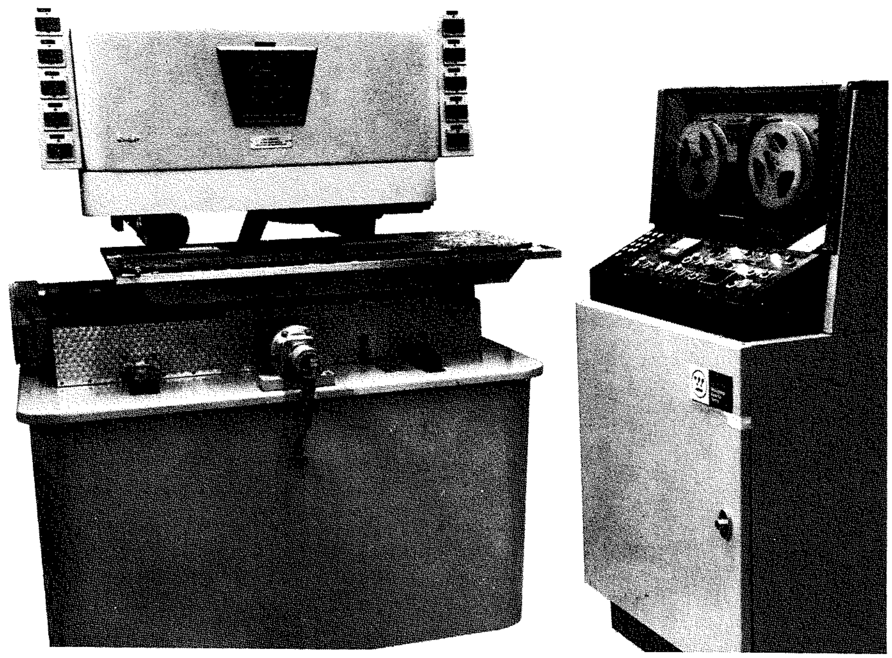

Fig. 2 — Printed-circuit board drilling equipment.

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Impact on the design-manufacturing interface

Such changes have, or will have a dramatic impact on the interface between design and manufacturing. Designing for automation, component selection, module technology, hybrid versus printed circuitry, etc. are now becoming joint decisions between product design engineers and production engineers.

Another change is in the distribution of manufacturing cost elements. The assembly and test labor percentage is decreasing while the amount of microelectronics, IC's, hybrids, transistors, and diodes is increasing. Many factors are at work to cause this shift; one major factor is the increasing use of automatic manufacturing equipment.

The outputs from computer-aided design systems fit well into the automated manufacturing operation. An overview of this relationship is depicted in Fig. 1.

Design engineers use CAD programs as an aid to their basic design work; however, with the addition of a few subroutines, manufacturing and test-control data can also be generated (except TESTGEN, a common program). These programs are small (some can be run on a minicomputer), but more importantly they are developed from a common-design data base, reducing translation and revision level errors. A different subroutine is required for each type of manufacturing equipment controlled and is of necessity in the form (paper tape, punched card, mag tape, etc.) required by the design of the equipment. Through these additional subroutines the effort required to produce the control information can be reduced by as much as three to one.

CAD outputs for manufacturing

The current outputs of CAD provide manufacturing with control information for six operations (Table I) to perform

Table I — Outputs of CAD to manufacturing.

CAD Output	*Manufacturing Function*
Drill tape	Controls PC-board drilling
Sequence tape	Controls placement sequence on insertion tape
Insertion tape	Controls automatic component insertion
Wire wrap deck	Controls automatic backplane wiring
DITMCO tape	Controls automatic circuit check for both bare boards & backplane wiring
Test-Gen tape	Controls logic testing of completed boards

five major manufacturing functions: PC-board drilling, automatic-component insertion, automatic backplane wiring and testing, and computer-controlled testing.

PC-board drilling

Component and hardware mounting holes are made in PC boards either by punching or drilling. Punching is the method most frequently used when specifications permit (board thickness is not too great and boards are simple double-sided copper) — and when the production volume permits. Most PC-boards of medium quantity, complex boards, or multilayer boards are drilled. Pantograph, NC or computer-controlled equipments (Fig. 2) are generally used. Drilling progressed from "eyeball" drilling in the center of copper patterns in the early 1950's through multiple-spindle template drilling in the mid 1950's, through NC drilling in the late 1950's, to modern-day computer-controlled drilling.

CAD tape inputs provide rectangular *X* and *Y* coordinates for each hole along with the drill size to be used; proper spindle or turret position is activated according to the type of equipment used. Manufacturing-Engineering initially provides the CAD activity with such machine information as the number and spacing of spindles and drill sizes for preparing the appropriate drill tapes.

For actual drilling operation, manufacturing adds specific machine "zero zero" information, reproduces a more durable tape, proves out the tape on an image board — and determines the number of boards to be stacked over locating pins. The drilling operation is then essentially ready to proceed.

Production rates vary considerably depending on the number of boards stacked, number of spindles, etc. The number of holes drilled ranges from 120/min. to 1,600/min., with a reasonable average being 480/min.

Automatic component insertion

Automatic component-insertion equipment has been in use for approximately 20 years. Such equipment has advanced from simple single-station units, through multiple-station in-line systems, to

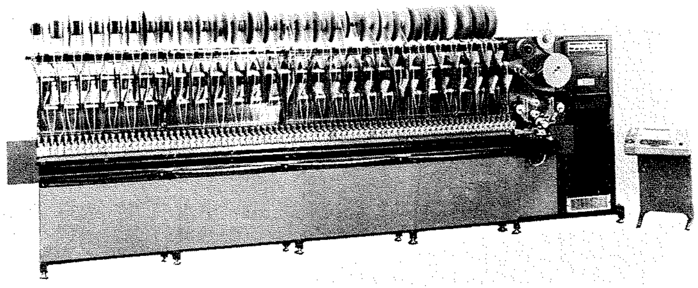


Fig. 3a — An expandable sequencer.

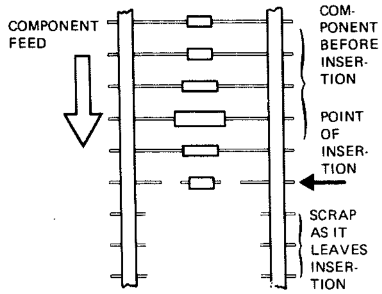


Fig. 3b — Sketch of components on sequenced tape.

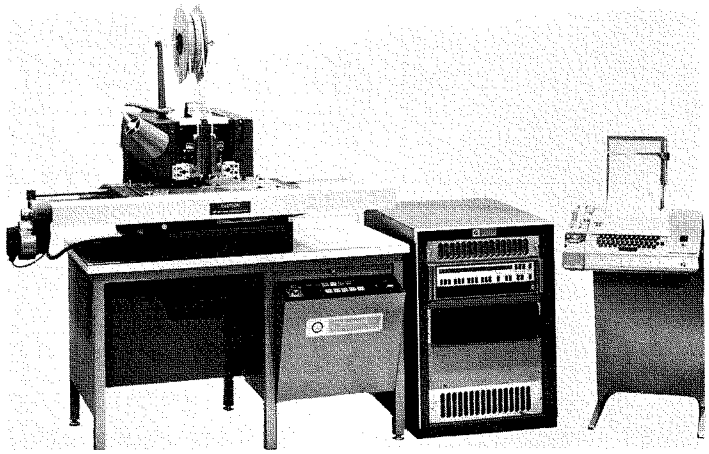


Fig. 3c — Variable center-distance insertion equipment system.

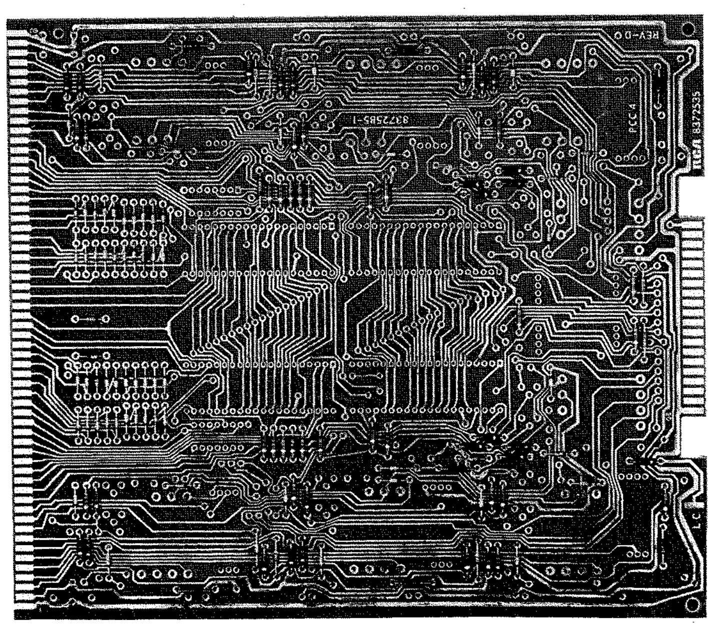


Fig. 3d — Product with components automatically inserted.

pantograph-controlled systems with X-Y tables, to NC machines, and now to high-speed computer-controlled machines inserting 5,000 to 8,000 components/h.

Components most often machine-inserted are axial-leaded resistors, capacitors, diodes and inductors. Dual in-line packages (DIP) that meet certain specifications may also be inserted on a different piece of equipment.

Creation of control tapes

CAD outputs can directly interface with these systems, providing control for sequencing and insertion. Before controlling tapes can be generated, however, it is necessary for manufacturing engineers to develop the insertion sequence and provide such information to systems programmers. This information is matched with the board-hole locations and the parts identifications to produce the sequence and insertion tapes.

The sequence (Fig. 3) most often used for automatic insertion of axial leaded components is as follows:

3a — Sequencer,
3b — Components on a sequenced tape,
3c — Insertion equipment, and
3d — Product with components automatically inserted.

Sequencing

Components received from the vendor on reels (one part number per reel) are sequenced by placing the parts reel on a varied number of axial devices, arranging them in order, and then retaping them on a *sequenced reel* for handling by the insertion machine. Most currently installed sequencers are paper-tape controlled, but the newest equipments (Fig. 3a) are computer controlled. In either case the outputs from the CAD package can control the equipment.

Insertion

Once the correct sequence of parts for a board has been taped (Fig. 3b) it can be loaded onto the insertion machine (Fig. 3c). Generally the boards are manually loaded and unloaded in a dual workplace setup while the other boards are having components inserted (Fig. 3d).

Low-volume users, (500,000 insertable components per year), may be able to justify a pantograph machine. As the volume of insertable components exceeds 5,000,000/yr., computer-controlled equipment and a high-speed sequencer should be considered. For DIP packages, both pantograph and computer-controlled machines are available with production rates of 2000/h and 4000/h, respectively.

Automatic backplane wiring and testing

Wiring

Automatic wire interconnecting of backplane panels became a reality approximately 15 years ago when a major computer manufacturer had the equipment developed. Originally programmed only from punched cards, interconnection equipment is now available with higher speed tapes, and card-reader inputs. Fig. 4 shows a new, high-speed equipment just purchased by RCA Corporation.

CAD programs such as RCA's AUTODRAFT/AEWRAP have been developed to provide the control cards or tapes. The interconnections are mostly provided by solderless wire wraps. The machine consists essentially of two heads and several dressing fingers that automatically remove the required length of wire from a master drum, cut and strip the ends, route from one designated terminal to another over a prescribed route (preferably straight or L shaped), and simultaneously wrap the wires around the terminals. The equipment is capable of applying three levels of interconnection with production rates from 300 to 1,000 wires/h, depending on equipment used and layout employed.

Twisted pairs

Twisted pairs of wires cannot be installed by the fully automatic equipment and, therefore, semi-automatic equipment is employed. Positioning of the head over the terminals to be wired and selection of the correct pre-twisted pair of wires is NC controlled.

Back-plane testing

In addition to providing wire wrap control data, the CAD program also provides connection and insulation test programs. Such programs are on punched tape and control a sequence of resistance comparison tests on passive wiring systems. Up to 50,000 test points can be checked at speeds of up to 1,000 tests/min., with insulation testing of up to 1,500 V dc. A

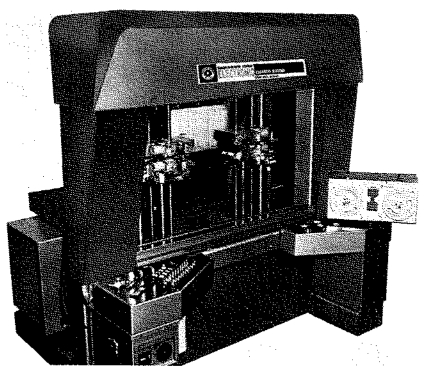


Fig. 4 — Backplane interconnection wiring equipment.

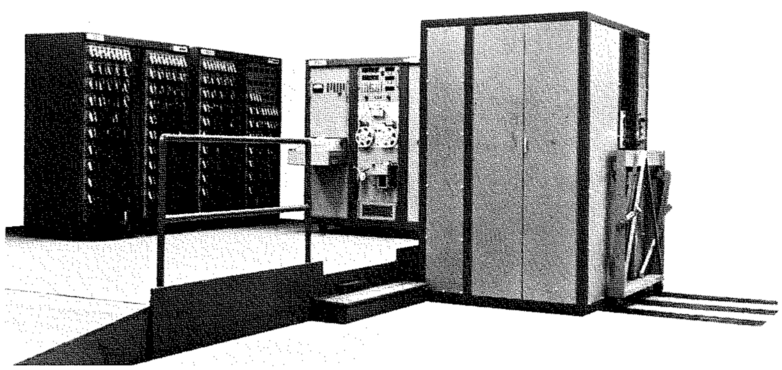


Fig. 5 — A complete testing setup for checking backplanes.

complete installation, including the interface fixture for large backplanes is shown in Fig. 5.

Computer controlled testing

Automatic testing developed during the last twenty years to the point today where most manufacturers of electronic equipment use some sort of automation for testing deliverable products. Starting in the early fifties with crude, mostly special-purpose testers, automatic testing has progressed to the multipurpose computer-controlled equipments currently available commercially. Control of automatic testing progressed from stepping switches, to paper tape, to minicomputers. The introduction of the low cost minicomputer in the mid-sixties coupled with the availability of programmable test instruments has spurred the development of universal software test languages and created a sizeable market for test automation.

Automatic test systems typically consist of stimulus equipment, measurement equipment, and switching. The computer controls the application of the proper stimulus to the unit under test, selects the proper measurement devices, and makes a series of go/no-go decisions as the test progresses. In some cases, the computer is also used for statistical analysis and process control. Fig. 6 shows a modern computer-controlled test system capable of testing digital and analog products.

Most automatic test systems available to the commercial market are used for testing components and digital circuits. These systems are usually dedicated to a minicomputer and perform functional (truth table) testing, or parametric (pulse characteristics) testing. These are multipurpose equipments in that they test types of products rather than a single product on a given project.

The efficiency of automatic testers has been further improved in the last several years with the introduction of computer aided design (CAD). Test sequences and diagnostics are now generated for digital circuits by an operator who is in an interactive mode with a central time-shared computer. One such system, called TESTGEN, invented by and presently used at RCA, produces required test and diagnostic patterns for both combinational and sequential logic. System outputs are in the form of paper tape and/or punched cards used to sequence the production test equipment.

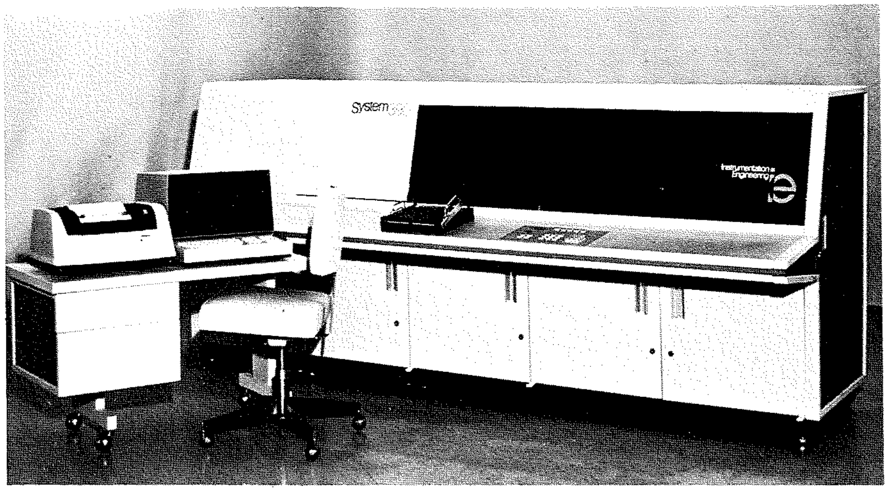


Fig. 6 — Computer-controlled testing setup.

Automatic test equipment now exists in most divisions of RCA and consists of a mixture of purchased equipments and in-house designs using the RCA-1600 computer as the control device. Several-hundred-thousand digital boards have been automatically tested in G&CS and several million digital integrated circuits have been tested in the Solid State Division.

Results in manufacturing

Increased use of automatic equipment and the interface with CAD has resulted in lower assembly and test costs for those products designed to use these techniques. Not all products use backplane assemblies, nor can all components be machine inserted. Most products, however, can be tested using computer-controlled testers, and dramatic testing-time reductions of 20-to-1 and 40-to1 have resulted. Reductions of 20% in assembly time are reasonable to expect from automatic insertion. This percentage is much higher with large quantities of DIP's or other insertable components, and it becomes lower or uneconomical when only a few components are insertable.

CAD manufacturing implementation in RCA

Not all activities have all of the described CAD manufacturing interfaces fully operational at this writing. All of the automatic manufacturing equipment discussed is in one or more plants. The component sequencing and insertion CAD programs remain to be completed.

Another type of important output from CAD not discussed in this article (because it does not interface with *automated* manufacturing), is the interactive CAD system using graphic terminals, now operational at MSRD and producing a significant amount of manufacturing documentation in the thick-film processing operation. This not only reduces somewhat the effort required of Manufacturing Engineering but also provides Manufacturing with information directly from the design data base.

Future direction

Completion of sequencing and insertion program development should be emphasized. Facilitation should be evaluated where programs do exist but are not being utilized for such reasons as lack of specific hardware items.

The future will see further refinements in test equipment and in methods of test generation. Since it is extremely difficult to generate test patterns for today's LSI's and PC boards, it is reasonable to assume that automatic test generation for tomorrow's LSI's and PC Boards will be even more demanding. More efficient test generation algorithms must be developed. Hardware will be improved in terms of clock speed of test patterns and diagnostic capability.

RCA system for compatible fm broadcasting of quadraphonic sound

J. J. Gibson | R. M. Christensen | A. L. R. Limberg

The system described in this paper has been proposed by RCA to the National Quadraphonic Radio Committee (NQRC), an industry committee sponsored by the Electronic Industries Association. During 1974, the RCA system and four competing systems were field tested by the NQRC over station KIOI in San Francisco. For these tests, a transmitter has been developed by Broadcast Systems in Camden and a receiver has been developed by Consumer Electronics in Indianapolis. This paper is restricted to basic systems considerations. The implementation of the systems, the results of field tests, subjective tests, analytical work, and studies will be published by the NQRC in a final report to be submitted to the Federal Communications Commission during 1975.

A BASEBAND SIGNAL for compatible fm broadcasting of four-channel sound is designed with particular concern to:

- The relative significance and importance of the audio signals for the reproduction of an acoustic picture around the horizon.
- Baseband signal contraints (compatibility, fidelity, and economy as well as availability and quality of baseband spectrum).

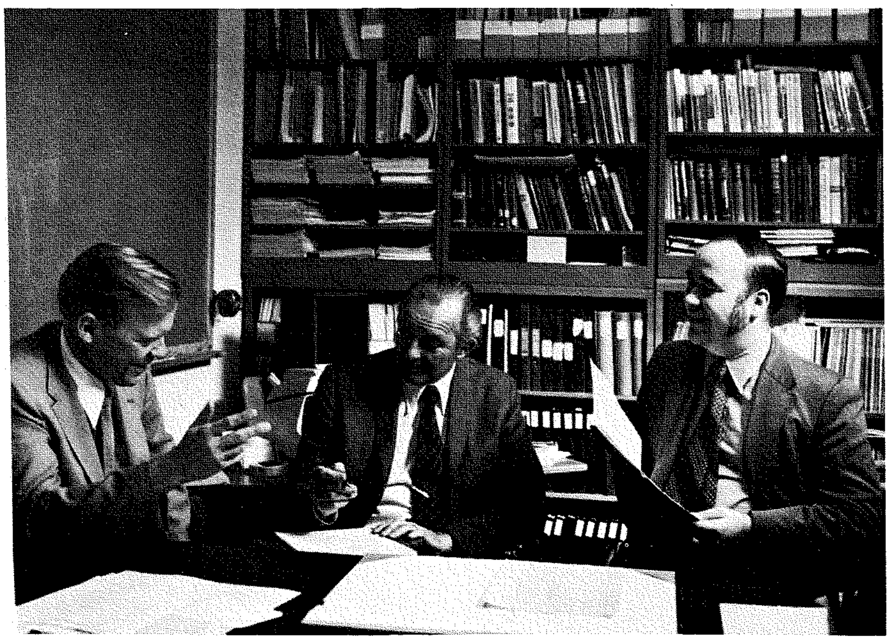
In assessing the significance of the audio signals, the viewpoint is taken that the purpose of the transmission system is to communicate an acoustic field. The field is defined by an acoustic picture which in turn is defined by a set of signals. Principles for deriving the signals from the field and for reproducing the field from the signals are formulated. The resolution of a reproduced picture is related to the selection and the number of signals conveyed by the system. In particular, it is shown that a minimum of three signals are required to reproduce an acoustic picture around the horizon with uniform response and uniform angular resolution (panoramic sound). One signal conveys the monophonic or "standing wave" information while the other two convey the basic directional information (Left-Right, Front-Back) for "traveling waves". More signals can contribute increased angular resolution.

Based on these considerations, the baseband signal is so designed that the three basic signals are conveyed by the three better quality channels which are available on the fm baseband compatibly with monophonic, two-channel stereo, and SCA services (Subsidiary Channel Authorization for commercial sources). A fourth channel may be optionally transmitted at the upper end of the baseband. This channel, which is more contaminated by noise, intermodulation, and adjacent channel interference than the other three, can also be optionally dropped at the receiver.

Signal environment on the fm baseband

The availability and quality of spectrum on the fm broadcast baseband are illustrated in Fig. 1. The sum of all signals on the baseband must not deviate the main carrier by more than 75 kHz (100% modulation) to conform to present FCC rules. Other constraints are imposed by the FCC rules for out-of-band radiation. It shall be assumed that these rules will be retained for compatibility with present station allocations and receivers. A further constraint on channel capacity lies in the fact that in fm transmission the intensity of noise, intermodulation, and co-channel interference increases at least

Authors (left to right) Christensen, Gibson, and Limberg.



J. James Gibson's biography appears with his other paper in this issue.

Roy M. Christensen, Patent Operations, David Sarnoff Research Center, Princeton, N. J. received the BSEE from City College of New York in 1953. From 1953 to 1958 he was a member of the RCA Industry Service Laboratory in New York working on color tv receiver designs. In 1958 he transferred to RCA Laboratories continuing his work in color tv receivers and display systems. Mr. Christensen has also worked on digital data communications systems. His interest in audio reproduction is a corollary to his long term interest in home instrument designs.

Allen L. R. Limberg, Patent Operations, David Sarnoff Research Center, Princeton, N.J., received the BEE from Union College in 1958; the MSEE from the University of Pennsylvania in 1966; and the Juris Doctor degree from Seton Hall School of Law in 1973. He presently is employed in Patent Operations of the RCA Corporation, and is an Attorney-at-Law in the State of New Jersey. He joined RCA Corporation in 1958, pursuing research and development in the radio and television fields until 1969 and has designed stereo multiplex generators and multiplex decoders for FM radio receivers. Mr. Limberg has had fifteen patents issued to him.

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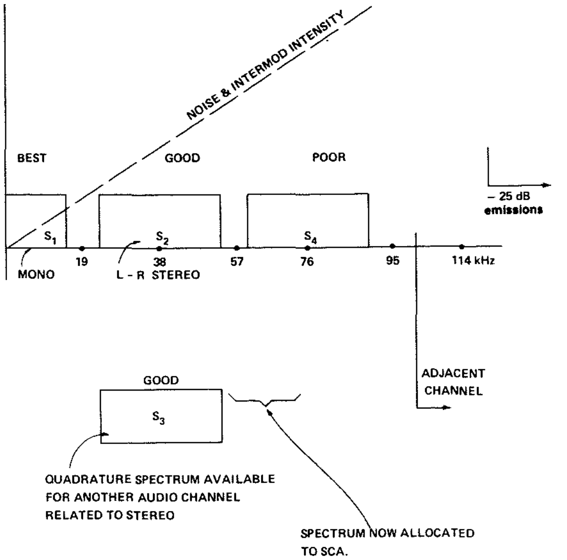


Fig. 1 — Availability and quality of spectrum on the fm broadcast baseband.

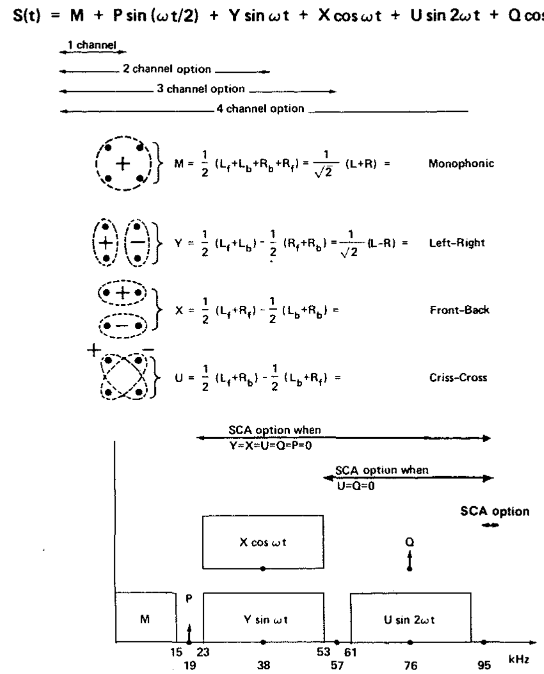


Fig. 2 — Proposed baseband signal for compatible fm transmission of four-channel sound.

linearly with the baseband frequency. Still another constraint is required compatibility with present allocations of fm-baseband spectrum. The 15-kHz bandwidth monophonic signal S_1 is allocated to the high quality main channel, while the 15-kHz bandwidth left-minus-right stereo difference signal S_2 modulates a 38-kHz subcarrier double-sideband-a.m. suppressed carrier. A pilot tone at 19-kHz required for synchronous detection modulates the main carrier 8 to 10%.

Within the above constraints it is clear that one more channel, the quadrature channel on the 38-kHz subcarrier, is presently available to carry another 15-kHz bandwidth audio signal S_3. Because of unavoidable crosstalk in existing receivers between S_2 and S_3, S_3 must be an audio signal with a program material related to S_2. Virtually all stereophonic receivers in the field utilize synchronous detection methods to recover S_2 information. In these receivers, S_3 will not cause any quadrature distortion in the S_2 signal. The S_3 signal can be received with a conventional two-channel receiver provided with an additional synchronous detector.

A fourth channel carrying an audio signal S_4 (and even a fifth channel carrying a signal S_5) can be placed in the portion of the baseband above 53 kHz. This is clearly an inferior part of the spectrum due to contamination by noise and intermodulation. Transmission of a fourth channel precludes the simultaneous transmission of SCA channels which presently are allocated to the band from 53 to 75 kHz. The reception of a signal S_4 with acceptable linear and non-linear distortion requires a receiver with better front-end characteristics than present two-channel receivers. A comparatively strong signal at the upper end of the baseband also increases noise and intermodulation in the lower channels. This may be particularly the case in existing receivers which are not designed to handle a strong signal at the upper end of the baseband. The problems of compatibility, fidelity, and economy presented by the accommodation of a fourth channel on the fm baseband suggest that the signal S_4 convey the least significant information for the reproduction of four channel sound at the receiver. With such a choice, the signal S_4 may be optionally transmitted or received.

Proposed baseband signal

The proposed baseband signal with one-, two-, three-, and four-channel options is shown in Fig. 2. The monophonic $[M = \frac{1}{2}(L_f + L_b + R_b + R_f)]$ signal is carried on the main channel. The 38-kHz stereo subcarrier is modulated double-sideband-a.m. suppressed carrier by the left-minus-right information $Y = \frac{1}{2}(L_f + L_b) - \frac{1}{2}(R_f + R_b)$. A 38-kHz subcarrier in quadrature with the stereo subcarrier can also be modulated double-sideband-a.m. suppressed carrier to form a third channel. This channel, presently unused, carries the front-minus-back information $X = \frac{1}{2}(L_f + R_f) - \frac{1}{2}(L_b + R_f)$, which is of major importance for the reproduction of a four channel acoustic environment.

For perfectly discrete four-channel sound reproduction, a fourth signal $U = \frac{1}{2}(L_f + R_b) - \frac{1}{2}(L_b + R_f)$ is required. It is proposed that the U-signal may be transmitted by double-sideband-a.m. suppressed carrier on 76 kHz, a frequency which is twice the stereo subcarrier frequency. When the U channel is transmitted, the RCA proposal includes the option of transmitting a narrow band (2kHz) SCA channel at 95 kHz with 5% injection. This SCA channel is primarily intended for telemetering but can also be used for voice, data, and facsimile. When L_f alone is present, *i.e.* $L_b = R_b = R_f = 0$, the channels carrying M, Y, X and U each modulate the main carrier by equal amounts. When the pilot tone P, at 19 kHz, crosses the time axis in a positive direction, swinging the main carrier towards a higher frequency, the Y channel subcarrier and the U channel subcarrier also cross the time axis in a positive direction, as indicated by the equation on top of Fig. 2.

The presence of the fourth channel, carrying the U-signal, is indicated by the transmission of a pilot tone, Q, at 76 kHz in quadrature with the U channel. This

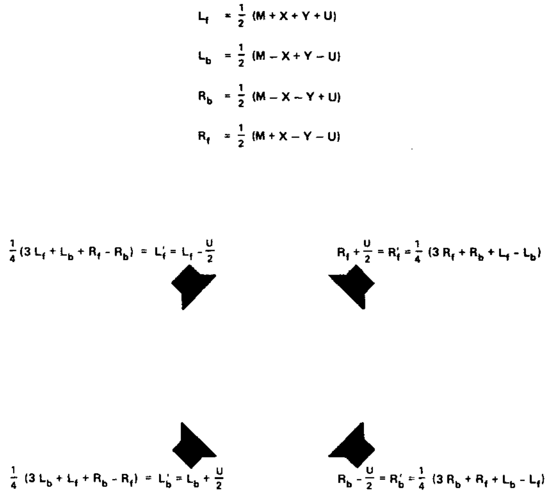


Fig. 3 — The signals in the four speakers when only three channels are transmitted (the U-channel is dropped).

pilot tone modulates the main carrier by 5%. The two-channel stereo pilot tone P at 19 kHz modulates the main carrier by 8 to 10%, in accordance with present standards. The sum of all baseband signals carrying M, Y, X, U, P, and Q modulate the main carrier by at most 100%, *i.e.* by a 75-kHz swing.

At the receiver, the signals M, Y, X, U are linearly combined in a non-reactive matrix network to form the speaker signals

$$L_f = \tfrac{1}{2}(M + Y + X + U)$$
$$L_b = \tfrac{1}{2}(M + Y - X - U)$$
$$R_b = \tfrac{1}{2}(M - Y - X + U)$$
$$R_f = \tfrac{1}{2}(M - Y + X - U)$$

When the U channel is dropped, the signals in the four speakers are as shown in Fig. 3. Speaker crosstalk is about −10 dB. Adjacent speakers are fed in antiphase by the alien signal $\pm U/2$, however, so the effect of this alien signal on angular positioning and resolution of sound sources is quite small. Thus, Fig. 3 shows how standard discrete four-channel recordings will be reproduced with three channel transmission. Subjective tests conducted by the NQRC[1] show that dropping the U channel has the expected effect of reducing the angular resolution at the location of the speakers ("real" sources) while the resolution of "phantom" sources between the speakers is unchanged. Comparative preference tests indicate virtually no difference between three and four channel transmissions.

Table I — Signal-power-to-random-noise-power ratio per speaker compared with a monophonic reference.

No. of transmitted channels	*No. of speakers used at the receiver*		
	1	2	4
1	0	0	0
2	−7	−26.2	−26.2
3	−8.6	−27.8	−29.1
4	−11.6	−30.8	−35.6

The signal statistics which tax the modulation system the most are obtained when the signal M, X, Y, and U have the same statistics but are statistically independent of each other. Using as a reference the monophonic signal-to-noise ratio obtained when M alone modulates the main carrier 100%, the signal power to random noise power ratios per speaker for one-, two-, three-, and four-channel transmission are summarized in Table I. All audio signals are assumed to have a bandwidth of 15 kHz and to be pre-emphasized at the transmitter and de-emphasized at the receiver with a 75-μs RC time constant.

Other assumptions about signal statistics yield less degradation. However, as shall be discussed later, a situation when M, X, Y, and U are statistically independent may well occur and must be considered as a worst case.

Table I indicates that the major degradation in signal-to-noise ratio was done when two-channel stereo was introduced. However, random noise is only one form of degradation which increases with the number of channels. The number of intermodulation products increases with the number of channels far more rapidly than noise, and is consequently a more serious form of degradation.

One reason for choosing a 76-kHz subcarrier for the fourth channel is that the receiver can simply derive the U-signal by synchronous detection. The proposed baseband signal is also naturally generated and detected by sequential sampling of L_f, L_b, R_b, and R_f in that order. For certain statistics of the audio signal, the four channels may interleave so that the peak amplitude of the baseband signal is less than the sum of the peaks of the channels. This, however, is not an important consideration, since for other statistics they may not interleave. Single-sideband or vestigal-sideband filtering of the U-channel introduces a quadrature channel which tends to be peaky on transients and so reduces the modulation capability of all channels without substantially reducing the out-of-band radiation, which already is below FCC specifications.

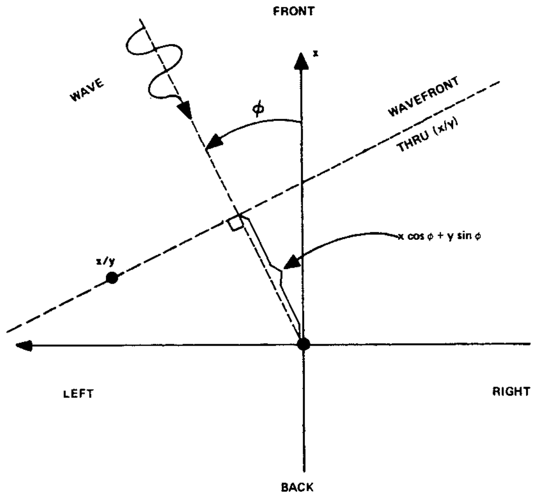
Communication of an acoustic field with a selected set of audio signals

The question that remains to be discussed is why the signal U is of less significance for the reproduction of an acoustic picture around the horizon. This question may be approached from the viewpoint that the purpose of the system is to communicate an acoustic field. As shown in Appendix A, the information in any field can be completely defined by a set of audio signals. With a limited set of signals, a field can in general only be reproduced with a limited accuracy. Of main concern in setting broadcast signal standards is that the information which is missing in the selected set of signals conveyed by the system causes minimal subjective effects and imposes minimal artistic constraints. Two considerations are of particular importance.:

- Required accuracy in the reproduced field as a function of frequency
- Required angular resolution in different directions.

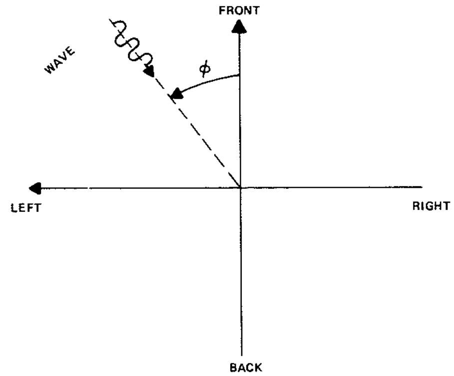
To get an initial handle on the problems of signal design the worst case requirements that the accuracy of reproduction shall be independent of direction and frequency (up to 15 kHz) shall be assumed.

The acoustic picture is precisely defined in Appendix A. The acoustic field, which satisfies the wave equation, is considered as a superposition of plane waves coming from all directions. In this way the field is



$$F(x,y,t) = \int_0^{2\pi} H\left(\phi, t + \frac{x \cos\phi + y \sin\phi}{v}\right) d\phi$$

Fig. 4 — A representation of the acoustic field F (x,y,t) as a superposition of plane waves propagating with a velocity v defines an acoustic picture around the horizon.



$$H(\phi, t) = A_o(t) + 2 \sum_1^{\infty} A_m(t) \cos m\phi + B_m(t) \sin m\phi$$

$$A_m(t) = \frac{1}{2\pi} \int_0^{2\pi} H(\phi, t) \cos m\phi \, d\phi$$

$$B_m(t) = \frac{1}{2\pi} \int_0^{2\pi} H(\phi, t) \sin m\phi \, d\phi$$

Fig. 5 — An expansion of the acoustic picture in a Fourier series relates the order m of angular resolution with the number 2 m + 1 of required channels.

defined everywhere in a homogenous room by the wave amplitude per unit solid angle at an arbitrarily selected center point or origin. The field can thus be represented as a time variable picture on the surface of a unit sphere. Fig. 4 defines this acoustic picture $H(\phi,t)$ for the simpler, and for our present considerations more relevant, situation when all the waves propagate in the horizontal plane (panoramic picture). This acoustic picture is thus a time-variable intensity distribution on the unit circle. As shown in Fig. 5, this picture can be represented as a Fourier series with time variable coefficients $A_m(t)$ and $B_m(t)$. These time-variable independent coefficients, which are Fourier samples of the picture, form a set of signals which completely define the field. The angular resolution with which the field can be reproduced at the receiver increases as the number of signals increases. An angular resolution of order m requires $2m+1$ channels; *i.e.*, zero-order resolution requires one channel; first-order, three channels; second-order, five; etc. Four channels do not provide uniform angular resolution. (Appendix A discusses these relations for a three-dimensional picture expanded in spherical harmonics.)

Fig. 6 shows the first five sampling functions in polar coordinates. Physically, the signals $A_m(t)$ and $B_m(t)$ can be thought of as having been picked up by a set of microphones located at the origin and having directional characteristics as shown in Fig. 6. Another viewpoint, which more corresponds to the present recording practice of blending individual sources, is that a source to be allocated in the direction ϕ should be consistently weighted into the different channels in the proportion 1, sin ϕ, cos ϕ, sin 2ϕ, etc. if it is to stay put at location ϕ.

The omnidirectional pattern corresponds to the monophonic signal M; the sin ϕ pattern, to the left-minus-right signal Y; the cos ϕ pattern, to the front-minus-back signal X; and the sin 2ϕ pattern, to the signal U. These patterns are also sketched in Fig. 2. A fifth channel corresponding to the pattern cos 2ϕ is, of course, omitted in four-channel transmission. Clearly, the U signal, which contributes with an element of second-order resolution, is the least significant signal.

Fig. 7 shows the redundancy in four-channel transmission if the sound sources are weighted with cardoidal-type directional patterns in each of the four channels. The U signal in this system is always identical to zero. Another feature of this system is that the total power of the signals in response to a single wave source is independent of the direction ϕ of the

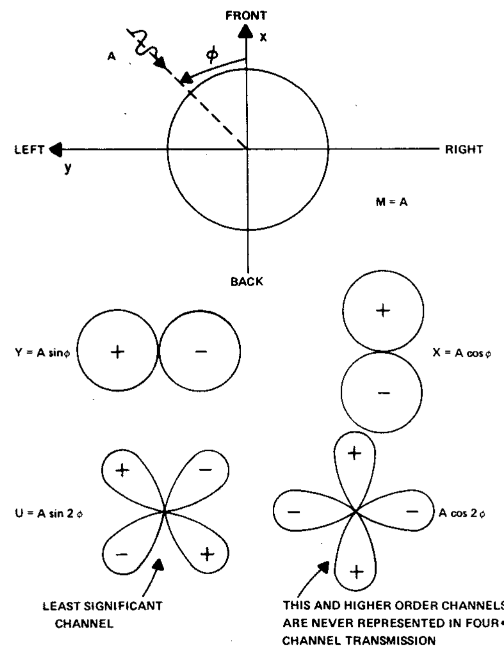


Fig. 6 — Audio channels as Fourier samples of the acoustic picture.

wave. Cardioidal weighting may be a good practice to follow when blending sound sources.

The analysis indicates that at least three channels are required for uniform reproduction of an acoustic scene around the horizon. In particular the analysis emphasizes the importance of the monophonic signal which carries the "standing wave" information.

Generation of the baseband signal by scanning the acoustic picture

The audio signals $A_m(t)$ and $B_m(t)$ which are generated by Fourier sampling of the acoustic picture $H(\phi,t)$, as shown in Fig. 5, can be simply related by scanning process to the proposed baseband signal, as defined in Fig. 2. In this process, the acoustic picture is scanned by a symmetrical beam which rotates counter-clockwise with an angular frequency ω (38 kHz) as shown in Fig. 8. This symmetrical rotating beam can be defined by a Fourier series

$$P(\phi - \omega t) = P_o + 2 \sum_{1}^{\infty} P_k \cos k(\phi - \omega t)$$

Scanning the picture $H(\phi,t)$ yields a signal

$$s(t) = 1/2\pi \int_{o}^{2\pi} H(\phi,t)\ P(\phi - \omega t)\ d\phi$$

$$= A_o(t)\ P_o + 2 \sum_{1}^{\infty} P_m[A_m(t) \cos m\omega t + B_m(t) \sin m\omega t]$$

This signal consists of a monophonic signal $A_o(t)$ P_o and a number of suppressed carriers at frequencies $m\omega$ each modulated double-sideband-a.m. by its respective part of Fourier samples $A_m(t)$ and $B_m(t)$. Thus, information conveying higher orders of resolution is carried by correspondingly higher-order carriers. The entire picture can be rotated by an angle α simply by changing the phase of ωt to $\omega t - \alpha$. This rotation of the scene can be done at the receiver simply by changing the phase of the reference carrier (or pilot tone).

Of particular concern is a scanning beam which generates the proposed baseband signal. As indicated in Fig. 8, this beam is

$$P(\phi - \omega t) = \tfrac{1}{2} [1 + 2^{1/2} \cos (\phi - \omega t) + k \cos 2\ (\phi - \omega t)]$$

where $k = 0$ in 3-channel transmission and $k = 1$ in 4-channel transmission.

The scanning process yields, in general, a five-channel signal

$$s(t) = A_o/2 + 1/2^{1/2}\ (A_1 \cos \omega t + B_1 \sin \omega t) + k/2\,(A_2 \cos 2\omega t + B_2 \sin 2\omega t)\ .$$

In the case when the original picture consists of N discrete point sources A_n at locations α_n,

$$H(\phi,t) = \sum_{1}^{N} A_m [1 + 2 \sum_{m=1}^{\infty} \cos m(\phi - \alpha_n)]$$

In particular, if

$A_1 = L_f$ $A_2 = L_b$ $A_3 = R_b$ $A_4 = R_f$
$\alpha_1 = \pi/4$ $\alpha_2 = 3\pi/4$ $\alpha_3 = -3\pi/4$ $\alpha_4 = -\pi/4$

The resulting baseband signal is

$$S(t) = M + Y \sin \omega t + X \cos \omega t + kU \sin 2\omega t$$

which is the proposed baseband signal as defined in Fig. 2. This clearly brings out the fact that the U signal carries information of second-order resolution. It also brings out the fact that four-channel stereo may have a second-order resolution term in the form $B_2 \sin 2\phi$, but lacks the second-order term $A_2 \cos 2\phi$, which would have required a fifth channel and more speakers ($\geqslant 5$). Thus, four-channel stereo has more angular resolution in the direction of the speakers than in the direction of a point between two speakers. Three-channel transmisison yields a uniform resolution around the horizon.

Reproduction of the field from the signals

Given a set of $2M + 1$ signals $A_m(t)$ and $B_m(t)$, an acoustic picture $H_1(\phi,t)$ can be reconstructed at the receiver as

$$H_1(\phi;t) = a_0 A_o(t) + 2 \sum_{1}^{m} a_m A_m(t) \cos m\phi + b_m B_m(t) \cos m\phi$$

The constants a_m and b_m are weighting constants which can be set by volume controls at the receiver to optimize the match between the original picture $H(\phi,t)$ and the reproduced picture $H_1(\phi,t)$. When $M = \infty$, the match is perfect for $a_m = b_m = 1$. Consider first the case with an infinite number of speakers distributed on a circle with a radius R which is so large that the wave each speaker launches toward the center is approximately plane when it reaches the area in which the field is to be reproduced. The definition of $H_1(\phi,t)$ then implies that a speaker at a location $\phi = \alpha$ should be fed with a signal $H_1(\alpha, t + R/v)$, or simply $H_1(\alpha,t)$ since R/v is a constant time advance. This suggests, as a guiding principle, that even with a finite number of speakers on a finite radius R, a speaker at angular

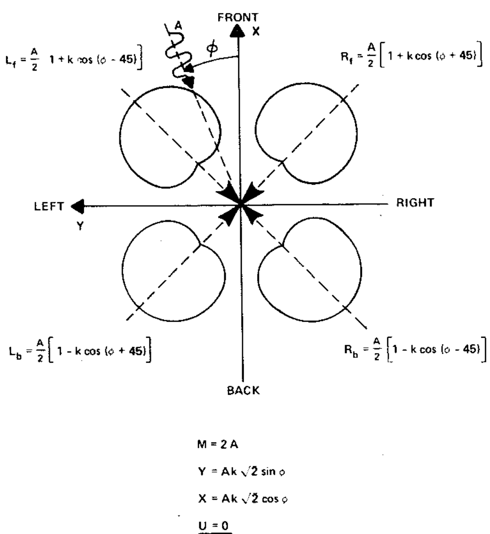


Fig. 7 — With cardioidal type weighting of the sound sources according to their orientation angle, the U channel is always identically zero and the total power is independent of the orientation angle.

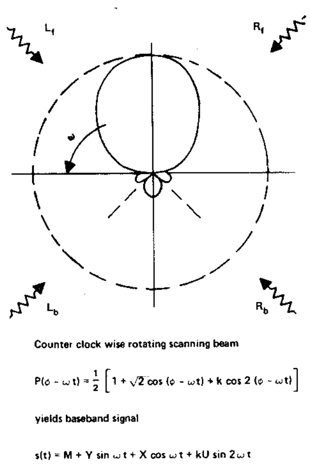


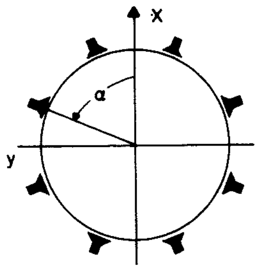
Fig. 8 — Generation of the proposed baseband signal by scanning (sampling) the acoustic picture with a counter clockwise rotating beam.

location α should also be fed with a signal $H_1(\alpha;t)$. With a finite number of speakers at a finite distance, there will be a further loss of information beyond the loss caused by the finite number of channels. The resulting distortion of the field can be reduced by increasing the number of speakers. Eventually the only information missing is due to a limited number of channels and not to a limited number of speakers.

Particular cases of interest are three- and four-channel transmission. By choosing the weighting constants to be $a_0 = a_1 = b_1 = 1$ and $b_2 = k/2$, where $k = 0$ for three transmission channels and $k = 1$ for four transmission channels, a speaker at a location angle α is fed with a signal

$$B_1(\alpha,t) = \tfrac{1}{4}[A_0 + 2A_1\cos\alpha + 2B_1\sin\alpha + kB_2\sin 2\alpha]$$
$$= \tfrac{1}{2}[M + 2^{1/2}(X\cos\alpha + Y\sin\alpha) + kU\sin 2\alpha]$$

This case is illustrated in Fig. 3 for four speakers ($\alpha = \pm\ 45°, \pm\ 135°$). Other choices of the constants a_m, b_m, which are set by volume controls at the receiver, may be better depending on room acoustics, speaker locations and program material. The general principle, however, is that a signal A_m should contribute to the signal in a speaker at an angular position α in proportion to $\cos m\alpha$, and a signal B_m in proportion to $\sin m\alpha$. This principle is illustrated in Fig. 9.



$$H(\alpha,t) = a_0A_0(t) + 2\sum_{1}^{M} a_mA_m(t)\cos m\alpha + b_mB_m(t)\sin m\alpha$$

Fig. 9 — Principal for matrixing signals into speakers for reproduction of the field.

Reference

1. Woodward, J.G.: "NQRC measurement of subjective aspects of quadraphonic sources," *J. of AES*, Vol. 23 (part 1, Jan-Feb 1975 and part 2, Mar. 1975).

Appendix A — Relation between the number of audio channels and the angular resolution of a reproduced acoustic field

In a uniform, isotropic, and loss-free medium, the instantaneous amplitude $F(r';t)$ of an acoustic field satisfies the wave equation

$$\left[\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} - \frac{\partial^2}{v^2\partial t^2}\right] F(\bar{r};t) = 0$$

where

$\bar{r} = |x,y,z| =$ position vector
$t =$ time
$v =$ velocity of sound in the medium

As a consequence, $F(\bar{r};t)$ can be represented as a superposition of plane waves coming from all directions

$$F(\bar{r};t) = \int H(\bar{u};t + \bar{r}\cdot\bar{u}/v)\,dS$$

$dS =$ element of surface on the unit sphere
$\bar{u} =$ unit vector pointing in the direction from which the wave is coming
$\bar{u}\cdot\bar{r}/v =$ time advance by which a wave coming from $\bar{u}$ reaches position $\bar{r}$ before it reaches the origin (see Fig. 4 for a two-dimensional case)
$H(\bar{u};t)\,dS =$ instantaneous amplitude at the origin of a plane wave coming from the direction $\bar{u}$.

Clearly $H(\bar{u};t)$, the wave amplitude per unit solid angle can be viewed as an acoustic picture on the surface of the unit sphere. As in television, the purpose of a transmission system is to convey this picture. This can be done with a set of independent signals $s_p(t)$ formed by sampling the picture with a set of functions $\Psi_p(\bar{u})$ which are orghogonal over the unit sphere, *i.e.*

$$s_p(t) = \int H(\bar{u};t)\,\Psi_p(\bar{u})\,dS$$

$$H(\bar{u};t) = \sum_{q=0}^{\infty} s_q(t)\,\Psi_q(\bar{u})$$

Of particular interest is to find a finite set of signals which contain the information required to reproduce the acoustic picture with a resolution which is uniformly limited over the entire sphere. This implies that the response at a location $\bar{u}$ to a point source at location $\bar{u}'$ only depends on the angle between $\bar{u}$ and $\bar{u}'$ and not on the locaiton $\bar{u}'$ of the source. Such a symmetrical impulse response on the sphere $g(\bar{u}\cdot\bar{u}')$ can be represented by a finite series of Legendre functions of the cosine of the angle between $\bar{u}$ and $\bar{u}$.

$$g(\bar{u}\bullet\bar{u}') = \sum_{n=0}^{N} C_nP_n(\bar{u}\cdot\bar{u}')$$

The reproduced picture

$$H_1(\bar{u};t) = \int H(\bar{u}';t)\,g(\bar{u}\cdot\bar{u}')\,dS'$$

thereby becomes a *superposition of* $N+1$ *spherical harmonics* $Y_n(\bar{u};t)$ of order $n = 0$ to $n = N$,

$$Y_n(\bar{u};t) = 2n+1/4\pi \int H(\bar{u}';t)\,P_n(\bar{u}\cdot\bar{u}')\,dS'$$

With $N = \infty$, any picture can be exactly reproduced as

$$H(\bar{u};t) = \sum_{n=0}^{\infty} Y_n(\bar{u};t)$$

Using spherical coordinates,

$$\bar{u} = |\sin\theta\cos\phi, \sin\theta\sin\phi, \cos\theta|$$

spherical harmonics can be expressed as

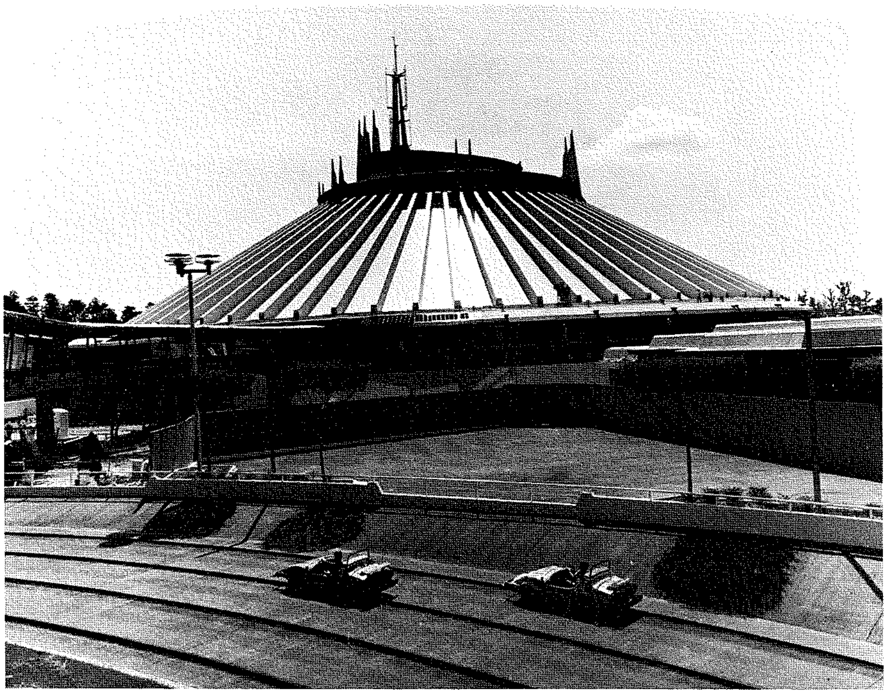
$$Y_n(\theta,\phi,t) = a_n(t)P_n(\cos\theta) + 2\sum_{m=1}^{n} [a_{nm}(t)\cos m\phi + b_{nm}(t)\sin m\phi]\,P_n^m(\cos\theta)$$

where P_n^m are Associated Legendre functions. It is noticed that there are $2n+1$ independent constants (or rather signals) required to define a spherical harmonic of order n. A monophonic field (N=0) requires, as expected, one signal or channel. The next order of uniform angular resolution requires the monophonic channel plus three more channels, or a total of four channels. Second-order resolution requires five more channels or a total of 9, etc.

A particular case of interest is when all the waves propagate in the horizontal plane ($\theta = \pi/2$). This eliminates all variations in θ, concentrating the acoustic picture on the equator

$$H(\phi,t) = A_0(t) + 2\sum_{m=1}^{\infty} (A_m(t)\cos m\phi + B_m(t)\sin m\phi)$$

Thus, a panoramic acoustic picture with an angular resolution of order m can be conveyed with $2m+1$ channels. First-order angular resolution requires three channels; the next order, five; etc.



Space Mountain dominates the Tomorrowland area at Walt Disney World. The ribbed beams that comprise the roof stand out in bold relief to create an attention-getting pattern. (Copyright Walt Disney Productions.)

RCA space mountain

R.E. Flory

A sparkling new edifice on the skyline of Walt Disney World in Florida marks the fulfillment of more than a decade of planning by Walt Disney designers and builders, and RCA engineers. Plans for Space Mountain with RCA as a sponsor began about three years ago. Kenneth W. Bilby, RCA Executive Vice President, Public Affairs, designated Mort Gaffin as project manager for Space Mountain. Mr. Gaffin, Director, Corporate Identification and Graphics, has served as RCA's liaison with the Disney organization in the conceptualization and development of the exhibit and continues with overall responsibility for our participation at Walt Disney World. RCA management looks upon Space Mountain not only as an opportunity to promote good will for the company as a whole, but as a direct support for our products and services. It will become a showcase during the next decade for our advanced products and systems.

PLANNING for RCA participation in Space Mountain went into high gear by mid-72. Project Manager, Mort Gaffin worked with a number of key engineering, marketing, and design people in RCA to help make RCA part of the project. Notable among these were Dr. James Hillier, Executive V.P., Research and Engineering; Dr. W.M. Webster, V.P., RCA Laboratories; J.W. Curran, V.P. Engineering Marketing Services; Dr. D.S. McCoy, now Consumer Electronics Div. V.P., Development Engineering; and T.P. Madawick, Consumer Electronics Div. V.P., Industrial Design. From their discussions, a plan evolved which culminated in the opening of RCA Space Mountain on January 15, 1975. To provide a full appreciation for RCA's role in this attraction, we will first describe Space Mountain.

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Space Mountain

The success of the Matterhorn Mountain at Disneyland in California prompted the designers at Disney's WED Enterprises to create a high-speed ride for Florida's Disney World which would be the ultimate thrill ride with a smooth, silent trip resembling more the acceleration of a space ride than the slam and jerk of a roller coaster. To carry the space theme further, the ride is operated in near darkness to allow display of visual effects simulating outer space. The building is 183 ft high and the floor area is more than 72,000 ft^2.

The landmark building is itself an engineering feat. The enclosing structure is designed to be a projection screen for creating the illusion of deep space. The totally unique structure rises in a sloping cone shape, 183 ft above the surrounding landscape, characterizing an electronic mountain in space age artistry. The basic structure is composed of great ribbed slopes—72 massive pre-stressed concrete beams forming a sealed cone. Each is 117 ft long, 13 ft wide at the bottom and 4 ft wide at the top. The weight of each slab is 74 tons. They provide a single span from a perimetral ring to a center support slab. The central slab is supported on four large concrete columns poured in place.

The largest part of the volume of this enclosure is taken up with the track for the space ride. There are two parallel systems, each having over 3000 ft of tubular track. The use of two tracks permits doubling capacity for the ride. Aside from the many visual effects, the track configuration was computer-designed for maximum space ride "thrill" within conservative bounds of safety. The ride is controlled and monitored by minicomputer. The rides have a combined capacity of almost 3000 visitors/hour, and it is estimated that 5 to 6 million visitors will experience this space ride each year.

Before embarking upon the space ride, visitors entering Space Mountain will walk past "windows in space" which will depict the role of electronic communication in the exploration of space. To add an unearthly appearance to these displays, Disney designers have used a novel optical system to present this story, using sculptured figures and scale models which are imaged by a large spherical mirror in such a way that the visitors are viewing an aerial image of the actual display. The unreal parallax and perspective changes of such a display, presented to a moving observer, create an effect quite in keeping with the outer-space theme of the building. The mirrors used in these displays were made in the Disney shops. They are made of acrylic plastic and are almost eight feet in diameter.

After the space ride, visitors will board a moving speedramp and be presented a view of the "Home of Future Living" where Disney Audio-Animatronics figures will show how communications and electronics might play a part in the future home. The trip via the beltway continues through a corridor where RCA products, such as, XL-100 tv sets, *etc.*, seem to float in space overhead. These are imaged by means of the same type of spherical mirrors used in the earlier space communication exhibit.

Before leaving Space Mountain, the visitor is treated to a view of himself in a "see yourself on color tv" display, in which the speed ramp moves past an array of nine television screens and three concealed cameras. It is in this last area that the largest amount of detailed collaboration between RCA and Disney engineers was needed. At the end of the tv exhibits, the space traveler will have spent approximately 25 minutes in space, with RCA.

RCA Participation

Consultation on exhibit content

Disney designers wanted to imbue Space Mountain with the essence of RCA. To achieve this, there were many discussions with RCA people. Inputs from the Communications Research Laboratory in Princeton, and the Consumer Electronics Division Industrial Design Group figure significantly in the design of the "space communication" and the "home of future living" displays. Marketing and Industrial Design staffs assisted in specification and placement of the RCA products which are displayed floating in space.

The "see yourself on tv" display represents the only display and operation of RCA hardware in Space Mountain and therefore involved the largest number of RCA engineers and designers in its planning and execution.

Consultation on television display feasibility

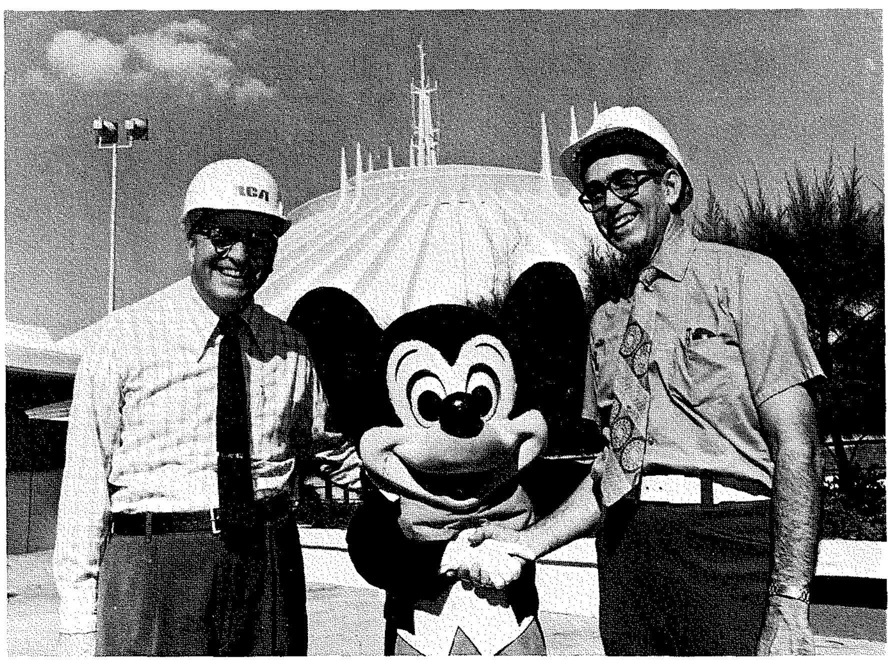
In the spring of 1973, the author was approached about the technical feasibility of "see-yourself" configuration using color television equipment. The technical question to be answered was whether the light level required for a high-quality picture would result in so much light on the picture display, or in viewer's eyes, that the desired effect would be lost in glare. Flory's background not only included recent work on color cameras, but experience with a see-yourself on color tv system in a television studio installed and operated by RCA for the U.S. State Department in Moscow, USSR in 1959. This experience led to the conclusion that the system would yield high quality pictures especially considering the advances made in camera equipment and kinescope brightness since 1959.

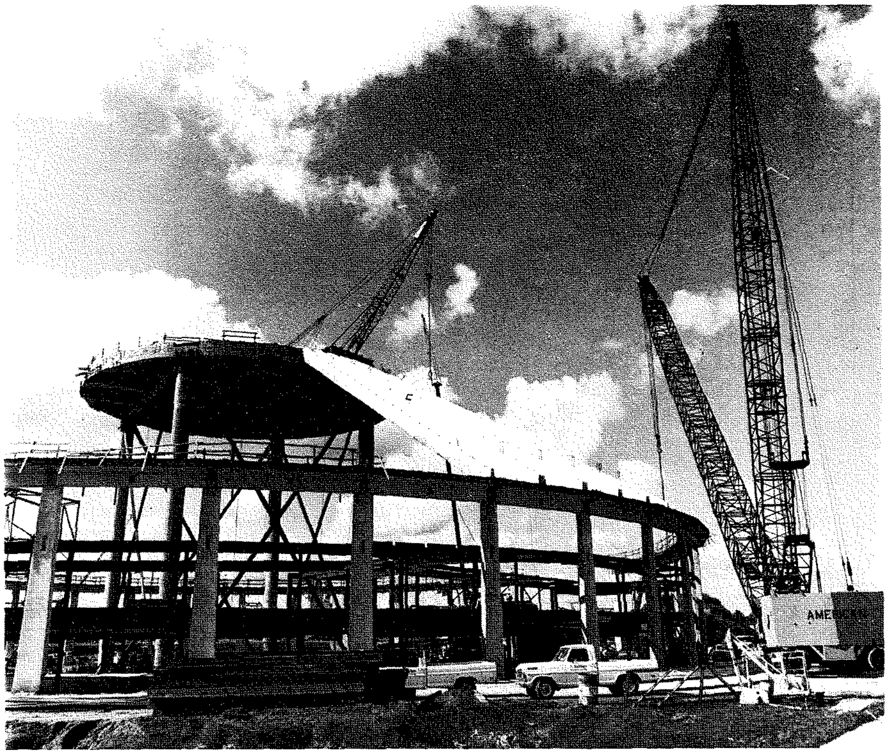
Feasibility demonstration

The Disney design group at WED Enterprises, Glendale, California, has created a mock-up of the see-yourself area and were ready for advice as to lighting and choice of equipment. To get a first impression of how the system would perform, a two-man remote pick-up van with an RCA TK-44 broadcast color camera was acquired from NBC in Burbank. It was possible then to visualize how such a system might look, and the achievement of a good picture was easily demonstrated under the lighting conditions required. One of the earliest subjective observations on the system which came out of this test was that the camera horizontal scan should be reversed. It must be remembered that the tv camera transmits the scene to a monitor as it would be viewed by an observer behind the camera. In the see-yourself mode, the monitor is placed in such a way that the televised viewer appears to be looking in a mirror—but not quite. When, he raises his right arm,

Robert E. Flory received the BEE from Cornell University in 1954. After graduation he joined RCA Laboratories. In 1955 he was awarded an RCA David Sarnoff Fellowship to attend the University of Pennsylvania for one academic year. Later, upon completion of his thesis on a time division multiplex system, the MSEE was granted in 1962. At RCA Laboratories, Mr. Flory has been engaged in work on video recording systems, tv standards conversion, ultra-high speed computer, and various tv projects, including digitally addressed electroluminescent displays and color tv displays. In 1959 he spent three months in the Soviet Union installing and operating color television equipment for RCA at the American Exhibition in Moscow. In 1959-1960 Mr. Flory was administrator of Professional Placement for RCA Laboratories, responsible for recruitment and training of BS, MS graduates, and placement of experienced professionals seeking employment at RCA Laboratories. Mr. Flory is currently a member of the Communications Research Laboratory. He participated in the earliest work on the RCA Video Disc. He was team leader for video and sound on the HoloTape project and was later involved in work on color tv cameras, and other imaging systems. He received a 1970 RCA Labs Achievement Award for Electron Beam Recording of Color tv. In 1972, he shared the David Sarnoff Outstanding Achievement Award in Science for the HoloTape project. The same work resulted in the 1974 Journal Award from SMPTE for his co-authorship of a paper on HoloTape. Mr. Flory is currently engaged in work on advanced video recording systems in the Electro-Optics Systems group of the Communications Research Laboratory. He is a Senior Member of the IEEE, Member SMPTE, and past editor of the Princeton Section Newsletter for IEEE. He holds six patents and has taught tv principles in an industrial arts school.

Bob Flory (l) and Dick Orth, manager of RCA Space Mountain congratulate Disney's M. Mouse on his latest triumph, RCA Space Mountain. (Copyright Walt Disney Productions.)





While under construction, the anatomy of Space Mountain was evident. The beams span the space between the outer ring and "waffle plate" supported on four columns poured in place. (Copyright Walt Disney Productions.)

the viewer's image on the monitor raises the arm seen to be on the left. While this is not in itself too serious, it must be remembered that the viewers will be on a moving ramp when passing the cameras. It would be most disconcerting to be moving to the left, and see one's image move past to the right!

A number of potentially degrading influences in the environment were identified. The speed-ramp motor and a near-by "people mover" system using linear induction motors could possibly have enough magnetic field to affect camera registration or receiver color purity. On the assumption that camera shielding was probably more effective, both these disturbances were tested against a receiver in the Disney laboratory. A steam locomotive runs within a few yards of some of the receivers in the final installation. Such a large steel mass might upset color purity on the receivers. To test this, a receiver was moved near the tracks at Disneyland and color purity checked as the trains passed by. All tests were passed with "flying colors".

Selection of equipment

In choosing equipment, many considerations entered into the final specification. Considering the five million or more visitors expected annually, and an operating day ranging up to eighteen hours, reliability was seen to be an important consideration.

Since RCA is a leading source of broadcast television equipment, a logical source for pickup equipment was the RCA broadcast equipment line. A desirable adjunct to the availability of proven equipment was the engineering and service organization of RCA Broadcast Systems.

At the time of our planning, in the spring of 1973, RCA had just announced the TK-45A camera, an evolutionary development from the TK-44B, which has been our best-selling color camera. The new camera offered some automatic features and a more compact control unit. The newly automatic features on this camera were the color balancing functions, which will allow rapid and consistent color balancing of the camera.

For picture display, the technical choice was constrained to be RCA production receivers, because in the earliest concept of the system, it was planned to have a discreet "soft-sell" display of a variety of receiver cabinet styles. As it turns out, this non-technical constraint matches the technical opinion that conventional receivers offer the best mix of performance and reliability for this application. The performance parameter which is most critical for this application is picture brightness. A scene illuminance of about 100 ft candles is required for an adequate depth of field and good camera signal-to-noise ratio. In this case, for pleasing illumination of the subject, it is necessary to direct a good portion of this illumination into the eyes of the viewer (who is in fact the subject). For this reason, the picture brightness must be as high as possible to overcome the glare.

Monitors for use in television studios are designed for high reliability and for highest resolution, stability, and fidelity. Generally, all of these performance parameters are achieved at the expense of brightness.

The design of a receiver tends to maximize brightness capability and to achieve other performance parameters in the most cost-effective way possible to allow competition in the marketplace. In the XL-100 line of receivers, it was judged that an optimum mix of performance, reliability and ease of service made their use in this application very desirable from a technical standpoint.

Artistic design of tv exhibit

The interaction of design and technical performance in the tv display was particularly complex. Designers and engineers from WED Enterprises worked with Tucker Madawick and Pierre Brosseau of Consumer Electronics Industrial Design, Indianapolis and with the author.

The original concept had placed a concealed television camera behind a number of television receivers placed on pedestals against a backdrop of stars. The camera output would be fed to the receivers, thereby displaying the pictures of the visitors to them, as they move past on the speed ramp.

As the concept was further developed, it became apparent that displaying receiver cabinets was ineffective and out of keeping with the space theme. It also became apparent that viewers would have more of a chance to find themselves in the picture, if a large number of pictures were displayed, and more than one camera were used. The final development of the system has the pictures appear to be floating in space, with three concealed cameras each displaying their outputs on three receivers. The three receiver sizes chosen were 15, 19, and 25 inch.

The receivers are enclosed within large boxes faced with black acrylic plastic. The pictures are framed with a formed black plastic mask treated to be non-reflecting. The black acrylic enclosures reflect images of a large number of stars created by means of back-lit perforated screens or suspended "grain-of-wheat"lamps. The illusion created is that the pictures are floating in star-filled space. The entire receiver area is painted black, and with the aid of the television lighting shining in the vistor's' eyes, the illusion is highly successful.

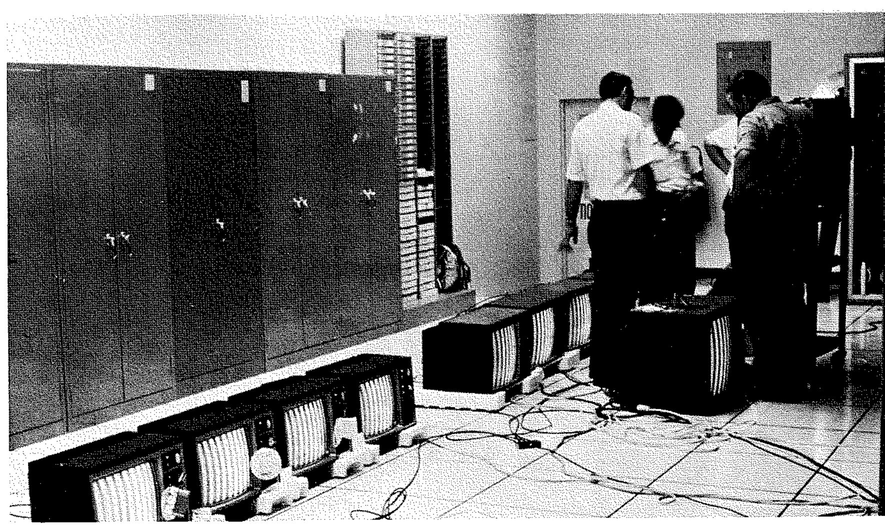
Close cooperation between Disney an RCA staffs was involved in construction and testing of mock-ups of the visual effects. The excellent result was due to a high degree of mutual interest in the success of the project.

System design

When RCA Broadcast Systems equipment was selected for the project, the camera system design responsibility was given to the TV Systems Engineering group of Commercial Communications Systems Division, Camden. Based on specifications and recommendations made by the author, the system was developed to take fullest advantage of equipment redundancy to ensure continuity of operation. The three cameras are driven by one sync generator, but a second operates at all times, monitored and automatically switched by a sync changeover system in the event of prime generator failure. Each camera is directly coupled to an rf modulator. The outputs of the rf modulators are fed through a switcher to the appropriate group of three receivers. In the event of camera or modulator failure, the switcher will allow the diversion of another camera to feed the affected receivers. By this means, all receivers can have a feed, even if two cameras fail. All rf modulators operate on channel four, an unassigned channel in Orlando. This allows switching the feeds to the receivers from behind the scenes, but raises the possibility of carrier beats between the rf modulators To circumvent this possibility, the modulators used (EIE Model CTM1) have a phase lock capability which synchronizes all three carriers. The rf switching is also used for local and remote selection of camera outputs for monitoring system performance. The equipment is divided among three racks, one for each camera control unit, with picture and waveform monitor. In addition, one of these racks contains pulse generation, distribution and sync changeover facilities, and another rack contains the three modulators, rf switching relays and connector fields.

Artist's sketch of tv area. Viewers move past cameras and receivers on powered speedramp at 2 feet per second. Audio-animatronic robot boy at right is holding a dummy vidicon camera patterned after the RCA TC 1055 produced by Electronic Components.

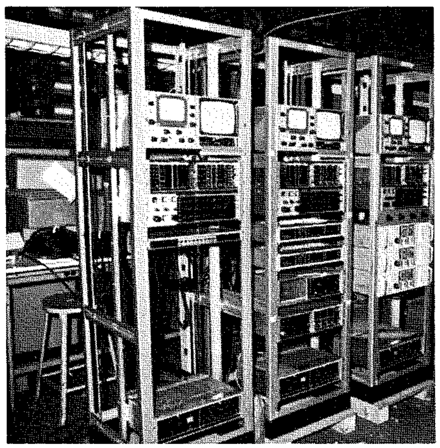
The receivers selected for the project were from the table model selections of the XL-100 line, chassis types CTC-68, CTC-71, and CTC-72. J.A. McDonald of Consumer Electronics Division, was selected to coordinate the specification of operating conditions and installation of the receivers. Drawing on test data available and running new tests for the special conditions of this application, McDonald was able to specify an optimum mode of operation for the receivers, considering such variables as line voltage, thermal environment, and on-to-off-time ratio. Standard receivers are used, and aside from a "break-in" period to eliminate any early failures, they were installed as received from the factory. One concession for reliability assurance is the use of regulated line voltage. Continuous operation 12 to 18 hrs every day of the year will represent a most rigorous service and may provide some new data on receiver reliability. Maintenance will be done by Disney personnel during down time at night, as is customary in all Disney operations. Module replacement will make possible many on-the-spot repairs, and two spare receivers of each type will be available,



Television receivers for see-yourself area getting burn-in at site. Paul Crookshanks, CE at left and Jim Cravens, Service Company at right; discuss performance with Disney engineers.

TV area under construction. Jim Cravens, Service Company; Paul Crookshanks, CE, and Greg Bell, Disney (right to left) during the first tests of tv receivers in place.

One of the RCA TK-45 cameras and control rack are shown in front of Space Mountain, on their way in for installation by Ralph Ölweg (1) and Oscar Klampfer (r), Communications Systems Div. (Copyright Walt Disney Productions.)



Television equipment racks were assembled and tested at CCSD, Camden before shipment to Florida. Each rack houses one camera control unit, the center rack holds pulse generation and distribution equipment, and right hand rack contains the rf modulators and switches.

stored in a good environment and turned on periodically for capacitor forming and to drive out any condensation. By these means, it is expected that nine receivers will be running every day of the year.

Installation, service, training

The camera and rf equipment was installed by RCA field engineers, as is customary with those products. To get the earliest feedback of any problems that might arise, a preliminary camera installation was made while the building was still being finished inside. This created much confusion and deposited much dust on camera lenses and prisms, but was valuable in allowing some leisurely "fine tuning" of a number of problem areas, as well as an early promise of an effective exhibit.

Television receivers are customarily shipped from the manufacturer without a follow-up from engineering or manufacturing at the time of installation. In this case, in the interests of highest reliability and performance, representatives from Consumer Electronics Division and RCA Service Company were on hand at the site to review the design philosophy of the exhibit and to assure the most satisfactory installation. This was a singular occasion, when two manufacturing divisions, a service division, and the research laboratory were all working on the same project, frequently crossing lines of divisional responsibility. Seldom can a camera installation engineer reach out and adjust the controls of all of the receivers his camera feeds.

After installation of the camera equipment was completed, a maintenance routine was worked out for the Disney personnel who will operate the cameras. Key Disney people attended an RCA camera operation and maintenance seminar given in Camden. RCA field engineers will pay periodic visits to assure that quality is up to standard, and to offer what assistance is needed.

The Disney engineers responsible for equipment maintenance also have responsibility for thousands of RCA television receivers in the Disney World hotels. They have received complete service data on the receivers used in the exhibit and will be able to draw on the resources of the Consumer Electronics Division and RCA Service Company when needed. One advantage of using receivers for the picture output is the ease and low cost with which they can be replaced when they have reached the end of their useful life. For instance, it may prove more cost effective to replace the entire receiver than to replace a picture tube. In addition it will be easily possible to upgrade the performance of the system in the event of technological advances in receivers.

Summary

RCA Space Mountain is one of the major attractions of Walt Disney World. Those of us of RCA who have worked with the Disney organization have been deeply impressed with the genius, the technical competence, and the genuine pleasure which these people bring to their work. This spirit is infectious, as all of us have taken great pleasure in helping to bring the RCA name before the public in a most fun-filled way.

Acknowledgment

The following RCA engineers and managers contributed materially to the RCA Space Mountain project: Communications System Division, O. Klampfer, A.T. Montemuro, R. Olweg, M. Perzel, R.A. Roehm, R.J. Smith, S. Starr, L. Walker, S. Willson; Consumer Electronics Division—P.E. Crookshanks; RCA Service Company—J. Cravens; NBC—E.Ancona, K. Erhardt.

Geometric-correction constant-resolution processor

J. Danko | M. Hecht | T. Altman

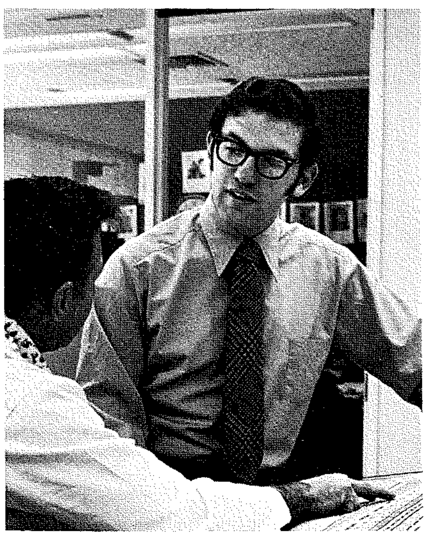
Cross-track scanning radiometers are used in the operational meteorological satellite system to provide data that are resolved into images of the earth's cloud cover and other geographical features. However, the uniform scan rate of the radiometer and the curvature of the earth result in an inherent geometric distortion of the image. This paper describes a geometric-correction algorithm which can be implemented on board the spacecraft to produce improved meteorological interpretability and greater information content.

SINCE the launch of ITOS 1 (TIROS-M), cross-track scanning radiometers have been used in the operational meterological satellite system. The radiometers measure electromagnetic radiation reflected and emitted from the earth and its atmosphere in selected wavelength intervals. These data are then combined to produce images which display distributions of cloud cover, snow, ice, and surface temperature. Characteristically the radiometers utilize a primary scan mirror inclined 45 degrees to its axis of rotation, the axis being parallel to the velocity vector of the spacecraft. The optical scan path thus lies in a plane perpendicular to the orbital motion. In contrast to television sensors, no image is formed within the radiometer; the detector merely integrates the received radiation into an electrical output. The scan mirror rotates at a uniform rate, such that adjacent scans are contiguous at the satellite subpoint and the data are constructed into an image of the observed scene. However, the uniform scan rate and earth's curvature result in a non-linear relationship between earth distance and distance in the image along the scan direction. This causes foreshortening near the horizons in images produced by a linear scan display. Furthermore, the fixed instantaneous field of view (IFOV) of the instrument yields a variable resolution across the image, with a maximum at the satellite subpoint and a rapidly decreasing resolution towards the horizons.

A unique data requirement currently exists in the operational meteorological satellite system. Data is acquired by the spacecraft scanning radiometers at two different resolutions, which provide three output data streams. The Scanning Radiometer (SR) provides the medium-resolution output for real-time readout on the vhf link and a medium-resolution output for globally recorded data, which is centrally processed. The Very High Resolution Radiometer (VHRR) provides the high-resolution output for

Ted Altman, Lead Engineer, Astro-Electronics Division, Princeton, N.J., received the BS in Electrical Engineering from the City College of New York in 1965 and the MS in Electrical Engineering from the Polytechnic Institute of Brooklyn in 1968. Mr. Altman joined RCA in 1965. Early assignments included the logic design of a flight decoder using C-MOS logical elements and the development of a time dissemination receiver for the Navy Navigation Satellite. Mr. Altman was a systems design engineer on the ITOS D and E spacecraft. and he completed work on the Apollo Television Scan Converter, where he was responsible for the design of the Slow Scan Test Pattern Generator and the Sync Lock Phaselock Loops. He was involved in the integration of the TV Scan Converters and provided field support during the Apollo 8 mission at Madrid, Spain. Mr. Altman has been lead engineer for the TIROS M Incremental Tape Recorder Test Unit and the AVCS Camera and Recorder Simulator, which incorporated both analog and digital design. Mr. Altman most recently was responsible for investigating the data handling requirements of TIROS N, including configuration of the Manipulated Information Rate Processor.

Since this article was written, Mr. Altman has left RCA.



Dr. Martin A. Hecht, Systems Engineering, Astro-Electronics Division, Princeton, N.J., received the BSEE, MSEE, and PhD from the Polytechnic Institute of Brooklyn, in 1963, 1965, and 1968, respectively. He specialized in statistical communications and investigated sequential detection theory for his doctoral research. Dr. Hecht joined RCA in 1967, and conducted studies in the major areas of signal analysis and communications systems. These studies included two-dimensional digital filtering for image enhancements, data compression techniques, and non-uniform sampling theory. Also included were a PAM and multi-level PCM time-division system for NASA, block-coding analysis for a classified space program, signal detection analysis for the Viking Program, and coding techniques to improve the packing density in digital tape recording systems. From 1963 to 1965, he worked for the Bell Telephone Laboratories. Dr. Hecht has written three technical papers, and is a member of IEEE, Sigma Xi, Tau Beta Pi, and Eta Kappa Nu.

John M. Danko, Spacecraft Preliminary Design Group, Astro-Electronics Division, Princeton, N.J., received the BS in Engineering Physics from Lehigh University in 1964; and attended graduate school at Pennsylvania State University, majoring in meteorology, from 1965 to 1966; and received the MS in Systems Engineering from University of Pennsylvania in 1972. Mr. Danko has worked on the system requirements for meteorological satellite systems at AED since joining RCA in 1968. Mr. Danko is currently responsible for meteorological mission and sensor requirements for RCA's studies of both TIROS-N, the next generation operational meteorological satellite, and EOS, the next generation research and development satellite. He is also a principal investigator in the NASA ERTS data utilization program and is conducting an experiment to evaluate the meteorological utility of ERTS imagery. Previously, as a member of the Earth Observation Systems Group, he was extensively involved in defining data requirements and analyzing remote sensors and techniques for advanced operational meterological satellite systems. He was specifically involved in the requirements analysis for RCA's concept of the "Environmental Satellite Systems of the Seventies," a total operational system for the future. During 1969, he participated in the integration, test, and launch of the TIROS M spacecraft as a member of the integration team. From 1965 to 1968, he was an officer in the U.S. Air Force, assigned to the Air Weather Service as a forecaster in support of air operations. In his position as Chief Forecaster at Sewart AFB, he was responsible for all forecasting operations for the base. He also conducted several investigations on the improvement of operational forecasting techniques.

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Authors Hecht (left) and Danko.

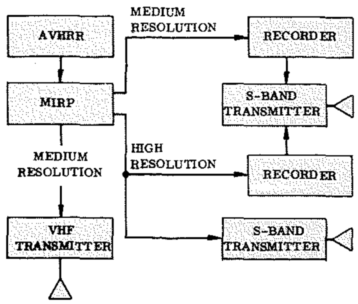

Fig. 1 — Advanced data processing system block diagram.

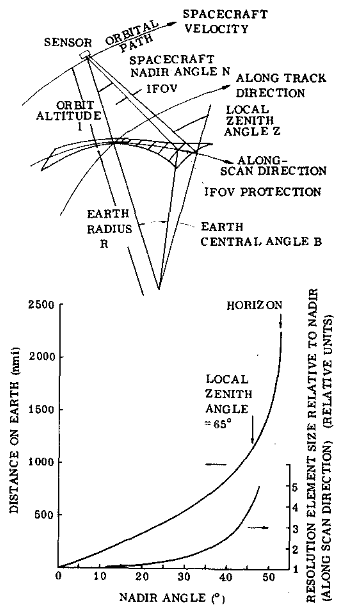

Fig. 2 — Earth distance and resolution element size vs. spacecraft nadir angle.

Table I — AVHRR parameters.

Charactersitic	*Value*
Scan speed	360 rpm
No. of channels	4
IFOV* (element size at subpoint)	0.55 millirads (0.5 nmi)
Video output data rate	100-k samples/channes/s
Quantization	8 bits

*For the 3 high-resolution spectral channels.

Table II — VHF real-time (APT) link parameters.

Characteristics	*Value*
Frequency	137.5 or 137.62 MHz
Modulation	fm/am
Subcarrier frequency	4.8 kHz
Receiver bandwidth	50 kHz
Display line rate	120 LPM (lines/min)
Information bandwidth	3 kHz

real-time transmission via S-band and for selective recording.

Concepts for future development in the operational meteorological satellite system include the use of only one radiometer, the Advanced Very High Resolution Radiometer (AVHRR) — currently under development and a digital processing unit to produce all three of these outputs. Such a sampled data system is particularly amenable to correction of the image foreshortening. Moreover, a correction algorithm can be implemented on board the spacecraft, which not only improves the interpretability of the medium resolution outputs by correcting the inherent geometric distortion, but also increases the average resolution of the imagery.

This paper describes such an algorithm, the data processing required, and the parameters of the resulting data stream. Included are simulations of the actual implementation process on space-acquired imagery from the VHRR.

System concept

Fig. 1 shows the baseline spacecraft data processicg system in which the correction algorithm would be implemented. The AVHRR is a four-channel, cross-track scanning radiometer designed to operate in a 907-nmi, circular, sun-synchronous orbit. The significant parameters for this sensor are given in Table I. Its output is a serial digital word stream controlled by the Manipulated Information Rate Processor (MIRP). Since the AVHRR acquires data in all four channels simul5ously on approximately a 25-% duty cycle, the MIRP is required to generate different sampling rates for various portions of the sensor scan and to buffer and smooth the resulting sample train to achieve output-bandwidth reduction. In addition to the bandwidth reduction and formatting tasks required for various combinations of the four spectral channels, the MIRP will produce two reduced resolution outputs. One of these, the vhf real-time output, is the specific target for the correction procedure. The main parameters for this analog output are given in Table II. With minor implementation impact, the processing within the MIRP can be configured to achieve geometric correction of this reduced resolution output while maximizing the resolution of the resulting real-time imagery.

Geometric distortion

The distortion in the along-scan direction results from the fact that high-resolution samples of the AVHRR data are taken at a constant rate (100 k samples/s), and thus, at equal increments of nadir angle along the scan. Additionally, since the sensor IFOV is fixed, the earth's curvature contributes to a decrease in resolution in the along-scan direction from nadir outward to the horizons. There is also attendant geometric distortion and a decrease in the resolution in the along-track direction. The correction of these latter effects will not be addressed by this paper.

Fig. 2 shows the scan geometry and a graph of earth distance versus the spacecraft nadir angle. The desired result is a linear relationship between these two parameters since ground displays in the vhf ground stations can be expected to have a linear sweep. If geometric correction were the only result desired, the data that was acquired at a constant sampling rate could be read out at a variable rate with the readout period between samples being proportional to the derivative of the curve in Fig. 2.

However, since one vhf output line consists of two time-multiplexed analog spectral channels with a maximum baseband of 3 kHz transmitted at a 120-line/min rate, resolution reduction on the AVHRR data, as well as buffering and smoothing, must be accomplished by the MIRP. One concept that has been advanced for this process provides for arithmetic averaging of a rectangular matrix composed of four AVHRR samples in the along-scan direction and samples from three scans in the along-track direction to produce one reduced-resolution sample. The matrix is rectangular, because the sampling rate in the along-scan direction is higher than in the along-track direction. At nadir, this produces an effective resolution element size of 1.5 by 1.5 nmi, but this value increases rapidly near the horizon as in shown in Fig. 2. Near-constant resolution in the along-scan direction can be obtained by varying the number of high-resolution samples averaged during particular portions of each scan. By averaging fewer samples near the horizon, a discrete approximation to constant resolution can be accomplished.

Geometric-correction algorithm

The prime objective of the correction algorithm is to remove the geometric distortion in the along-scan direction while maximizing the information content within the bandwidth constraint of the communications link. The algorithm in this paper accomplishes this in a discrete manner by sampling at a variable rate (or averaging a variable number of samples) and reading out the data at a variable rate. Both of these processes vary as a function of position in the scan. The earth scan included between the nadir angles of ±46 degrees is divided into 13 discrete regions — 6 regions symmetrically placed on each side of the nadir region. Geometric correction can not be reasonably performed near the horizon, since the required readout rate approaches infinity. Also, for the application under consideration here, the information bandwidth must be kept below the 3-kHz maximum information bandwidth capability of the vhf link. For these reasons, the data taken at nadir angles greater than 46 degrees is discarded. This represents a local zenith angle of 65 degrees, beyond which the imagery contains little or no useful meteorological information. The number of samples averaged and the readout rate is constant within each region but can differ from region to region. The selection of seven regions, while somewhat arbitrary, was made on the basis of the algorithm yielding a satisfactory geometric accuracy.

The boundaries for each region could be determined for any of several error criteria. In the algorithm presented in this paper, peak displacement error was minimized in an *ad hoc* manner. Specifically, for the parameters shown in Table III a peak geometric error of 4 nmi will result. This means that the maximum displacement for any picture element would be approximately two elements from a linear position. If the algorithm when implemented in the spacecraft is fixed to some scan-related parameter such as a line-synchronization signal, spacecraft attitude error will result in a greater geometric error in the corrected image. The geometric error in the image introduced by the correction algorithm with a 0-degree and 0.2-degree spacecraft roll error is shown in Fig. 3.

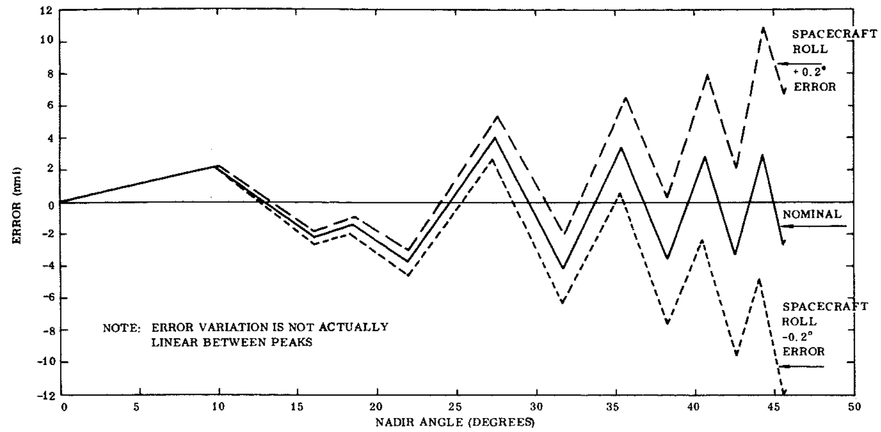

Fig. 3 — Geometric error with distortion correction logic (907-nmi altitude).

The result of the variable averaging scheme on the resolution in the along-scan direction is depicted by Fig. 4. The average resolution element size varies from 1.3 to 2.3 nmi with a mean value of 1.8 nmi. In the direction perpendicular to the scan, the element size varies from 1.5 nmi at nadir to 1.59 nmi at a local zenith angle of 65 degrees.

One possible processor configuration for implementing this algorithm is shown in the functional block diagram in Fig. 5. The high-resolution AVHRR samples are first buffered, smoothed and formatted with two spectral channels time multiplexed in each line. The variable along-scan average process is then accomplished under control of a fixed program. Three consecutive lines are averaged, using a recirculating memory with an output rate again under the control of a fixed program. The digital data stream is then converted to analog, filtered, and used to modulate the 4.8-kHz subcarrier of the vhf real-time link.

From an implementation viewpoint, the increase in hardware complexity required for this algorithm over that required for a simple resolution reduction process is small. Moreover, since the control memory requirements are small, the hardware complexity is not strongly dependent on the number of regions used. Hence the specific number of different correction regions could be changed within relatively large bounds with little change in the hardware complexity.

Simulations

Simulations of the correction algorithm were performed at the AED Image Processing Laboratory. The vehicle for these simulations was an RCA 70/8800 Color Scanner and associated Data General Super Nova Computer. (The color-separation capabilities of the processor were not used in this particular application. All operations were performed in a single spectral interval.) Photographic transparencies were placed

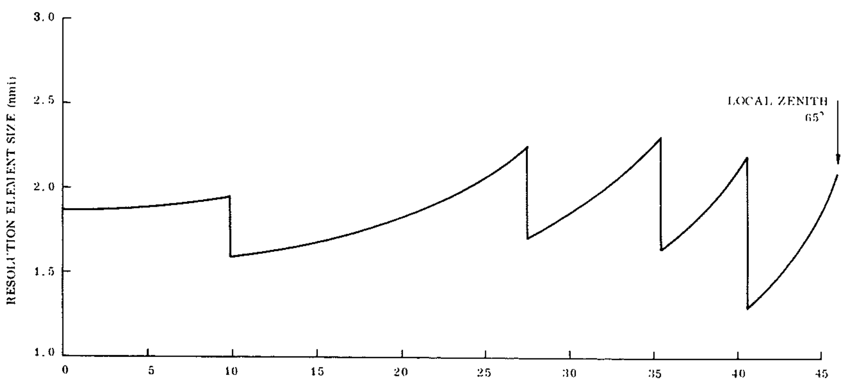

Fig. 4 — Resolution element size in along-scan direction, after geometric correction.

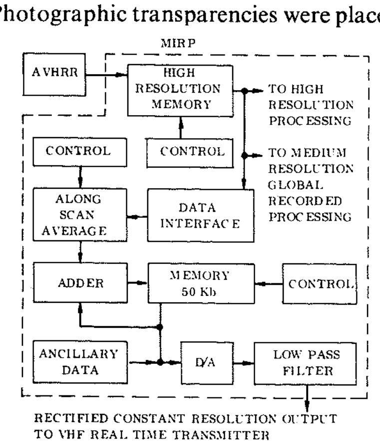

Fig. 5 — Geometric-correction implementation logic.

Table III — Geometric-correction constant-resolution process parameters.

Region	*Number of samples averaged*	*Readout rate**	*Net expansion*	*Region boundaries (nadir angle, degrees)* 907 *nmi orbit*	*Simulation* 790 *nmi orbit*
1 (Nadir)	5	0.2	1	0 - 9.85	0 - 10.05
2	4	0.222	1.125	9.85 - 18.50	10.05 - 18.80
3	4	0.2	1.25	18.50 - 27.50	18.80 - 28.20
4	3	0.2	1.67	27.50 - 35.45	28.20 - 36.40
5	2	0.222	2.25	35.45 - 40.65	36.40 - 41.80
6	1	0.333	3	40.65 - 44.25	41.80 - 45.55
7	1	0.25	4	44.25 - 46.00	45.55 - 47.50
Data discarded				46.0 - horizon	47.5 - horizon

*Relative to high-resolution sample rate

on the rotary input drum of the color scanner, the imagery read and the analog signals converted to a digital data stream. The data was then manipulated in real time within the computer according to the specifications of the algorithm. The resulting simulated vhf real-time output was used to drive the write aperture, producing a negative transparency on the rotary output drum of the scanner.

Space-acquired VHRR imagery from the NOAA-2 spacecraft was used as input data for the simulations. Since the data was acquired at an altitude of 790 nmi, the region boundaries were optimized for this altitude. These values are given in Table III. Also, the size of the input imagery was adjusted so that the 0.003-in. diameter read aperture of the color scanner was equal to 0.5 nmi on the

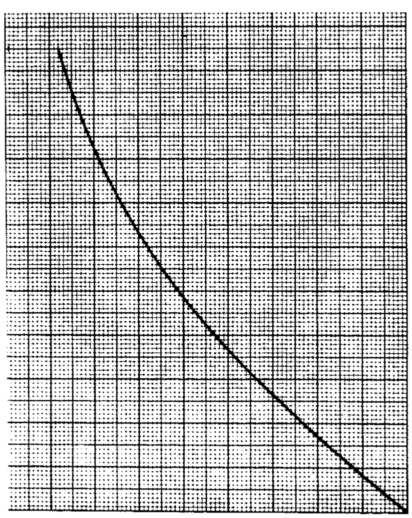

Fig. 6 — Graph of earth distance vs. distance in the image.

photograph, thus accurately simulating the IFOV of the VHRR.

Fig. 6 is a plot of ground distance *vs.* distance in the image from nadir to a local zenith of 65 degrees for a 790 nmi orbit altitude. The correction algorithm was run on this image with the scan direction parallel to the graph abscissa. The resulting output, shown in Fig. 7, is a discrete seven-stage approximation to a straight line. The region boundaries are barely visible as cusps within the line.

One VHRR image used as an input for the simulations is shown in Fig. 8. Geometrically corrected vhf real-time output simulations made from the VHRR image with and without a grid are shown in Figs. 9 and 10 respectively. Note that the resolution has been degraded slightly near nadir, but that the interpretability of the image near the edges has been greatly improved. Also in the ungridded image, the region boundaries are undetectable. Fig. 11 is a simulation of a vhf real-time output without geometric correction. The improvement resulting from the correction algorithm by comparing the outputs in Figs. 9 and 11, both of which require approximately the same baseband. Note that the cloud formations over the Atlantic Ocean near the top edge of the image are presented much more accurately, as compared with the original of Fig. 8.

Present system status

Subsequent to the work reported on this paper, the planned orbit of the next

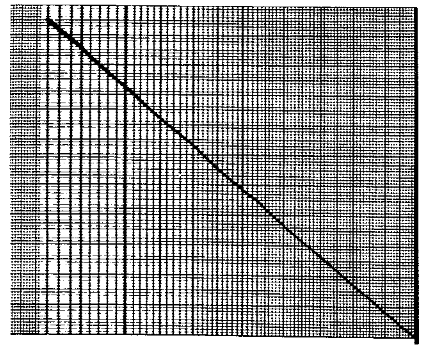

Fig. 7 — Graph of earth distance vs. distance in the image after correction algorithm has been implemented.

generation operational meteorological spacecraft was changed from a nominal altitude of 907 nmi to 450 nmi. Correspondingly, the AVHRR IFOV was changed from 0.55 mrad to 1.3 mrad, while the scan mirror speed remained at 360 r/min. As a result of these changes, the details of the geometric-correction algorithm were modified to conform to the specific parameters of the planned system; however, the objectives and general approach of the procedure remained intact. The 450-nmi, constant-resolution, geometric-correction algorithm is summarized in Table IV.

Table IV — Geometric-correction constant resolution process parameters for 450-nmi orbit.

Region	*No. of samples averaged*	Readout *rate**	*Region boundaries (nadir angle, degrees)* 450 *nmi orbit*
1	4	0.25	0 - 17.0°
2	3	0.25	17.0° - 34.8°
3	2	0.25	34.8° - 43.8°
4	121	0.25	43.8° - 48.9°
6	Data discarded		56° - horizon

*Relative to high-resolution sample rate.

Note that the output rate is constant for all regions, whereas it previously varied between regions. A constant output rate eliminates variable contouring along an APT scan line, reduces timing complexities in equipment implementation, and lends itself to tape recorder storage of the data (although this is not presently contemplated).

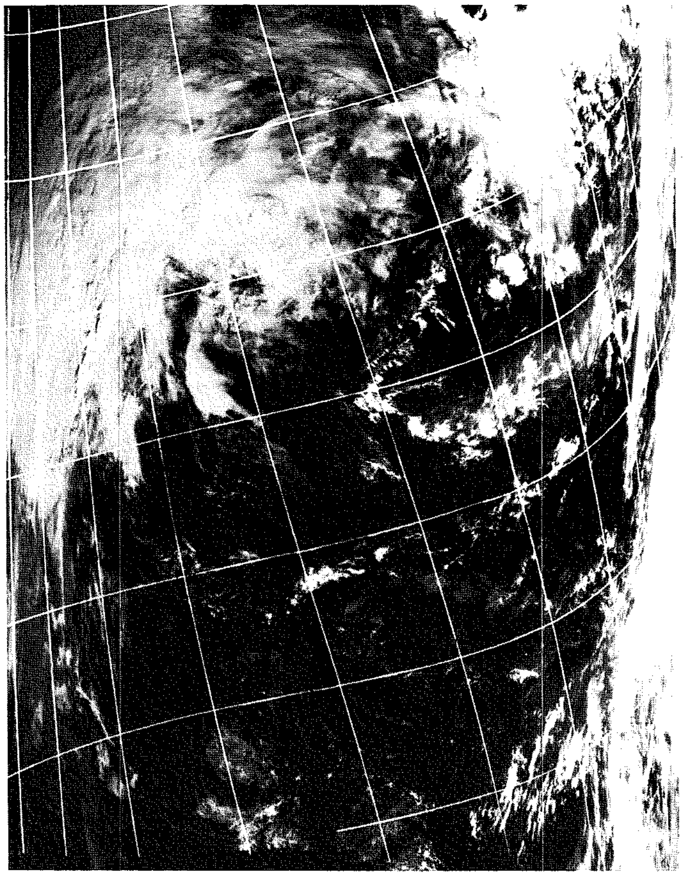

Fig. 8 — Original image. This image was originally produced from the NOAA-2 high-resolution real-time S-band output on the direct readout ground station display on October 31, 1972. (The grids on this photo were subsequently added manually.) The picture is made from data acquired by the VHRR visible channel (0.6 to 0.7 micrometer) during a 0900 local descending-node pass over the east coast of the United States. Florida, Cuba, and the Yucatan peninsula are clearly visible. The verticle lines on each side of the picture, between the nadir and each horizon, are formed by the subsynch markers introduced by the spacecraft into each line of VHRR data.

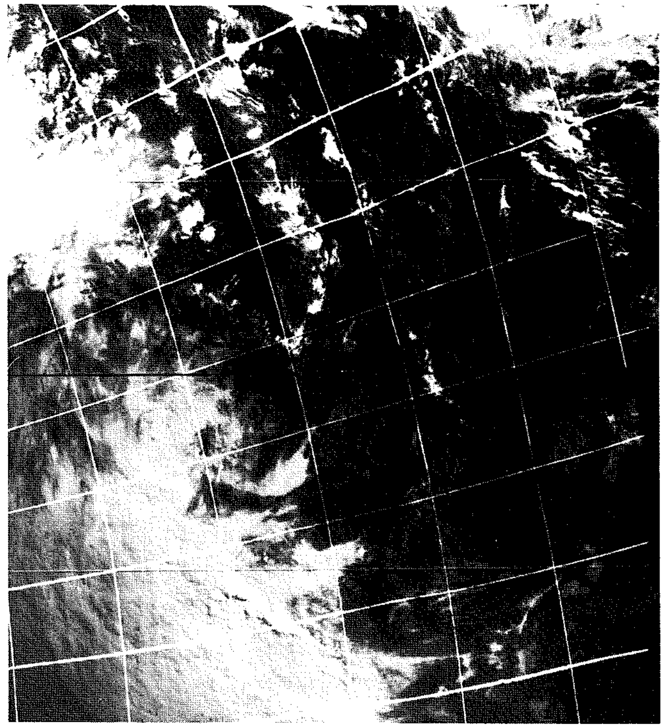

Fig. 9 — VHF simulation with geometric correction (with grid).

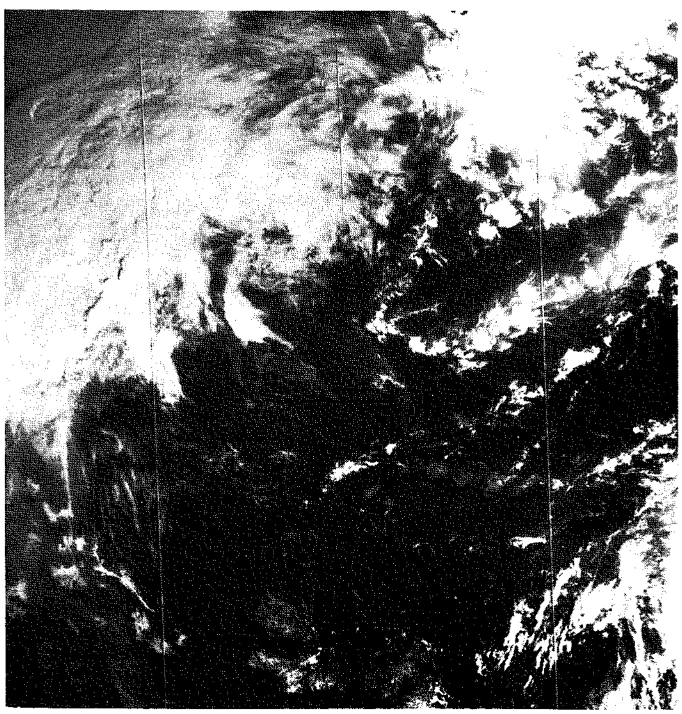

Fig. 10 — VHF simulation with geometric correction.

Fig. 11 — VHF simulation without geometric correction. This photo was made by performing a 4- by 3- element average over the entire image, and thus has a resulting resolution in the along-scan direction of 1.5 nmi at nadir and approximately 6.4 nmi at a local zenith of 65 degrees.

Modular switching for local and remote subscribers

P. J. Bird

Recent evaluations conducted by the Government Communications and Automated Systems Division have shown that large scale integration (LSI) can be applied effectively to telecommunications switching systems used in tactical military situations. The switches considered in the evaluation included both time and space division at the central and dispersed points. The transmission media for interconnection employed multi-pair cable and coaxial cable; the latter used in conjunction with PCM multiplex equipment of varying channel sizes. These evaluations were focused mainly on the application of dispersed switching to the tactical complex, with switches located according to the density of personnel, thereby limiting the extent and cost of cable plant while at the same time providing a degree of survivability unattainable in the central switch approach.

Philip J. Bird, Ldr., Digital Communications System & Government Communications and Automated Systems Division, Camden, NJ, was employed by Ericsson Telephones, Ltd., (now Plessy Co.) in Beeston, England from 1938 to 1956, and graduated from Nottingham and District Technical College where he was awarded the City & Guilds of London Institute Group Course in Telecommunications in 1942 and the Higher National Certificate in 1945. From 1939 to 1942, Mr. Bird was involved in the development of IFF and cable carrier equipment for the Armed Forces. He then became a Design Engineer on Central Office telephone switching equipment, telegraph equipment and PABX's. In 1956, Mr. Bird joined Stromberg-Carlson, Rochester, N.Y., where he was engaged in the design of a solid-state PAM time-division switching system for the US Army. From 1959-1962, he was employed by Teleregister Corporation, Stamford, Conn., where he was engaged in the development of communications for on-line air-line reservations and stock exchange information systems. He joined RCA in 1962 where responsibilities are the analysis and synthesis of communications equipment and systems for various Government Agencies. He has been concerned with analog & digital secure and non-secure systems which employ time-division & space-division techniques and wired and stored program control. Mr. Bird was the Leader of the switching effort for RCA on the Mallard program. He is a Senior Member of the IEEE.

PROJECTIONS of future military telecommunications switching systems have shown a trend toward the "all-digital" system. Also in such systems, the cost of multiplexing equipment represents a large part of the total system costs. Therefore, one of the immediate problems confronting the designers was the absorption of at least a part of the multiplex costs into the switch.

At the user end, since the conventional telephone will be extensively used for some lengthy period of time, it was difficult to justify the use of time-division switching in which subscriber analog information must be converted into digital format on a "per line" basis, adding extensively to the cost of the multiplexing equipment. It was concluded, therefore, that space-division switching could be effectively retained at the dispersed switch level with the dispersed switch acting either as a concentrator or as a stand-alone PABX. The concentrator would have minimum decision capability, relying on the main switch for performing the switching functions. The stand-alone PABX, on the other hand, would be capable of working independently of the main switch, except perhaps for the more sophisticated functions of the switching operation, *e.g.*, call forwarding.

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It is at the main switch that savings in multiplex equipment can be realized since the trunks from the dispersed concentrators and PABX's now appear as serial digital streams and it is not necessary to de-multiplex before performing the switching operation. The nature of the signal is such as to allow ready implementation using large scale integrated circuit techniques.

Design approach

A family of functional switching modules was developed to adapt this switching concept to various military situations (including fixed base, tactical air base, and shipboard installations) and to make optimum use of available LSI technology.

This required that functional groupings of these modules be capable of being arranged into:

- A central switch;
- A remotely controlled concentrator without local switching;
- A remotely controlled concentrator with local switching;
- A remotely controlled PABX;
- A locally controlled or stand-alone PABX; and
- Combinations of the above such as a central switch with remotely controlled concentrators, a main switch with remotely controlled PABX's groups of interconnected stand-alone PABX's, *etc.*

Hence there are three basic types of switches which must be configurable using subsets of the functional modules developed: a central switch, a PABX, and a concentrator. In the selection of specific configurations and modules, the follow-

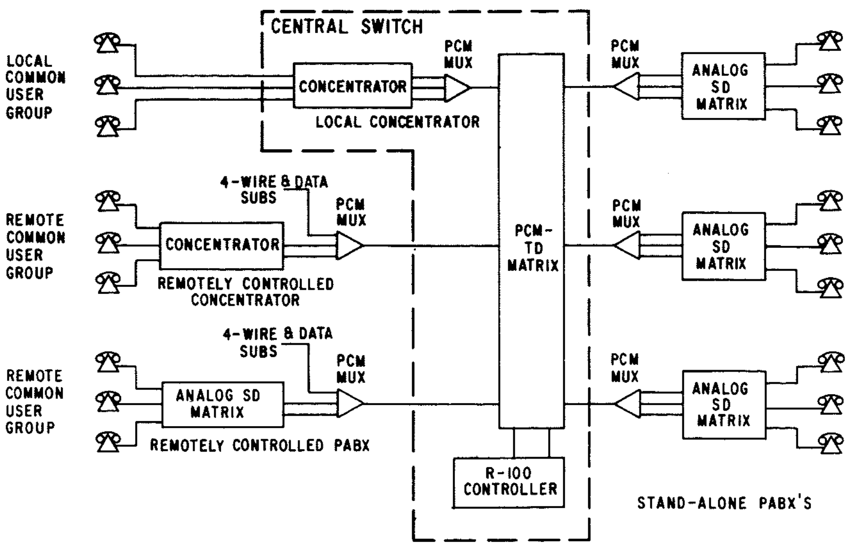


Fig. 1 — Composite switching configuration.

ing assumptions were made:

1) The central switch will be a PCM computer-controlled time-division tandem switch.
2) A time-space-time time-division matrix will be utilized within the central switch.
3) A 48-channel PCM highway will be used in the central switch (3.072 Mb/s).
4) Remote PABXs and concentrators will contain two-wire analog space division matrices and will utilize PCM trunking.
5) Remote PABXs and concentrators will be modular in size from 50 to 350 subscribers in increments of 50 subscribers.
6) All local analog subscribers will be two-wire except for a few four-wire Autovon phones which will be routed directly to a PCM-channel bank and not through the two-wire matrix. (This approach prevents introduction of complexity into the analog switch.)
7) Digital phone outputs, if used, will be at an ($8000 \times N$) b/s rate (where N will be 2 or 3 — a 16 or 24 kb/s data rate). Digital phones will be multiplexed up to a 64 kb/s rate and interleaved with PCM voice channels.
8) Data subscribers will be submultiplexed up to a 64 kb/s and interleaved with PCM voice channels.

Composite configuration

A composite configuration showing all the proposed switch elements appears in Fig. 1. The selection of the actual system depends on the criteria for selection in the specific application as will be seen later.

The analog switches vary in complexity from the concentrator upwards to the stand-alone PABX. In its simplest form, the concentrator has no decision-making capability, but is remotely controlled from the main switch, which performs all the switching functions including line to line connection. If the community of interest within a concentrator is high, it is possible to add a local switching matrix which has the effect of trunk-usage conservation.

The next level of complexity is represented by the remotely controlled PABX which further conserves trunk usage by registering locally dialed digits and spilling the number forward to the remote main switch. Local switching is provided under control of the main switch.

The highest level of complexity in the dispersed-switch family is represented by the stand-alone PABX which can be connected to the main switch or in an independent network composed of similar PABX's. Control of the PABX is by minicomputer.

The addition of data and four-wire Autovon handling requirements would greatly increase the complexity and consequently the cost of the dispersed switches in an environment where analog two-wire switching predominates. The capability of handling the more sophisticated switching is already available at the main switch and it therefore appears expedient to connect subscribers requiring such service by way of directly connected channels in the PCM multiplex equipment.

The main switch is a computer-controlled time-division PCM switch which will accept the bit streams from the connected PCM equipment without conversion.

Although Fig. 1 addresses the dispersed configurations, it is significant to note that the complex can become a single switching node by co-locating the dispersed switches with the main switch.

Application criteria

The dispersed switch approach is applicable to shipboard, tactical air base, tactical field army base, and fixed military base installations. Such configurations could be used advantageously in certain commercial applications. Since the entire concept is modular, a configuration can be built up to satisfy a wide range of system application criteria, including:

Installation time — Set-up and tear-down time are critical in tactical applications. The concept of using PCM multiplex groups as opposed to multi-pair cable would considerably enhance the build-up of the switching complex.

Cable plant size and cost — This factor applies to all applications, but is particularly critical on shipboard where highly packed conduits are increasingly encountered.

Survivability — Networks can be formed to ensure operation despite damage or equipment failure. The degree of survivability depends to a great extent on the community of interest between users on a given switch, *i.e.*, whether traffic is predominantly local or remote.

Overall cost — Many factors affect the cost-effectiveness of a given configuration but selection of the most economical network can be made by considering user needs and traffic and using the modules accordingly.

Sizing and community of interest — This criteria is directly related to all the above criteria. For example, the decision as to whether to provide a concentrator or a stand-alone PABX at a remote location affects cost, survivability, and installation; the location and interest of users must also be considered, and a full traffic analysis must be performed before final selection of the system is made.

Ideal goals

In developing the various equipments, it is highly desirable that the modularity at the system level be carried down as far as possible to the switch-module level. It will be seen in the description of the switches that, at the space-division level at least, there are a number of basic modules which apply universally whether the switch be in the form of a concentrator or a PABX. Ideally, the subsystems should be pluggable such that a concentrator could be upgraded readily to a PABX and vice versa.

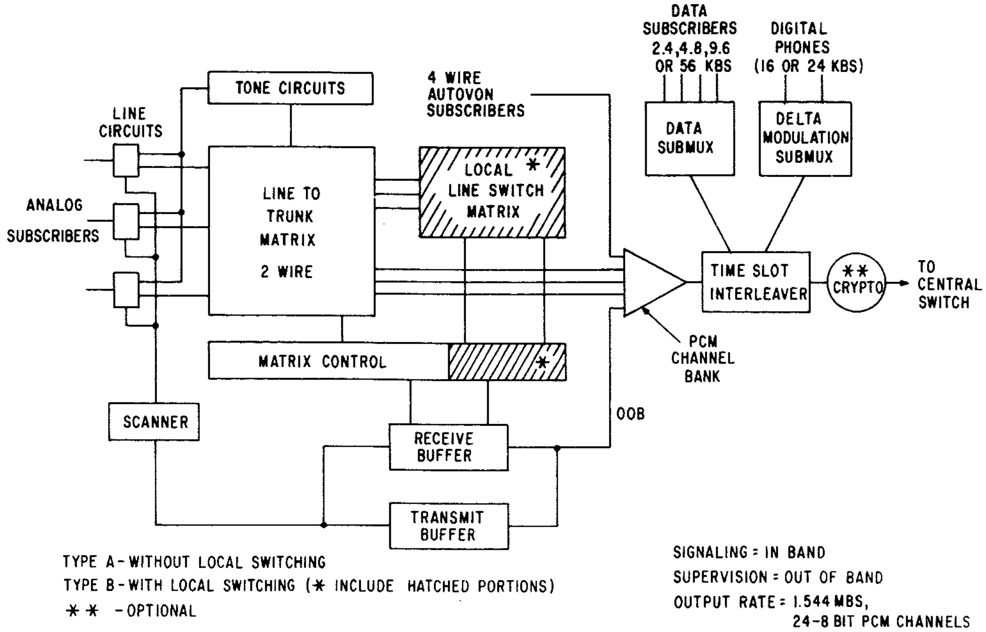


Fig. 2 — Concentrator.

Such an approach would produce commonality of hardware, maintenance, and, logistics, as well as complete flexibility to form any switching configuration.

Concentrator description

The functional elements of the concentrator are shown in Fig. 2 and consist basically of subscriber-line circuits, local matrix, trunk matrix, PCM mux equipment, tone circuits, scanner, link crypto equipment, transmit and receive buffers, and matrix control circuits. The concentrator communicates with the main switch over a dedicated out-of-band channel allocated in the PCM multiplexer. This channel is reserved strictly for supervision (on-hook/off-hook) and control information. Signaling is accomplished directly from the subscriber over the trunk allocated to the specific call. This in-band signalling approach alleviates the necessity to provide registers at the concentrator. The out-of-band supervision and control can utilize the technique of Common Channel Interoffice Signalling (CCIS) now under consideration for becoming the International Standard (CCITT #6).

It has been assumed that the basic matrix element will be a solid-state cross-point which, along with reed relays, lacks the capacity to switch the high level ringing current. This source has therefore been distributed on a per line basis. Other supervisory tones such as busy tone and ringback, are distributed on a switched basis from tone links. An alternate approach to tone generation is to provide tones from the main switch via a digital tone generator.

The concentrator operates in the following manner. The scanner generates a continuous bit stream via the transmit buffer to the out-of-band channel, and the bit stream is continually monitored by the main switch processor, thus the processor can detect a change of state in any line while knowing which line has in fact changed. On detecting an off-hook

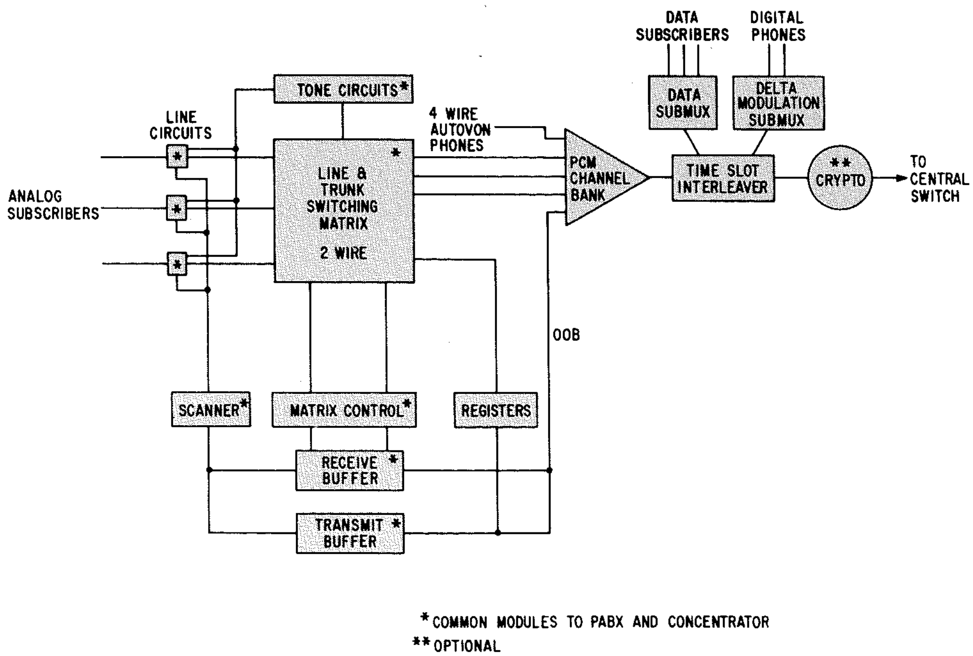


Fig. 3 — Remotely controlled PABX.

condition, the processor allocates a free trunk to the call and attaches a register. Then it transmits the selected trunk identity and the calling line identity to the concentrator receive buffer. This information is decoded and the connection between the calling line and trunk is completed allowing dial tone from the main switch register to be given to the subscriber. The subscriber now dials the required number into the main switch.

On a concentrator with local switching, local calls are processed as follows. If the dialed number is that of another subscriber on the same concentrator, the main switch sends the calling and called numbers to the receive buffer of the concentrator and an indication to connect ring forward to the called line and ringback to the calling line. Additionally, the processor makes a connection between called and calling lines in the local matrix. The trunk used for the dialing is disconnected. When the called party goes off-hook, he is already connected. Release of the call by either party is indicated to the main switch by a change in state of the scanner bit stream and causes the main switch to generate a release message which includes the calling and called line identity. On a concentrator without local switching, local calls require two trunks interconnected through the main switch.

If the number dialed into the main switch by a concentrator subscriber is that of a user in another system or on a similar concentrator, the trunk between concentrator and main switch is permanently allocated for the duration of the call. The same applies to calls incoming from another switch to the concentrator.

It is emphasized here that no information pertaining to subscribers other than physical location of their position on the switch is contained in the concentrator. All other information such as class of service, type of user, service restrictions, *etc.*, are contained in the main switch. Thus, if the concentrator is designed for the requisite transmission capability any type or mix of subscribers can be readily accommodated.

Remotely controlled PABX

Shown in Fig. 3 is a remotely controlled PABX. Its equipment complement and operation are similar to the concentrator. The basic difference is that the remotely controlled PABX contains registers which reduce the complexity of the main switch and permit local calls to be made without using trunks. Digit translation is still performed at the main switch.

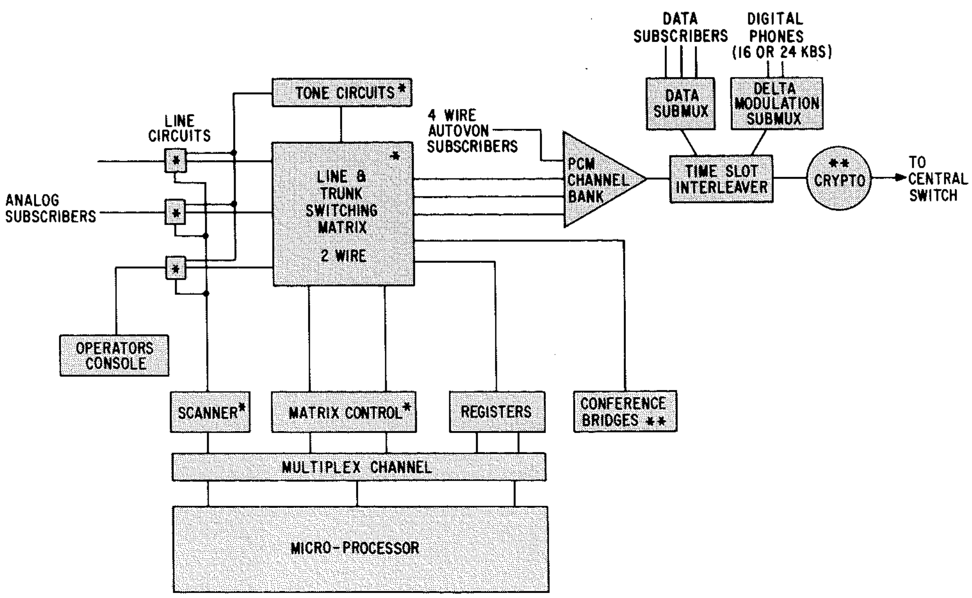
Four-wire Autovon phones physically located in the vicinity of the remotely controlled PABX will be handled as direct inputs to the PCM channel bank. Low speed data subscribers will be multiplexed up to the channel speed but will not be switched at the concentrator. They will each have dedicated slots within the channel and will be integrated with PCM voice trunks via the time slot interleaver. The same will be true of digital phone subscribers where two or three will be multiplexed up to channel speed. Link encryption would be an optional feature for selected PCM multiplexer outputs.

Stand-alone PABX

The locally controlled or stand-alone PABX (Fig. 4) also uses modules common to the concentrator with the addition of registers, an operator's console, plus a control mini-processor. It is an autonomous unit and works with a second dial tone to communicate with the main switch or other satellite PABXs. Its main advantage is its survivability: local communications are not dependent on an external source as in the case of the earlier switches described.

Hybrid central switch

The hybrid central switch consists of a tandem PCM time division switch and one or more colocated concentrators. The central switch assumes the complexity normally associated with the more sophisticated features encountered in circuit switch operations. Dispersal of switching functions do little toward reducing the degree of sophistication of the central switch from a feature standpoint; however, much can be done to reduce the size and complexity of the matrix by the relocation of subscribers at the dispersed PABXs or remotely controlled PABX's.



*COMMON MODULES TO PABX & CONCENTRATORS
** OPTIONAL

Fig. 4 — Stand-alone PABX.

Current concepts in computer-controlled telex switching systems

L.P. Correard

The availability of low-cost minicomputers and associated peripheral equipment has made it practical to design large-scale communications switching systems utilizing a multi-mini-subsystem approach. Such a new large-scale telex system is presently under manufacture for RCA Globcom.

THE FUNDAMENTALS of telephone switching were long established and implemented (within the limiatations of the state of the art of the period) when keyboard-to-keyboard international teleprinter service (telex) was first offered to RCA private wire subscribers in 1950. The limited traffic handled the first year (1500 calls) was elegantly serviced via a manual exchange utilizing a "TexTable" which provided manual switching, manual accounting, and manual call supervision (see Fig. 1).

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L.P. Correard, Manager, Computer Switching Engineering, RCA Global Communications, Inc., New York, N.Y., received the BEE from Manhattan College in 1958 and the MSEE from Columbia University in 1960. He joined RCA Globcom in 1960 and since that time has been associated in varying levels of responsibility with the system design, procurement, installation, and test of most of the major computer-controlled communications switches which have been installed by Globcom to service its message and telex traffic. These projects have included the Computer Telegram Exchange in 1962, Aircon (4104's) in 1966, Computer Telex Exchange (special) in 1969, Telextra (1600's) in 1970, and more recently the CTE II (RCA CCT's) discussed in this paper. In 1973, Mr. Correard was made responsible for the overall engineering project effort and planning associated with the provision of newly designed systems and equipment for the telex switching plant. He is a registered Professional Engineer in the State of New York and is a member of NSPE and of IEEE.

The general acceptance and usage of the service caused a phenomenal growth rate and, by 1955, when RCA extended international telex service to Bell System teletypewriter subscribers, enabling them to place and receive overseas calls on their domestic TWX machines, the number of calls handled rose to 105,000 per year. Obviously, manual handling of this volume became prohibitive, and RCA had to adopt automated switching exchange techniques to properly service the traffic.

The sharp slope of the growth curve of international telex calls required an almost immediate expansion of switching plant. When plant requirements, traffic projections, and delivery and installation cycles were examined, it was realized that there would be insufficient time to properly research and engineer a major new exchange designed primarily for telex service.

However, the telephone switching industry already had available automated electromechanical step-by-step and crossbar common control equipment and the associated circuit switching technology. These available telephone switching products — minimally modified as required for telex service — could be procured and installed. And why not? This equipment was providing adequate telephone service throughout the world. Several large companies had developed the technology and manufacturing facilities and complete product lines were available.

Thus, in the late 1950's RCA procured the initial installation of an electromechanical step-by-step exchange manufactured by T&N (*Telefonbau und Normalzeit*) of Germany. In the course of its lifetime, this exchange, installed at RCA's headquarters at 60 Broad Street, New York, was expanded many times as the service continued to grow (see Fig. 2).

By 1961 nearly 750,000 telex calls per year were being handled by the electromechanical exchange. The "why nots" associated with the adaptation of the electromechanical exchange for telex switching were by then manifold and evident. Long lead times involved with procurement and installation, vast floor space areas required, and the huge power consumption of the electromechanical exchange made it nearly impossible to continue to expand switching plant at a rate approaching the business plan requirements for service and growth.

Requiem for a technology

In the early 1960's, RCA installed a large-scale, stored-program, computer-controlled store-and-forward message switch for international message telegram switching, the Computer Telegram System (CTS). The engineering and operating experience gained with the CTS indicated that a broad range of modern service features with distinct technical and long-range economic advantages were available by utilizing system designs which employed digital computer techniques. The drawback, however, was that no manufacturer had yet developed a product line of computer-controlled telex switching exchanges.

RCA undertook the task of specifying and system designing a large-scale computer-controlled telex exchange. The state of the art dictated that all such system designs be based upon the use of the large-scale general purpose digital computers, such as the RCA Spectra 70, which were available on the market at the time, or upon the design and procurement of special purpose computers. In either case, the communications interface or "front end" was unique and had to be designed and built especially for the task. Such a procurement was not necessarily economical, but it did provide an operational, extremely flexible exchange which could be expanded on a reasonable lead-time basis.

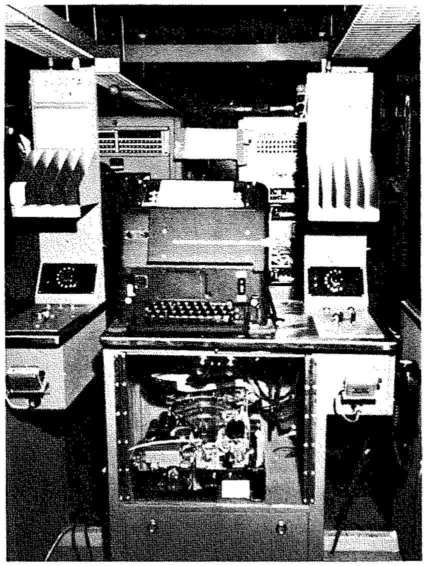

Fig. 1 — Tex Table.

The selection of a computer-controlled switch more than proved itself, as by 1971 the annual number of calls handled by RCA rose to more than 5.5 million.

The Computer Telex Exchange Number One (CTE I), manufactured by Astrodata, Inc., employed common control techniques and a specially designed and built multistage reed-relay switching network (see Fig. 3). As with a telephone crossbar exchange, the common control portion of the CTE I, which functions only with regard to the routing and billing of a call, is free to service another new call after it has selected and set the path through the switching network. The switching network itself maintains the connection until released by the common control at the termination of the call.

The stored program approach to common control for the CTE I was proven beyond a doubt. Experience with the multistage switching network, however, revealed the following limitations:

- Economics — the special switch modules were expensive to manufacture.
- Space — The switching network occupied substantial floor space in relation to the number of crosspoints.
- The network junctor topology had to be changed with each expansion.
- The slow-speed set time of the relays in the switching network reduced the overall call handling capability of the processor-based common control.
- The dc-through-voice bandwidth of the switch matrix was well in excess of the 50-baud capability required for telex.

The high cost of the special multistage switching network, and the expense of procurement of the special purpose computers and controller, made duplication of the CTE I for future exchanges extremely costly. Fortunately, leaps forward in semiconductor and large-scale integration technology made the minicomputer a cost effective system component. The "mini" no longer refered to machine capability but rather to size and cost. Indeed, some of the presently available minicomputers rival their large-scale predecessors in their capabilities. Telex exchange design criteria calling for relatively inexpensive, modular, redundant switching systems became quite realizable with the minicomputer.

The switching system design concepts that will be discussed herein are based upon the General Automation, Inc., SPC-16 series minicomputers and the RCA computer-controlled telex switches, including the special telex switching equipment manufactured by RCA Government Communications and Automated Systems Division, Camden, N.J.

CTE II Components

A block diagram of the Computer Telex Exchange Number Two (CTE II) is contained in Fig. 4. This system is the initial procurement, presently under manufacture. It is scheduled for installation in RCA Global Communications' new East Coast Operating Center early in 1975. The system will be expandable and will allow two additional fully redundant computer-controlled telex (CCT) systems to be added to the present system configuration.

As shown in the block diagram, the CTE II consists of a number of subsystems which are defined below:

CCT 1A and CCT 1B — Switching System 1: a redundant computer-controlled telex switch servicing up to 2000 terminations:

CCT 2A and CCT 2B — Switching System 2: a redundant computer-controlled telex switch servicing up to 2000 terminations.

IAS 1 and IAS 2 — Immediate Access System: a redundant accounting and statistical support subsystem servicing up to four CCT's.

UNICODE — an abbreviated dialing file storage and file control subystem.

System design considerations

The CTE II system has been arranged to operate in conjunction with the CTE I system described earlier. The CTE II will function primarily as a trunk switch. CTE I serves a large number of directly connected line subscribers in the New York Metropolitan area, and will trunk this traffic to the new remote operating center in Piscataway, New Jersey. Here CTE II will have easy access to the Bell System Telephone network hubs located in the area, and will switch traffic to these domestic trunks for distribution throughout the United States or to the RCA Global Communications'. West Coast Remote Operating Center at Lodi, California, for relay trunking to Pacific overseas areas.

The number of directly connected subscribers to CTE II will be limited primarily to RCA administrative printers. It should be noted however, that the CCT allows any mix of line or trunk termination so that, in the future, if a need to connect subscribers in the CTE II area

Fig. 2 — T&N Step-by-step exchange.

Fig. 3 — Computer Telex Exchange Number One.

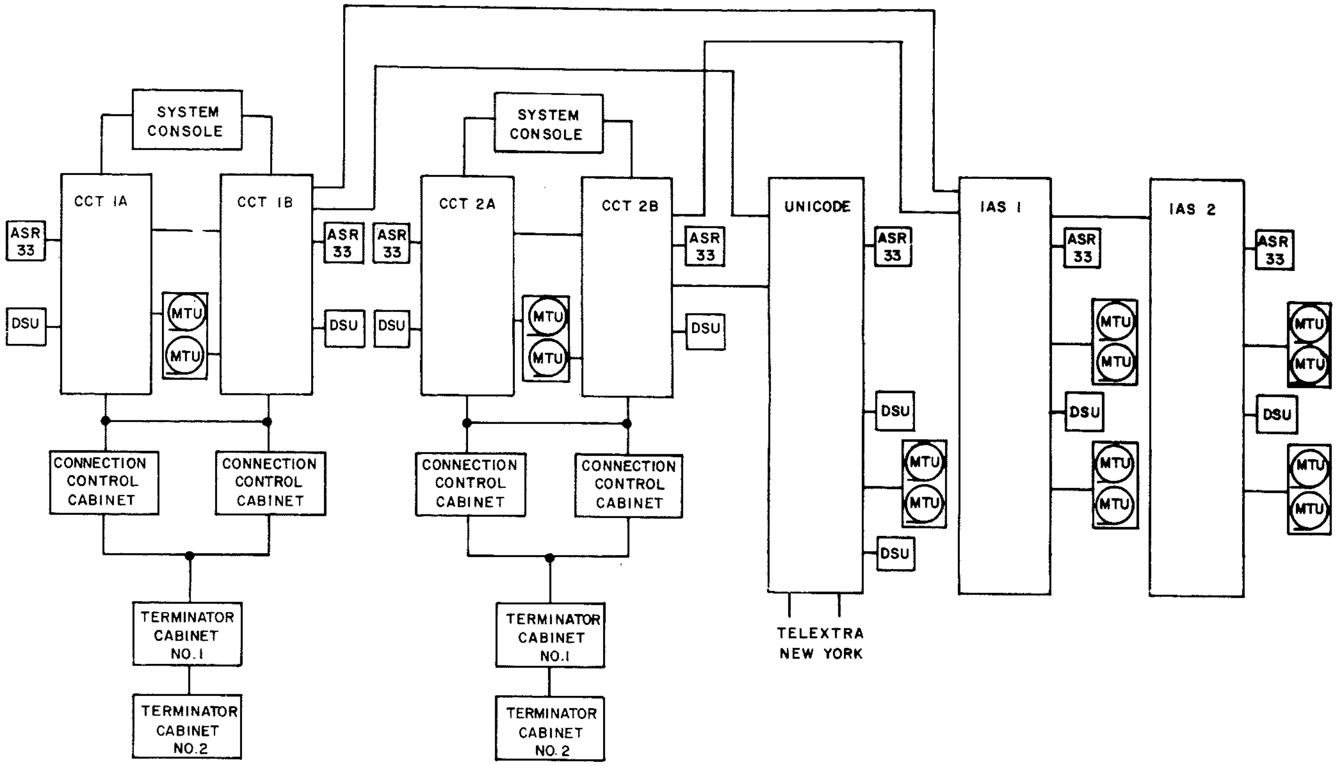

Fig. 4 — CTE II initial system configuration.

becomes a reality, it is only necessary to replace a plug-in terminator card to change any termination from a trunk to a line.

Computer controlled telex system

The maximum termination capability of a single CCT system is in excess of 4000 terminations. The planned ultimate capacity of CTE II is 8000 terminations. CTE II has been designed to utilize only half of the capacity of the CCT system. Therefore, CTE II will require four such CCT systems to handle the 8000 planned terminations. This system limitation was not imposed because of unknowns associated with the capacity of the CCT. Rather, it was desired to limit the effect on the overall grade of service of CTE II to a maximum of 25% degradation in the unlikely event that an entire redundant CCT system failed.

Thus, there is sufficient capacity on each CCT to add directly connected subscribers if needed. Also, CTE II is designed in such a way that two 4000-termination systems could be utilized to handle the 8000 terminations if experience indicates that the design should be modified to downgrade the ultimate CTE II from four 2000-termination CCT switching system to two 4000-termination types.

The critical area in the determination of the ultimate CTE II configuration is judged to be the computer-to-computer interface (CCIF) between the IAS and CCT, which will have to perform the data transfers associated with 4000 terminations instead of 2000 if the system design is changed in the future. A new CCIF incorporating data chaining will offer relief with regard to the overhead involved in the transfer of data between the subsystems.

Unicode subsystem

The Unicode subsystem provides RCA's abbreviated dialing service. An incoming call which contains selection information consisting of a single digit (0-9) is routed on the basis of full selection information associated with the particular digit. This selection information is obtained from a lookup of a disc resident file. Since the selection information is unique to the particular calling subscriber, the decoding of the single digit is performed by maintaining a file of subscriber answerbacks and the associated full selection information for each single digit. The Unicode subsystem accepts requests for file lookup from the CCT via the CCIF and returns the full selection information via the same path.

Facilities for file maintenance are included in the Unicode subsystem. Update of the answerback file on the disc can be accomplished manually via information entered through the ASR-33, or from a pre-prepared magnetic tape (prepared off line). In addition, low-speed lines connected to the RCA Telextra System in New York will allow RCA customer representatives to create or update a customer's Unicode file from the customer's office using the customer's teleprinter. By dialing a special number, the Telextra system will be reached. This system will provide the conversational mode and coaching necessary to allow the customer's file to be updated or created. Once this data is entered, the Telextra system will automatically format an entry and forward this entry to both CTE I and CTE II, and other RCA switching systems (such as Lodi, California) if necessary, and update this particular customer's file simultaneously in all exchanges having Unicode files.

IAS Subsystem

The IAS subsystem performs two basic tasks.

1) For each and every off hook, call attempt, call or CCT event such as peripheral device status change, operator command, error

printouts, etc., statistical information concerning the event is compiled on line by the CCT and forwarded to the IAS. The IAS operates upon these statistics which are received on a per-event basis so that statistical reports of CCT switch operation, traffic patterns, network performance, etc., are available. These reports may utilize either information stored on disc (transient short-term storage) which can be used to generate on line reports, or information stored on tape and run off line on the IAS or on line in a background mode.

2) A subset of the information contained in the above task is the call record necessary to produce an accounting record and subsequent subscriber billing. IAS will separate the call record from the mainstream and write a copy of it to a separate magnetic tape unit (MTU) assigned for the purpose. This tape is later processed off line by the central RCA Management Information System and subscriber bills are produced.

Redundancy of CTE II system

As can be seen from Fig. 4, all subsystems of the CTE II are fully redundant, except for the Unicode subsystem and the individual terminator cabinets of the CCT switching systems.

Unicode redundancy

The Unicode subsystem contains a redundant disc controller and disc storage unit (DSU) which serves as backup for the file storage since the most probable area of failure is in the mechanical moving head disc. The magnetic tape transport is not required for normal Unicode operation and is used only for file update. All other significant items of Unicode are fully electronic plug-in boards and the reliability after initial burn-in is anticipated to allow long-term operation between failures and rapid repair time by substitution of plug-in boards. If a total failure does occur, this simply means the Unicode feature is not available. Normal telex calls can still be made by dialing the full selection information. A spare system console teleprinter (ASR 33) will be kept on site for plug-in substitution if a failure occurs in this device.

IAS redundancy

The IAS subystem is made redundant primarily because of its role in writing the accounting record tape. While only one IAS need be on line at a time, the system design allows for both IAS subystems to receive data via the CCIF and both IAS subsystems can write an accounting tape as well as writing statistical data to the disc and other tapes. This allows two magnetic tapes to be prepared to protect against accidental loss or erasure of the accounting tape. The system can, of course, operate with only one IAS, in which case only a single tape copy is made.

A backup single tape is included on each CCT. This normally is used for program loading, etc., but can function as an accounting tape in an emergency when neither IAS is available. Temporary buffering of accounting data on the CCT disc provides time to accomplish a tape reel change when the tape supply is exhausted.

Since the accounting record is a subset of duplicate information transferred to the IAS disc and IAS tapes, these media provide an additional backup of accounting information. In an emergency, the accounting information could be extracted from the event statistics — manually from a printout if necessary — and bills prepared therefrom.

CCT redundancy

All parts of the the CCT are fully redundant except for the individual terminator cabinets. The present design of the terminator cabinets splits the cabinet into two groups of 128 terminators each, with each group deriving logic power from its own set of power supplies. Additionally, a separate plug-in card is used for each termination. It is anticipated that the terminator cabinet as described will provide sufficiently reliable service, since similar techniques used in CTE I and the Lodi CCT have proven this approach.

The CCT itself is designed so that no single equipment failure will render the entire switching system out of service.

The CCT allows for three modes of its two processing system. Either one of the processing systems is designated ON LINE and the remaining processing system can be either in a STANDBY or OFF LINE mode. In STANDBY, the backup processing system receives data from the ON LINE processing system via the CCIF. This data allows the backup processing system to keep its internal tables updated essentially in synchronism with those of the ON LINE processing system. If the ON LINE processing system fails, the switchover to the backup is automatic and service will continue without interruption. The only effect of a switchover will be to abort a call in the process of establishment which has not proceeded sufficiently to have a table entry completed for it. All established calls will continue uninterrupted.

In the OFF LINE mode, the backup processing system will be engaged in maintenance functions, or other work. It is not updated from the ON LINE processing system, nor is it immediately available for switchover. Manual switchover would be necessry to accomplish transfer of service from the failed ON LINE processing system to the backup OFF LINE processing system.

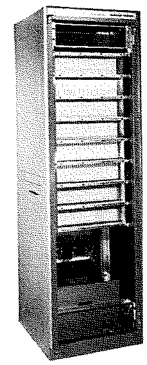

Fig. 5 — RCA Connection Control Cabinet.

CCT subsystem component characteristics

The areas of interest within the CCT subsystem involve primarily the communications switching "front end", since the bulk of the remainder of the configuration is standard general purpose stored-program computer equipment.

Connection control cabinet

Of primary interest is the Connection Control Cabinet (CCC), shown in Fig. 5. The CCC is the equivalent of the switching matrix through which the common control establishes a connection between two terminations, and which maintains this connection independently of the common control, once the connection is established.

The CCC employs time-division multiplexing (TDM) techniques, unlike a crossbar switch or the reed relay matrix of the CTE I discussed earlier, both of which employ space division and a dc copper

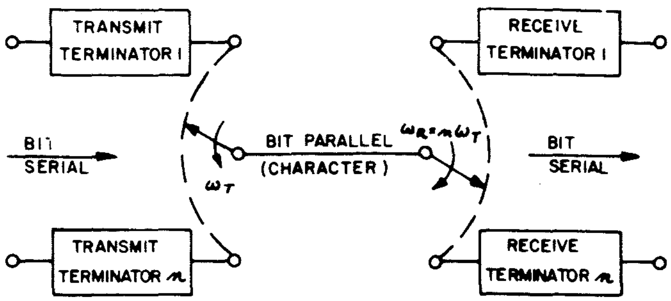

Fig. 6 — Simplified concept of CCC.

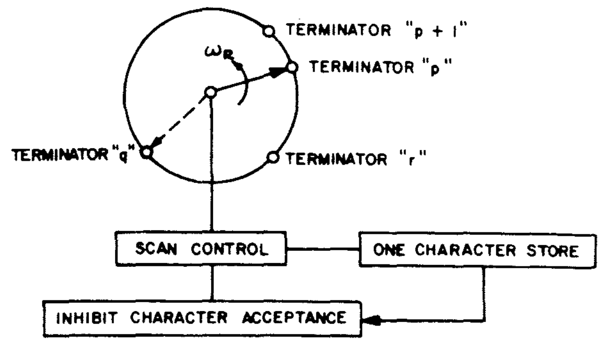

Fig. 7 — Modified concept of CCC.

path connection between the terminators connected.

The concept of TDM equipment is well known. Normally, synchronously scanning devices sweep across a number of communications channels at both ends of a circuit and time share a common interconnecting circuit by transferring some fixed block of data from channel n's time slot (transmit) to channel n's time slot (receive). The scan rate is selected so that the sweep of all channels will be completed and the scan will again reach channel n before another fixed block of data can be accumulated at the maximum modulation rate on that channel.

The TDM concept is modified somewhat in the CCC. The concept can be visualized as two rotating scanners, as shown in Fig. 6. Note that the terms receiving and transmitting terminator as used here refer to the transfer to/from the scanning device and not to the call direction.

The angular sweep velocity of the transmitting scanner, ω_T, is chosen so that it will complete its cycle within the time required for any terminator to accumulate a character bit serially. The angular sweep velocity of the receiving scanner, ω_R, is chosen so that it will complete its cycle within the time frame required for the transmitting scanner to sweep from channel m to channel m+1. Therefore, $\omega_R = n\omega_T$ for an n-port scanner.

In our model, the path is set between the two terminators to be connected by loading the addresses of the two terminators into the respective transmitting and receiving scanner controls. After the call is setup between two terminators by the processor, control logic associated with the transmitting scanner compares the position of the sweep with respect to a terminator address. When the receiving scanner reaches the corresponding position in its sweep, control logic associated with the receiving scanner detects the address comparison and causes the transmitting scanner to transfer a character (bit parallel) from the transmitting terminator to the receiving terminator. The receiving terminator will again convert the bit parallel character to bit serial for transmission on the communications channel.

We can modify the model of Fig. 6 somewhat. It can be seen that two scanners are not necessary, since the receiving scanner only (Fig. 7) could be used to accept and store one character from transmitting terminator "p", and be inhibited from further acceptance of characters from other terminators. When the scan position reaches the receiving terminator "q", the stored character is transferred to that terminator. The scanner control then resumes the scan and accepts a character from transmitting terminator "p+1", inhibiting further character acceptance until it transfers the character received from "p+1" from storage to the appropriate receiving terminator, "r".

The model of the time division connection control of Fig. 7 can be modified further, since the scanner in question is not a rotating mechanical switch. Instead, an electronic counter is used which sequentially scans the terminators utilizing a gating address derived from the counter. The counter address is generated by the count of stepping pulses — which is the contents of the register.

Since the position of the scanner can be forced at random to move to any port (*i.e.*, the scanner can move from position "p" to position "p+5" without sweeping through ports "p+1", "p+2", "p+3", and "p+4"), it will suffice to allow a true sequential scan to occur only for the acceptance of characters from the transmitting terminators. Fig. 8 illustrates a method whereby, once a character has been accepted from terminator "p" and stored in the scanner control, it is not necessary to wait for the scan to reach receiving terminator "q". Instead, the address of the receiving terminator, "q", which was loaded earlier by the common control into the respective scanner controls, could be "jammed" into the terminator gating address register, momentarily overriding the scan address, "p", and forcing the scanner to immediately gate receiving terminator "q". The stored character would then be cleared, and the next stepping pulse into the address counter would cause transmitting terminator "p+1" to be gated.

This process of sequentially scanning only for incoming characters, storing one and only one character from a specific terminator, stopping the scan, forcing the receiving terminator to be gated by the use of a prestored address, transferring the character, and then resuming the scan is exactly the process used in the RCA Connection Control Cabinet.

Since the jam transfer address for terminator "p" is that for terminator "q", and the jam transfer address for terminator "q" is that for terminator "p", it can be seen that the device is inherently bi-directional. A 4-wire equivalent full-duplex path is provided through the RCA CCC.

Several advantages of the time division switch are immediately apparent:

- It is inherently regenerative due to the serial-to-parallel and parallel-to-serial conversions.
- It utilizes minimum bandwidth through the switch.
- It is non-blocking.
- It allows 100% occupancy.
- It is easily adaptable to providing conference or broadcast-type call service since the same character from the same transmitting terminator can be transferred multiple times

to a number of receiving terminators sequentially.

The scanning rates in the RCA Connection Control Cabinet are such that modulation rates up to 600 baud at full occupancy can be accommodated while remaining with CCITT distortion recommendations.

The CCC is implemented utilizing integrated semiconductor memory and integrated semiconductor logic. It consists of a connection memory which stores the addresses of the connected terminators and a connection control which performs the scanning function and effects the transfer of data from terminator to terminator. The CCC will accommodate up to 4096 ports, allowing a maximum of 2048 simultaneous independent 4-wire equivalent connections.

The logic implementation of the CCC allows easy implementation of ancillary functions. For example, the CCC for the CTE II will incorporate detection of a sequence of five consecutive identical characters. The character is strap selectable.

In CTE II, the recognition of five combination 13's (M), will be performed by the CCC and a flag raised to the processor upon detection. The five M's are used in the RCA telex network to convey a request for chargeable time from a TWX/Telex subscriber who has completed a telex call to an overseas party.

The usual procedure of programming the processor to interpret a 600-ms spacing condition as a disconnect and then maintaining the connection until chargeable time is returned by it to the calling subscriber cannot be used with United States domestic subscribers (non-directly connected), since their access to the RCA telex network is via the domestic TWX/Telex (Western Union) teletypewriter switched network. The TWX/Telex network detects the 600-ms spacing condition and disconnects the link to the calling subscriber before the RCA CCT can return the chargeable time.

The inclusion of the five-character recognition in the CCC avoids the cost of providing this circuitry on each trunk terminator card (strap option), or of having special card types with the 5M recognition thereon. This approach avoids the operational problems associated with selectively plugging the proper terminator type into a slot (every strap option effectively creates a new board type). The 5M feature can simply be assigned by program to a specific terminator position and any applicable terminator type utilized.

A switchless switch

Under certain conditions, the design criteria regarding utilization of a separate device to maintain the terminator-to-terminator connection, thereby limiting the overhead on the processor to setting-up and taking-down calls, may be relaxed.

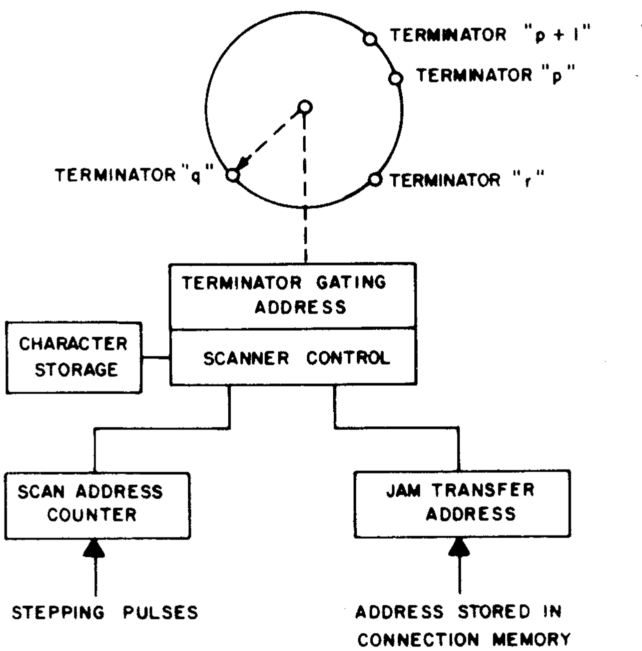

Fig. 8 — Actual CCC operating concept.

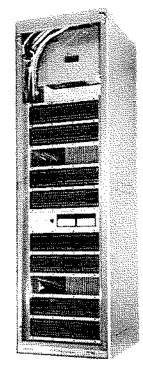

Fig. 9 — RCA line terminator cabinet.

A version of the RCA CCT is available which implements the CCC function, not in a separate device using semiconductor memory, but rather internally under the control of the processor, utilizing core memory. In this version every character transferred utilizes processor memory cycles. Therefore, in this RCA CCT system the maximum number of erminations which can be serviced in this manner is limited to approximately 1000. The switchless switch is, however, field expandable, and a CCC can be added at a future date if needed.

Terminators

The terminators (one plug-in circuit card per termination) are housed in a separate terminator cabinet (see Fig. 9) which can accommodate up to 256 terminators.

It was shown in the description of the function of the CCC that an effective 4-wire non-blocking path exists between any 2 terminators. Therefore, it is immaterial to the CCC whether a line terminator (2-wire) or a trunk terminator (4-wire) is assigned to a port. As far as the terminator cabinet is concerned, this means that the line/trunk card types can be plugged in any card socket at will, allowing any mix of the terminator types.

RCA has developed a number of terminator types (each type consisting of one plug-in board which can be plugged into any one of the 256 slots in a terminator cabinet); see Fig. 10.

All terminators employ solid state circuitry and utilize constant line current regulation such that over the allowable range of dc loop resistance, the nominal current will be maintained without the necessity for adjustment. Presently available terminator types are shown in Table I.

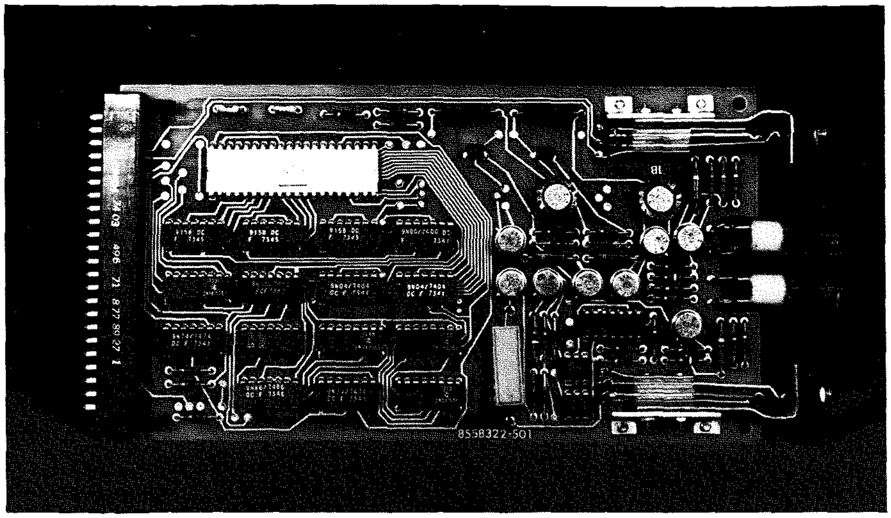

Fig. 10 — Trunk terminator card.

New terminator types which are reasonable variations of the above can be manufactured with minimum redesign efforts, since the majority of the logic remains the same and only the communications line interfacing circuitry need be changed.

In RCA's present design, the limiting factor on line interface in the allowable heat dissipation of the constant current regulator under conditions of low loop resistance. Present terminator and terminator cabinet design allows 2.4-W dissipation per terminator (614-W per terminator cabinet). High loop resistances (up to 3K ohms) can be accomodated by utilizing line current supply voltages of approximately 75 V, instead of the usual 60-V telegraph battery. The higher supply voltage allows for an internal drop across the constant current regulator, such that the terminator equivalent circuit across the line terminations appears as a 60-V source keyed through resistance-less contacts.

The RCA terminators have modulation rates available at 50, 75, 100, 110, 150, 200, 300, 600, 1200 and 1800 baud, any four of which can be provided and program selected. Additionally, each character may have 5, 6, 7, or 8 information bits, or dial plate pulses can be accommodated.

Table I — Available terminator types for RCA CCT.

	4-wire	*2-wire*	*2-wire*
Loop current return	Pair	Pair	Common ground
Loop current	20 mA	40 mA	20 mA
Idle current	−20 mA	5 mA	−20 mA
Signalling	Polar	Neutral	Neutral

The CTE II system

Thus far we have discussed primarily the individual subsystems and components of the CTE II. It might be appropriate at this point to examine some of the overall system considerations involved in mating the mini-based subsystems.

Links

With any multiple system exchange such as CTE II, it becomes necessary to route traffic between systems. A call originating via System 1 and needing outbound access to a trunk on System 2 will be routed on inter-system links between the two systems.

The links for the CTE II system utilize dedicated 4-wire terminators connected together, system-to-system. A special abbreviated signalling will be used to minimize the time of the bid for the outbound system and the subsequent confirmation back to the inbound system. In addition, the variable baud rate of the terminator will allow the inter-system signalling to operate at, say, 300 baud. After the end-to-end call is established, the link will go back to operation at 50 baud to pass the call itself.

Routing director

The Routing Director function is a method which accounts for the fact that multiple trunks to the same destination will be assigned equally over the four CCT subystems of the CTE II (unless actual traffic patterns dictate otherwise).

While this feature is *not* being implemented in the initial phases of CTE II, with only two CCT subsystems, the CTE II system is designed to permit the relatively simple addition of the required programming in the future as Systems 3 and 4 are added.

If a call entering via System 1 for destination "x" finds no trunks to destination "x" available within its own system, it is desirable that, instead of routinely trying the trunks to destination "x" on System 2, and then on System 3, etc., (if those on System 2 are congested), the system knows that a trunk to destination "x" is available at that time, say, on System 4. The system design and configuration of CTE II is uniquely qualified to allow easy implementation of such a routing director function.

As described earlier, the IAS system is receiving statistical data on a per-event basis from all CCT subsystems. This data includes termination status. It will be a relatively simply task in the future to have CTE II take advantage of this data in IAS. A call requiring a trunk to destination "x" which is served by trunks connected to more than two CCT subsystems can, upon encountering no available trunks in the originating CCT, cause the originating CCT to make a high-speed inquiry to the IAS over the computer-to-computer interface. The IAS can examine its file of termination status, and determine which other system has a free trunk available to destination "x". The IAS can then send a high-speed trunk reservation via the computer-to-computer interface to the CCT subsystem which has the available trunk. Upon confirmation of the reservation, IAS can then inform the originating CCT to establish the call on a link directly to the outbound CCT subsystem wherein the outbound trunk has been reserved. No additional equipment is needed to implement this function; only the necessary programming need be written and entered into the respective subystems of CTE II.

Operator consoles

At this point some readers may feel that the system design of CTE II has missed an important component, namely the Operator Console through which directory assistance, assistance in completing calls, booking calls, and interfacing to "manual" type foreign systems is provided.

Because of the relatively low volume of operator-assisted calls experienced by RCA no additional consoles are being provided in the CTE II configuration. Instead, existing consoles associated with the CTE I system in New York City will provide operator service to calls entering CTE II. The connection to CTE I will be made via standard low-speed intersystem trunks — with abbreviated signalling as necessary to expedite call handling. If the outbound trunk is also connected to CTE II, the CTE I Operator will seize the outbound circuit via another intersystem trunk and the call through-connected via the CTE I.

The low volume of operator-assisted calls permits this apparently wasteful application of intersystem trunks. It should be noted, however, that Operator Consoles are available as an option on the RCA CCT, and if necessary these can be added easily in the field.

Conclusion

The system and equipment design concepts that have been discussed are, of course, merely one application of the techniques available through the use of minicomputers and integrated circuit technology.

The conclusion regarding the overall concept, however, is quite clear. There are many applications in the field of communications switching which require that medium-and small-scale data processing techniques be applied to a large-scale number of input/outputs. There exist a number of unrelated functions, the exercise of which can be segregated from the mainstream of the communications switching task, processed independently, and the result *only* returned to the mainstream task. There are many small-scale dedicated switching requirements which can now be satisfied through the use of these inexpensive systems.

The advent of the minicomputer and application of the concepts discussed in this paper fulfill, in a very real sense, the "highly modular and flexible" system design that has been specified in so many procurement documents for so long. The multi-mini approach allows the overall switching load to be distributed over multiple small systems. A single small system can serve as the dedicated inexpensive switch alluded to previously, since the majority of the one-time engineering and programming costs are spread over the large-scale development, and are available virtually intact for use on a small system.

The multi-mini approach allows the user to minimize the effect of a full system down — which does happen occasionally. Instead of being totally out of service during such a period, a single subsystem outage still allows for continued service at reduced capacity. The multi-mini approach allows for a variety of redundancy concepts to be selected, depending upon the worth to the user of maintaining a 99.9% uptime as opposed to perhaps 99.8% or so. One floating spare subsystem, which can be switched in to take over the function of any failed on-line subsystem, is substantially less expensive than the redundancy techniques used for CTE II, if the finite down time associated with accomplishing the substitution can be tolerated.

The use of separate subsystems for special functions involving substantial processing or latency allows preprocessing and buffering, such that the overhead on the mainstream mini, for the special function, is substantially reduced, thus allowing more terminations to be serviced and switched.

Indeed, the cost of a mini-based "intelligent controller" rivals, and in many cases even enjoys a substantial advantage over, an equivalent hard-wired logic device by the time all the one-time engineering costs are included. It may be of interest to note that one such mini-based "intelligent controller" is presently under design for use with CTE I. Recall that the CTE I input/output is special purpose and a new controller design is required to interface any peripheral which has not previously been connected to CTE I. Despite the fact that engineering prototype hard-wired controllers had already been developed and are operating on line with CTE I (these controllers interface magnetic tape transports and moving head disc storage units identical to CTE II to the CTE I input/output), it was determined that for a one-time special application such as this, there was a cost advantage in scrapping the existing designs and going to a minibased controller. The "intelligent controller" utilizes the standard product line peripheral controllers and only an interface converter between the mini I/O and the CTE I input/output must be designed. All other controller functions which would have been provided by hard-wired logic will now be program controlled. Indeed many of the program routines being written for CTE II will be directly applicable in the "intelligent controller". Moreover, the buffering and preprocessing done by the mini-based controller will relieve some overhead on CTE I.

Thus it can be seen that application of the multi-mini concept can be useful even in existing large-scale systems.

The availability of low-cost minicomputers and associated peripheral equipment has made it practical to design large-scale communications switching systems utilizing the multi-mini-subsystem concept. Inherent advantages not only in cost, but in flexibility, interchangeability, standardization and adaptability result from the use of this concept. It is anticipated that future system designs will make more and more use of this approach, tempered perhaps by the increasing availability of the microprocessor.

Future large-scale systems composed of multiple minicomputer/microprocessor subsystems and units should advance communications switching technology in as great a step as did the first application of computers in place of electromechanical devices as common control.

Acknowledgment

The author greatefully acknowledges the assistance of Messrs.: W. Geen, A. Tonkoschkur, J. Schatz, M. Rosenthal, J. Fayer, and Mrs. D. Unger in the preparation and editing of this paper.

Fig. 1 — The 1800-MHz (left) and the 2200-MHz flight-model S-band quadrifilar antennas.

S-band resonant quadrifilar antenna for satellite communications

R.W. Bricker| H.H. Rickert

An S-band self-phased, half-turn, half-wavelength quadrifilar antenna has been designed for an Air Force satellite. The quadrifilar is an electrically small antenna providing circular polarization over a broad angular region.

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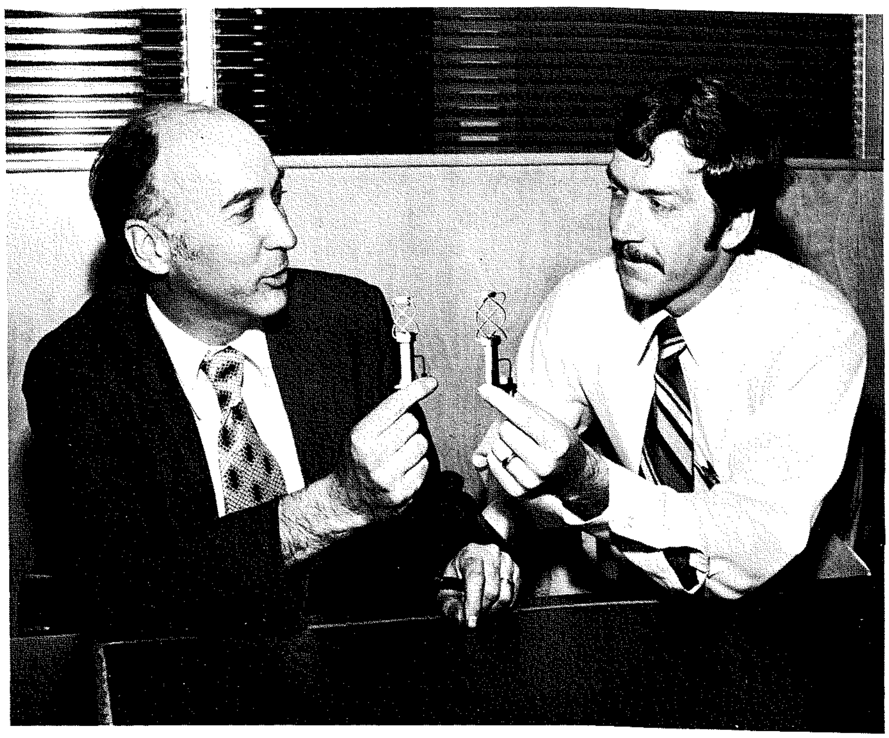
Authors Rickert (left) and Bricker.



THIS PAPER discusses the quadrifilar antenna relative to its performance in a satellite communication system, its electrical and mechanical characteristics as a single antenna, and its basic operating principle. General quadrifilar design information will also be presented as well as the fabrication method of this particular S-band antenna.

Satellite communication system

The satellite communication system requires omni-directional coverage for telemetry transmission and command traffic reception at 2200 MHz and 1800 MHz, respectively. This is accomplished by mounting two pairs of quadrifilars on opposite sides of the spacecraft. Each pair of antennas includes one resonant at each frequency. Fig. 1 shows flight-model Fig. 1 shows a pair of flight-model quadrifilar antennas. Fig. 2 shows a diagram of the mounting configuration and quadrature hybrids used to split the power from the transmitter and sum the power to the receivers. Pattern data recorded from scale model spacecraft measurements show that for over 95% of the coverage sphere each antenna system has a gain greater than the required -15 dB relative to circular isotropic. Fig. 3 shows a pattern through one plane of the omni-directional antennas on the scale model spacecraft.

Electrical and mechanical characteristics

A single half-turn, half-wavelength quadrifilar antenna has an on-axis gain of 5 dB above circular isotropic. A typical radiation pattern is shown in Fig. 4 where the 3-dB beamwidth is about 114 degrees. Fig. 5 shows the axial ratio characteristics taken of the quadrifilar by transmitting from a rotating dipole. The axial ratio is less than 2 dB and 5 dB to ±30 degrees and ±60 degrees, respectively. The quadrifilar has a nominal impedance of 40 ohms resulting in a VSWR of 1.3 to 1. In addition to these electrical characteristics the quadrifilar is mechanically desirable as well. The cylindrical dimensions of both antennas are about 1 in. in diameter by 1 3/4 in. long. The height including the supporting base as pictured in Fig. 1 is about 3 1/2 in. while the corresponding weight is about 0.7 oz.

The quadrifilar is designed to withstand the severe launch and space environment. Both ends of the quadrifilar are potted in teflon disks to support the delicate wires during the launch. One half of the quadrifilar is painted black to eliminate glint that would disturb forward-mounted optical sensors on the spacecraft while the other half is painted white to reduce heating due to the third-stage rocket plume.

Basic operating principle

The quadrifilar design was developed by Dr. C. Kilgus of the Applied Physics Laboratory of Johns Hopkins University. Dr. Kilgus has written several articles on the subject to explain its theoretical and practical functions[1,2,3]. He shows that the current distribution of a half-turn, half-wavelength quadrifilar is similar to the current distribution of a loop dipole antenna. From this analogy, equations are written to describe the normalized radiation field and show that circular

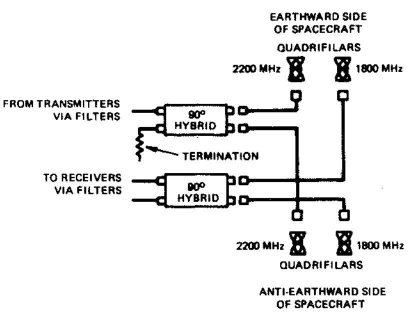


Fig. 2 — Mounting configuration of antenna subsystem on spacecraft.

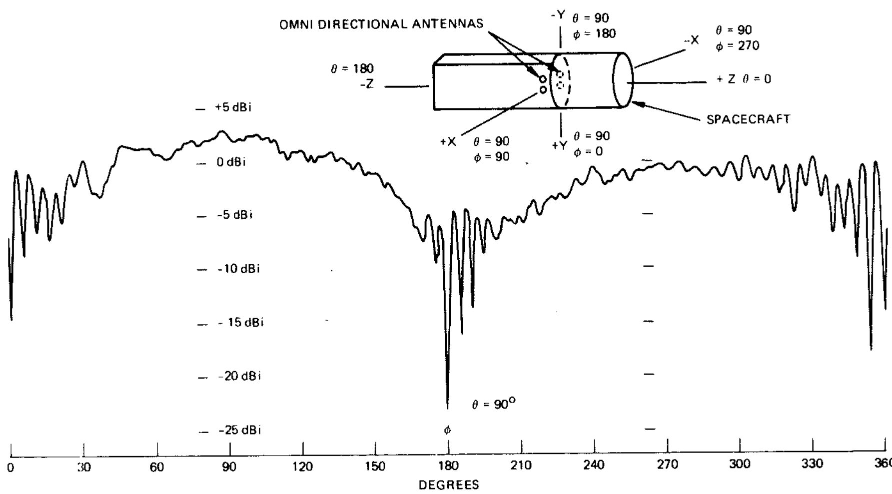


Fig. 3 — Omni-directional patterns on scale model spacecraft.

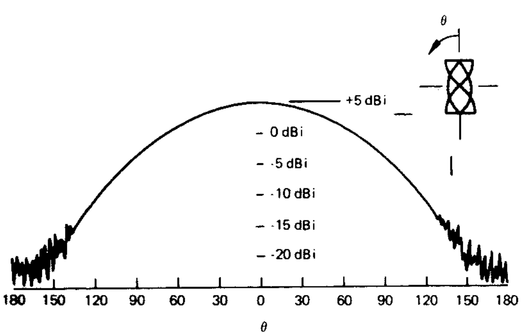


Fig. 4 — Quadrifilar pattern, circularly polarized source.

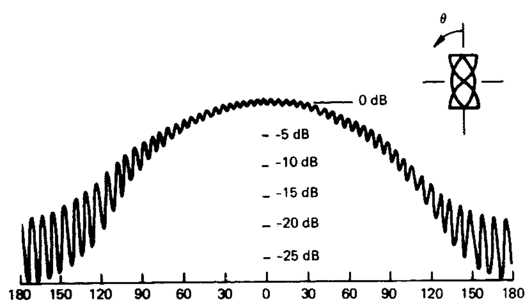


Fig. 5 — Quadrifilar pattern, rotating dipole source.

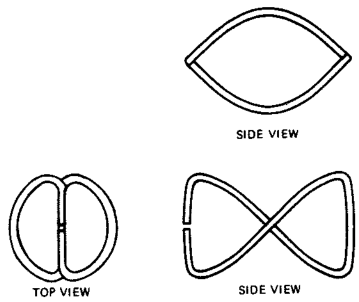


Fig. 6 — Half-turn, half-wave bifilar.

polarization exists over the sphere.

To best understand the operating principle of a quadrifilar, it must be examined in its component form. A quadrifilar in general is a fractional turn four-element helical antenna. It can also be described as two orthogonal bifilars fed in phase quadrature where a bifilar is a two-element helical antenna. A half-turn, half-wavelength bifilar is shown in Fig. 6. Each bifilar produces a toroidal circularly polarized pattern. Two orthogonal bifilars provide a directive circularlv polarized pattern with the pattern direction determined by the phasing between bifilars.

General design information

Several techniques to feed the half-turn, half-wavelength bifilar antenna will be presented followed by two methods of phasing the bifilar to produce a quadrifilar. As with all coaxially fed balanced antennas the bifilar requires a balun. The balun's function is to distribute equal currents of opposite phase from the feeding coax line to the elements of the antenna. Three known balun designs that can be applied to the bifilar are the folded, the split sheath,[4] and the infinite baluns. The folded and split-sheath baluns are similar in that they both are fed by coaxial cables mounted along the axis of the bifilar. Figs. 7 and 8 show a folded balun and a split-sheath balun, respectively. In both cases additional impedance matching networks are required to match the balun design to the coax and bifilar impedance.

The infinite balun method shown in Fig. 9 uses a semi-rigid coaxial cable as one of the elements of the bifilar. At the feed point the center conductor of the coax is soldered to the opposite wire. This connection causes equal currents of opposite phase to flow on the outer surfaces of the coaxial cable and adjoining wire. No additional impedance matching is required because the infinite balun causes no impedance transformation. The 40-ohm impedance of the bifilar when joined to the 50-ohm cable produces a total bifilar VSWR of 1.3 to 1.

The 90-degree phase relationship between bifilars needed to produce the quadrifilar can be achieved by either of two methods. The more direct method is to feed two identical orthogonal bifilars with a quadrature hybrid as shown in Fig. 10 using a split-sheath balun. Any of the three balun designs previously discussed may be used. The 90-degree phase difference is realized at the expense of losing power to the hybrid, adding the hybrid weight to the system, and requiring two cables to feed the two bifilars.

The second method is that of self-phasing the quadrifilar. The desired 90-degree phase difference is obtained by designing the orthogonal bifilars such that one bifilar is larger relative to the desired resonant frequency length and, therefore, inductive while the other bifilar is smaller and, therefore, capacitive. This self-phasing method requires only one coaxial cable for feeding. Any of the three balun designs may be used. Fig. 11 shows how the smaller bifilar is connected to the larger bifilar at the feed point. This connection determines whether the

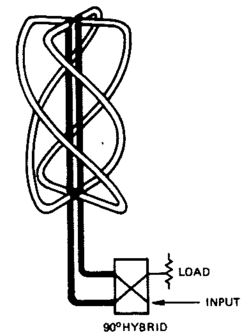


Fig. 10 — Two orthogonal bifilars phased by hybrid.

quadrifilar end-fires to the front or rear. As mentioned earlier the phasing between bifilars determines the pattern direction and the sense of the 90-degree phase relationship determines from which end the quadrifilar radiates. The forward end-fire signal for a right-hand circularly polarized quadrifilar is obtained by connecting the wires as shown in Fig. 11. This configuration produces the desired results because the current leads in the smaller capacitive bifilar and lags in the larger inductive bifilar.

Fig. 12 shows the impedance plot of the larger bifilar. This bifilar was designed such that its quadrifilar design frequency would correspond to the intersection of its frequency response and the $R=X$ curve where R is the resistance and X is the reactance. The $R=X$ curve is significant because in order for the phase of the smaller or larger bifilar to lead or lag, respectively, by 45 degrees, its phase angle must be 45 degrees or have an arc tangent of ± 1 which only occurs when $R=\pm X$. The smaller bifilar was similarly designed such that its quadrifilar design frequency would correspond to the intersection of its frequency response and the $R=-X$ curve. When the two bifilars are added in parallel the resultant impedance response is as shown in Fig. 13. The formation of the cusp is the design goal that signifies that the 90-

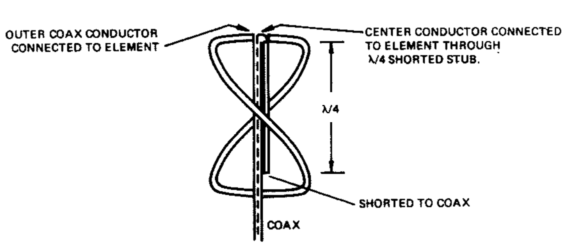


Fig. 7 — Folded balun on bifilar.

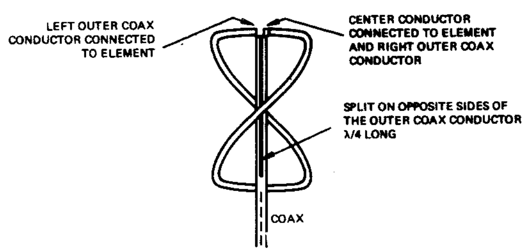


Fig. 8 — Split-sheath balun on bifilar.

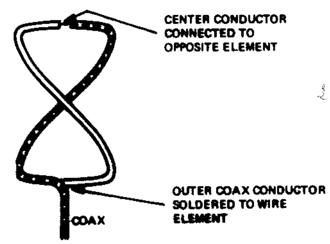


Fig. 9 — Infinite balun on bifilar.

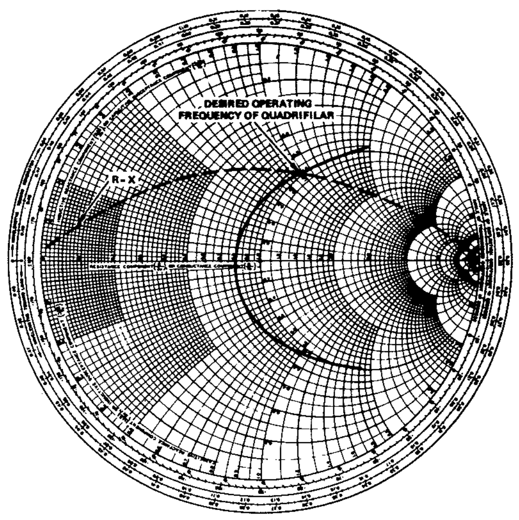


Fig. 12 — Impedance plot of larger bifilar.

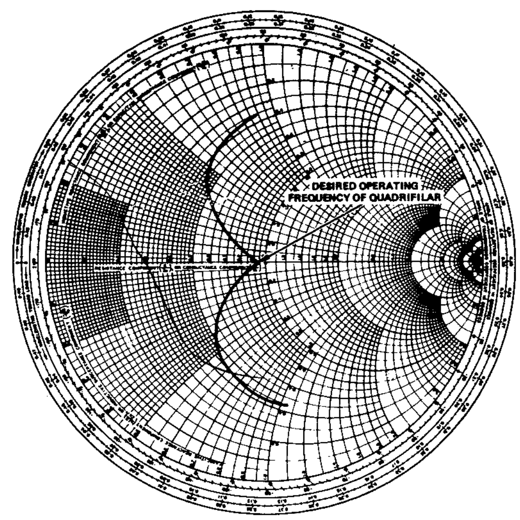


Fig. 13 — Impedance plot of self-phased quadrifilar antenna.

degree phase relationship exists between bifilars.

S-band quadrifilar design

The S-band half-turn, half-wavelength quadrifilar designed for the satellite system is fed by an infinite balun and self-phased. Based on data published in one of Dr. Kilgus' articles,[3] the half-turn, half-wavelength quadrifilar design was selected to be most applicable to the spacecraft system requirements. The choice of the infinite balun was made because it eliminated the necessary impedance matching of the other balun methods and also eliminated the weight of an axial member since the coaxial cable is one of the antenna elements. The self-phased method was selected over the hybrid-phased method because the hybrid would add loss and weight to the system and would require two feed lines to the bifilars. The proper phasing was obtained using the technique previously mentioned. Specific element lengths were wound on precision mandrels to acquire the correct phasing for the desired operating frequency. The element lengths relative to the operating frequency are 0.508λ for the capacitive elements and 0.560λ for the inductive elements. The cylindrical mandrel dimensions were 0.172λ in diameter by 0.260λ long for the larger inductive bifilar and 0.156λ in diameter by 0.238λ long for the smaller capacitive bifilar. Additional soldering and potting fixtures were made to maintain alignment during assembly.

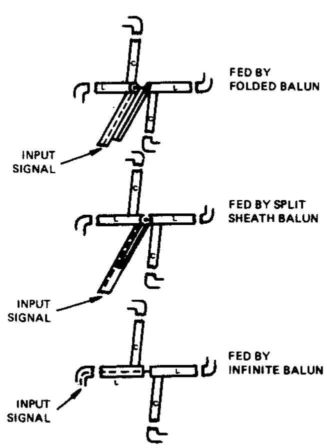


Fig. 11 — Feed-point connection for self-phased bifilar.

Fig. 14 is a drawing of the flight-model antenna. The cable is a 0.047-in. diameter semi-rigid coax that is terminated at an SMA connector mounted to the support base. The other three elements are copper-clad steel and add rigidity to the assembly.

The antennas were qualified by successfully passing test requirements that included thermal cycling from -40 to +100°C, a power test of 10 watts from ambient pressure through critical pressure to a hard vacuum, a three-axis vibration test, and pattern measurements.

Conclusion

This application of a half-turn, half-wavelength quadrifilar at S-band has been a significant step forward in improving the antenna subsystem of a specific Air Force spacecraft. This electrically and geometrically small, lightweight antenna described has electrical properties that accommodate spacecraft system requirements most satisfactorily.

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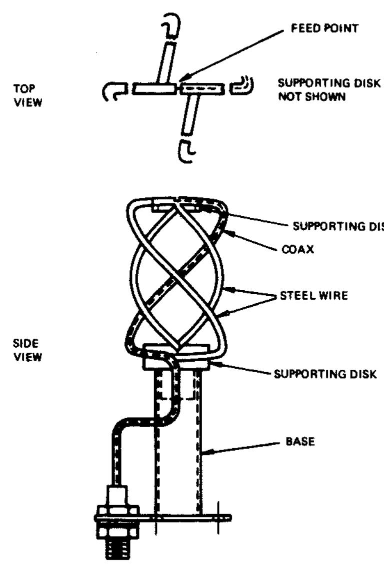


Fig. 14 — Quadrifilar sketch.

Minicomputer applications in building management systems

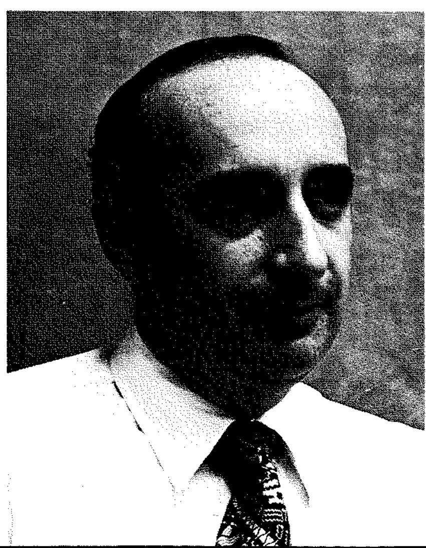
J.H. O'Connell | D.M. Priestley

Two modern RCA building-management system applications using minicomputers are the Disney World complex and the Wells Fargo bank-building management system now nearing completion. The Wells Fargo system manages a major new skyscraper, two other buildings in the same city, and a fourth building located forty miles away. In addition to providing security that may well set a new standard for the banking industry, the system optimizes mechanical systems operation to conserve energy. The minicomputers are configured with redundant peripherals to preclude interruption of system operation. The technical design considerations and tradeoffs for the principal hardware and software functions needed to implement a successful management system are explained by the authors.

MODERN BUILDINGS have become increasingly complex to manage because of demands by owners, operators, and occupants for more and better services beyond the basics of lighting, heating, and cooling. Building management has become so complex, in fact, that minicomputers are now used to monitor and control a wide range of building services: environmental control, security, energy management, life safety, system communications, and management information.

The two modern applications of minicomputers described in this paper provide the following advantages: reduced operating costs; reduced energy consumption; improved handling of many different demands simultaneously, with each problem demanding an immediate response; and provision of management reports of building system performance.

John H. O'Connell, Engineering Scientist, Building Management Systems, Burlington, Mass. received his BSEE degree from Fournier Institute of Technology, Lemont, Illinois in 1954. At RCA Laboratories, Princeton, N.J. from 1954 to 1961, he designed transistor circuits for radio and tv receivers and participated in the design of stereo broadcasting systems. From 1961 to 1965, he was with RCA Astro Electronics, Princeton, N.J., where he designed power supply systems for the Ranger and Nimbus spacecraft. In 1965, he transferred to RCA Aerospace Systems, Burlington, 'Mass. where he designed hardware and software for a variety of automatic test and monitoring systems. He also designed computer programs for collecting and summarizing factory test and reject data. In 1973, he joined RCA Building Management Systems where he is engaged in implementing computer programs for monitoring and control of building equipment. Mr. O'Connell is a registered professional engineer in the State of Massachusetts.



David M. Priestley, Manager, Building Management Systems, Burlington, Mass. received his B.S. degree in Electrical Engineering from Northeastern University. He has pursued engineering graduate study at the University of Pennsylvania, attended the Management Development Program of Northeastern University and recently completed the Progarm for Management Development at Harvard University Graduate School of Business Administration. At RCA Airborne Systems Division, Camden, N.J. from 1956 to 1960, he participated in the design of UHF transceivers. From 1960 to 1962, he was with RCA Industrial Automation Department, Natick, Mass., wehre he was project engineer for the supervisory and remote control subsystem of a transcontinental microwave system. After transfer to RCA Aersopace Systems Division, Burlington, Mass. in 1962, he managed development of hardware and software for a variety of automation systems including the Land Combat Support System, Walt Disney World Automatic Monitoring and Control System, and the AEGIS Operational Readiness and Test System. He joined RCA Building Management Systems in 1973 and is currently Manager, Technical Operations.

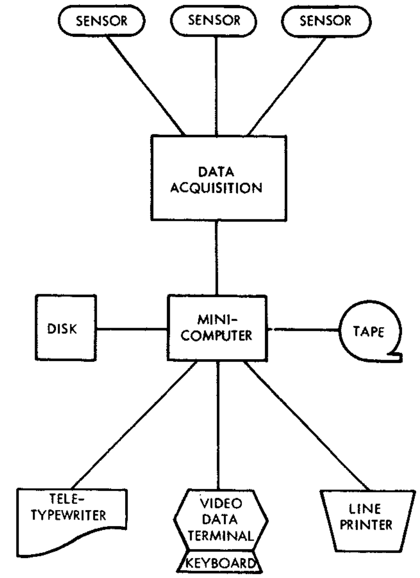


Fig. 1 — Basic system block diagram.

Basic system description

The essential elements of a building management system are:

1) data acquisition hardware to monitor sensor points and to control devices;
2) a minicomputer to periodically scan the sensor points, process point changes and output control commands and/or alarm messages;
3) video data terminals for operator display of system status and entering control commands,
4) printers and teletypewriters for hard copy reports and messages,
5) disks for storing application programs and data; and
6) magnetic tapes for logging information.

A simplified block diagram (Fig. 1) illustrates these elements. The minicomputer scans all the monitored points once per second. If any point changes state or value from the last saved value, it is passed to an application program that may type an alarm message, change a

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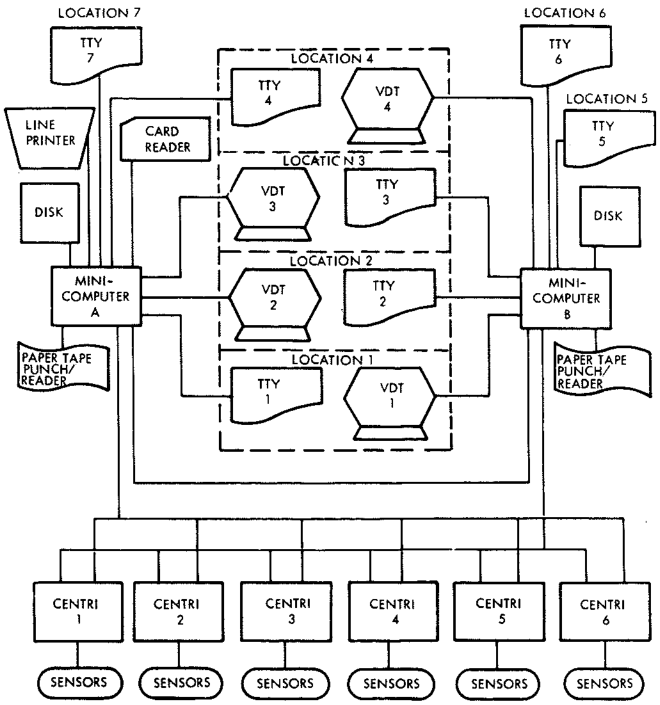

Fig. 2 — Disney World systems diagram.

controlled device, or save the change for future processing. At any time, the operator may use the video data terminal to display system status, enter commands for controlling building equipment, or to change the automatic system operating mode. All critical alarm messages are immediately typed by the teletypewriter and also written to the logging tape; the logging tape also contains system parameters which are periodically written to the tape. The contents of the logged tape may be selectively printed on the line printer.

Walt Disney World application

Disneyworld, in Orlando, Florida is the brainchild of Walt Disney and the product of the entire Disney organization. Disneyworld opened its gates in October, 1971; the project is already a success with the actual guest attendance about twice that predicted.

A communications-oriented monitoring, control and management system has resulted which includes a common user cable plant, and a wide variety of computerized services and electronic subsystems. The communications system called the automatic monitoring and control system (AM&CS), monitors and controls a wide variety of services shown below:

1) Air handler monitoring and control
2) Control energy plant monitoring and energy measuring
3) Fuel loading
4) Fire protection system monitoring
5) Park attendance monitoring
6) Refrigerated storage monitoring
7) Security protection system monitoring
8) Secondary power monitoring and control
9) Waste disposal system monitoring
10) Domestic water supply system monitoring
11) Drainage system monitoring

A block diagram of AM&CS is shown in Fig. 2. The instrument field, dispersed throughout Disneyworld, contains some 2000 sense and control points of the usual variety. Six strategically located data acquisition terminals called Centri's (Central Interrogators) scan the points in their own areas once during each second of operation. To meet redundancy requirements, certain important points, like fire, are scanned independently by two Centri's. The lines to these points are also supervised by the Centri's so that the system can differentiate between transmission line trouble and a true alarm. If the status of a point is unchanged from that of the previous scan, the Centri takes no action; if the point status has changed (or if there is a line trouble) the Centri so informs two redundant central computers, labeled A and B. Through operator request commands, the central computers can also ask the Centri's to send particular data even though a change has not occurred.

Acting as a clearing house for all of the data flowing to and from the Centri's, the central computers take appropriate final action such as:

1) perform a calculation,
2) store data for later use,
3) tell a Centri to close a contact,
4) ask other Centri's for additional information concerning associated points, or
5) simply output a message at one or more of the seven display locations.

All actions taken by the computers are routed through the appropriate Centri to the central computer; the actions are also displayed to appropriate operators. Information is sent selectively to each location, so that the particular operator has all the information he needs, but is not bothered by extraneous alarms and data.

Each Centri contains a 4000 word minicomputer. The minicomputer scans all the points interfaced with the Centri and sends point changes through modems and telephone lines to both central computer complexes.

The A and B central computers both process all point changes; however, through intercommunication, one computer is the master and the other is the slave. Each computer periodically tests the other one and the slave can assume the master function if the master should fail. At each central computer complex there is a 16,000-word computer, 256,000-word fixed head disk, paper-tape reader and punch, a teletypewriter and modems. The A computer complex also contains a card reader and high-speed line printer to allow program assembly and debugging.

The software system contains five major program categories:

1) The core resident Executive that initiates execution of application programs, services all input/output commands, allocates core memory, services operator requests, and controls computer role.
2) The application programs that process point changes and interact with the operator to acknowledge alarms, add or delete peripherals from the system, and define computer roles.
3) The self-test programs that periodically test the communications links between computers, check computer functions, check computer roles, and detect peripheral failures.

4) The data base defines which application program processes the point and which message or control function results from the point change.

5) The utility programs which facilitate program assembly and maintenance.

Wells Fargo application

RCA is finishing a building management system for the Wells Fargo Bank in San Francisco. The system monitors and controls the management activities of one new building (with 1-million square feet of floor space) — plus the activities of three other distant buildings; two of these are in downtown San Francisco, and the third located 40 miles away in San Jose. The major services provided are security, monitoring and control of electrical/mechanical systems, fire and smoke detection, and management information.

The security system types alarm messages for all breaches of secured doors. In addition, it provides access control to secure areas by restricting entry to badge holders allowed access to selected areas. These secure areas are monitored at a central location by computer control of a network of tv cameras and tv monitors.

The electrical/mechanical system reports all equipment malfunctions as alarm messages. Examples of these malfunctions are fans shutting down, exceeding temperature limits, and power failures. The building engineers may use a video data terminal to start or stop fans, chillers, or pumps. In addition, the computer automatically controls fans and lights in accordance with a real time schedule that may be changed by the building engineer. Plans for the future include automatic control of this equipment to achieve energy conservation.

Fire and smoke detection results in a typed alarm message whenever an alarm occurs. In addition, controls are provided in the lobby so that firemen may turn fans *on* or *off* to aid the fire fighting efforts.

The management information system includes the status displays for fire, lights, fans, air conditioning, and security systems. In addition, all alarm messages and status conditions are logged to magnetic tape. This log tape may be selectively searched to print any desired information.

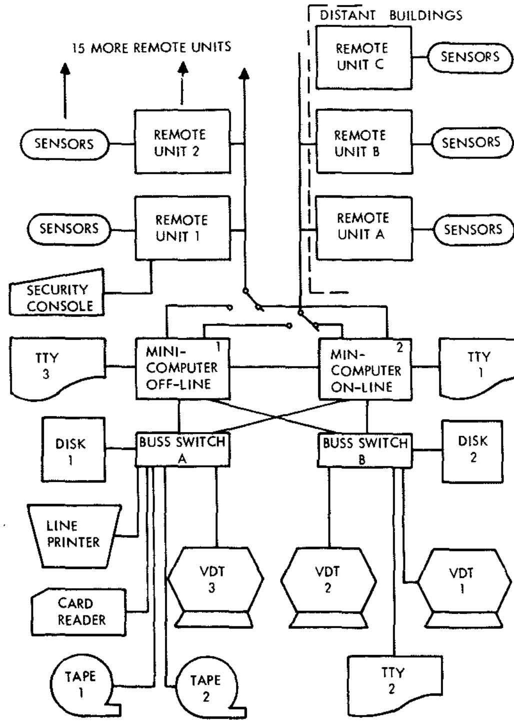

Fig. 3 — Wells Fargo system diagram.

The data base defines the hardware sensors for scan, control points for devices, and the access control for secure areas. This data base may be changed either on-line or off-line.

A block diagram of the Wells Fargo System is shown in Fig. 3. At the central computer complex, there are two 32,000-word computers. Either computer may scan data or control devices in remote units connected to computers by a cable of two twisted pairs. The remote units are located on several floors of the building and one remote unit is located in each of the three distant buildings. Only one computer processes all the point changes and operator requests, and the other serves as a backup that tests the on-line computer through a communications link. The computer peripherals are connected to the on-line computer through a programmable buss switch. These peripherals are two 512,000-word fixed-head disks, two magnetic tape units, three video data terminals, two teletypewriters, a high-speed line printer, and a card reader. The buss switch allows the back-up computer to assemble and debug programs, or change the data base while the on-line computer performs its normal functions.

The software system is similar to the Disneyworld system, except that the application programs are designed to satisfy specific Wells Fargo requirements.

Conclusions

Building management systems employing minicomputers provide a central location for monitoring and controlling a variety of building services. Moreover, the space required for the centralized system equipment is much less than systems requiring independent control of the various services.

Monitoring and control signals are multiplexed onto a single cable, reducing multiple runs of wires in the building. Building operating costs may be lowered through energy savings and reduced manpower. The rapid detection of equipment failures, life safety alarms, and security breaches leads to a quicker response to handling these problems. The logging functions provide building management with the information needed to develop better operating procedures and justify future growth and expansion of the system into new services. Finally, from a technical viewpoint, the system represents a successful consolidation of many unrelated functions into a single minicomputer with an effective means of sharing computer resources and processsing time.

Solid state optical recording

G.M. Claffie| J.E. Roddy

Laser diodes and acousto-optic beam deflectors have been developed that appear to be well suited for use in laser film recording systems of moderate complexity. This paper considers: 1) an internally modulated semiconductor laser as the replacement for the externally modulated gas laser—as the means for generating the record signal—and 2) an acousto-optic beam deflector as the replacement for a rotating mirror assembly to achieve fast horizontal film scanning.

CENTRAL COMPONENTS of today's laser recording systems are gas lasers, external laser beam intensity modulators, and high-speed rotating mirror assemblies. While impressive performance has been achieved, these components are bulky, mechanically elaborate and expensive. If laser recording is to be used for other than a few highly specialized data capture applications, the component costs must be reduced and the reliance upon high precision mechanical parts must be minimized. Semiconductor device and laser beam deflector research programs conducted at RCA Laboratories in Princeton indicate that these barriers to more general use of laser recording are temporary.

The laser diode — an internally modulated record signal source

Advanced Technology Laboratories G&CS is currently investigating the use of developmental laser diodes supplied by RCA Laboratories as the record signal source in a wideband laser recorder. Laser diodes are an attractive record signal source in that they are compact, can be internally modulated at very high rates, and are potentially inexpensive. Two developments have made the use of laser diodes in wideband recording systems particularly worth considering at this time. First, laser diodes that emit continuously at wavelengths below 720 nm, at power levels in excess of 5 mW have been fabricated.[1] Second, extended red-sensitive holographic films that can be used at wavelengths up to 720 nm have been developed by Kodak and Agfa-Gevaert, and they are being used in developmental laser recorders. In addition, experimental dry silver film, sensitive to 700 nm, has become available.

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Diode characteristics

The key characteristics of a diode to be used as a record signal source are the lasing threshold current density, external quantum efficiency, emission wavelength and intensity, emission pattern, and the rate at which it can be modulated.

Lasing action is initiated by injecting electrons into a p-n junction at a rate that exceeds the lasing threshold current density. The junction region is configured as a Fabry-Perot cavity formed by cleaving the two end (mirror) faces of the semiconductor specimen to support longitudinal oscillations and rough cutting the sides to reduce transverse oscillations. The reduction of the lasing threshold current density in recently developed diodes is largely due to the use of a "close-confinement" structure in the diode active region.[1]

A heterojunction is a junction between two dissimilar materials such as $(AlGa)As$ and $GaAs$ or $(Al_xGa_{1-x})As$ and $(Al_yGa_{1-y})As$. By choosing appropriate variations in diode layer composition, it is possible to adjust both the bandgap energy and the refractive index at the heterojunctions. The refractive index steps confine the optical flux and create a dielectric waveguide between the end facets. The potential barriers caused by the difference in material bandgap energy confine the carriers to a small volume and, thereby, reduce the current needed

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Authors Claffie (left) and Roddy. Claffie has his hand on a gas laser. To his left are the modulator and drive electronics used with this laser in a wideband recorder. Roddy is pointing to a laser diode mounted for use in a solid state recorder.

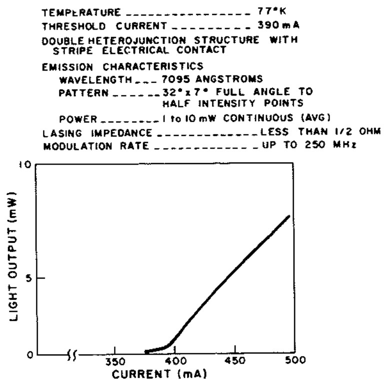

Fig. 1 — Laser diode characteristics.

to initiate lasing action. The lasing threshold current can be further reduced by using a narrow (stripe geometry) electrical contact to the diode.[2] A principal benefit derived from reducing the threshold current is that the diode is easier to cool and a higher continuous output can be maintained.

Above threshold, diode output is essentially a linear function of the drive current. The slope of the characteristic curve relating emitted output to current is defined as the differential quantum efficiency of the diode. The emission pattern depends upon the uniformity, the size and shape of the source, and the modes that have been excited. The lasing region of a heterojunction laser tends to be well defined if a stripe geometry electrical contact is used. The emitted radiation pattern is generally broad and may be dependent upon the average current supplied to the diode. Efficient collection of this radiation is a major consideration in the design of the optics that form the record spot.

The wavelength of the emitted radiation is determined by the effective bandgap of the active diode junction. Aluminum is used in the diode crystalline structure to increase the effective bandgap and, thereby, reduce the wavelength of the emitted radiation. However, this severely reduces diode quantum efficiency at a given operating temperature when the diode wavelength is reduced below 800 nm. This reduction in efficiency is a primary reason why currently available diode samples must be cooled to achieve continuous operation at the wavelengths required for film recording.

The characteristic curve of a diode sample currently being evaluated is shown in Fig. 1. The characteristic curve and the operating parameters noted in Fig. 1 apply for continuous diode operation when the diode is cooled by liquid nitrogen to 77° K.

Diode cooling and mounting structure

Although mechanical cryogenic refrigerators are commercially available, increased experimental flexibility is afforded by using cryogenic fluids in the custom cooling and mounting structure shown in Fig. 2. This unit, approximately 10 in. high with a 7-inch diameter, is constructed primarily of stainless steel. The laser diode is mounted on a copper plug, and is cooled by conduction. Tests at temperatures above liquid nitrogen can be conducted by using a suitable liquid coolant. For example, a dry ice and acetone mixture is convenient for operation near 200°. The diode is placed in a vacuum to prevent frost formation on the emitting facet. The cooling and mounting structure has been designed so that the diode output intensity can be modulated at frequencies in excess of 250 MHz. The sweep and singletone response for the diode described in Fig. 1 are shown in Fig. 3. The test equipment used to acquire data is shown in Fig. 4.

The laser diode investigation currently being conducted at the Advanced Technology Laboratories is directed toward using these diodes as the exposure energy source in film recorders that can accept baseband data rates as high as 100 MHz. For the following discussion, however, consider the use of the laser diode characterized in Fig. 1 as the source in a moderate resolution recorder that will continuously record image data at

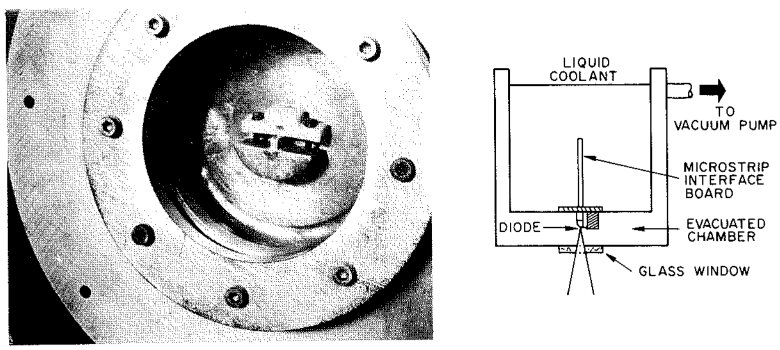

Fig. 2 — Diode cooling and mounting structure.

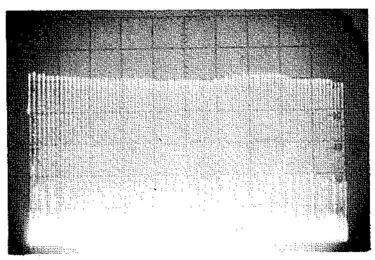

Fig. 3a — Detected signal, 1- to 200-MHz sweep (diode drive = 35 mA p-p).

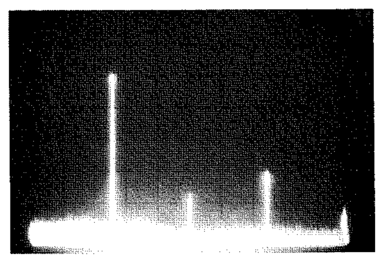

Fig. 3b — Harmonic distortion, 50-MHz detected signal (diode current = 35 mA p-p).

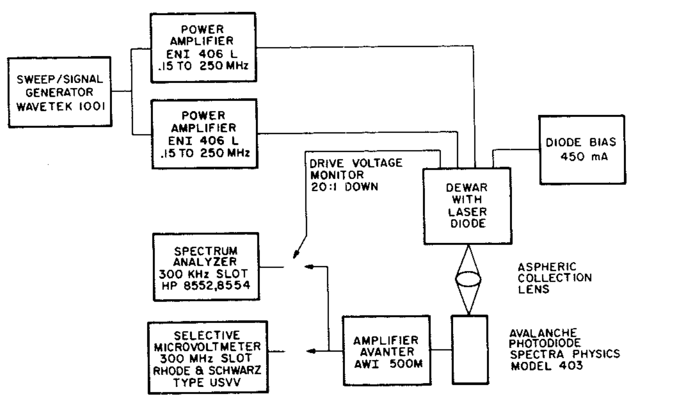

Fig. 4 — Test configuration for measuring diode frequency response, noise and distortion.

frequencies extending from dc to 5 MHz. The diode-related electrical, optical, and source power considerations for such a recorder are as follows.

Diode drive signal and bias electronics

When lasing, the diode impedance is about 1/2 ohm. The record signal is applied to the diode through an interface network that is placed close to the diode in the cooling and mounting structure. This network contains a 25-ohm load resistor placed in series with the diode and a pair of phase-matched 50-ohm line drivers A diode bias current is added to the drive signal through a resistor that is also placed very close to the diode.

Record optics

The diode power and output-beam divergence, the film scanner, and the record spot size determine the configuration of the record optics. The emitting facet of the diode is mounted orthogonal to the axis of the record optics. The junction dimension in the direction of record spot motion (along the track) is about 2 μm for the samples in use.

The dimension of the lasing region in the direction of record spot width (across the track) is primarily determined by the width of the stripe electrical contact. It is about one mil for the samples in use. The full-angle beamwidth to the half-intensity points is about 30° along the track and 7° across the track.

Consider that it is desired to place 500 Rayleigh spots across 16-mm film with equivalent resolution in the direction of film motion. For this case, where the usable film scan length is 10 mm, the effective record spot spacing should be 0.02 mm both along and across the scan directions.

Diode power requirement

A commercially available film that is sensitive in the 650 to 720 nm spectral region and has granularity and resolution properties suitable for a laser recorder is AGFA 10E75. The laser power required at the film is approximated by:

$$P = Kwv$$

where K is the film sensitivity, w is the record spot width and v is the record spot

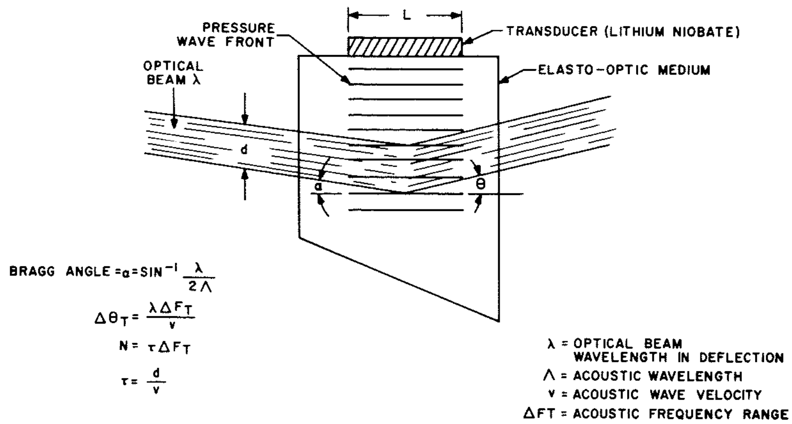

Fig. 5 — Acousto-optic deflection.

velocity. The spot velocity is set by requiring that two Rayleigh spots be placed on film for the highest recorded frequency of 5 MHz. This criterion is met if 10 x 10^6 spots are recorded per second. The corresponding film scan rate is 20 kHz and the spot velocity is 200 m/s. The film sensitivity corresponding to a density of 1.0 is about 50 erg/cm^2. Therefore, for a spot width of 0.04 mm to the first null points, the power required at the film is about 0.4 mW. Losses that can be expected, due to the transmission characteristics of the record optics and the failure to collect and image all of the widely divergent beam emitted by the diode, significantly increase the required diode power. The output of the diode samples that have been described is sufficient if these losses are less than 15 to 1.

Acousto-optic deflectors in laser film recorders

ATL has evaluated developmental high-speed laser-beam deflectors as a means to compensate for film scanning mirror inaccuracies, transport alignment erros, and film dimensional instabilities. Initial deflectors utilized the electric-field-dependent index of refraction of certain crystal materials to achieve deflection. These deflectors required drive signals in the kilovolt amplitude range at frequencies corresponding to the correction rate. In addition, they introduced severe beam attenuation, distortion, and scattering.[3]

More encouraging results were subsequently obtained by using acousto-optic beam deflectors that utilize the scattering of light caused by pressure-produced refractive index variations in lead molybdate material.[4] After the testing effort was concluded, an acousto-optic deflector with paratellurite material (TeO_2)the elasto-optic medium was used as the horizontal scanner in a tv-rate laser display.[5] It appears that a TeO_2deflector with characteristics quite similar to those used in the laser display is well suited for the horizontal film scanning task in moderate resolution film recorders.

The following paragraphs briefly present the characteristics of Bragg scattering in acousto-optic deflectors and highlight some of the characteristics of paratellurite versus lead molybdate material. The design of a continuous film scanner based on the use of a pair of TeO_2 deflectors is then discussed.

Bragg scattering

The deflection of laser beams by pressure-produced changes in the refractive index of an acousto-optic material has been described in detail.[6] Briefly, if a laser beam of wavelength λ and an acoustic wave of wavelength Λ are propagating in an acousto-optic material, and the beam intersects the acoustic wavefronts at the Bragg angle given by

$$\alpha = \sin^{-1} \lambda/2\Lambda \qquad (1)$$

the beam will be split primarily into a non-deflected component and a single deflected component. The angular orientation and intensity of the deflected component depend on the frequency and amplitude of the acoustic wave, respectively. The time τ required for an acoustic wavefront to pass across the incident beam in the deflector shown in Fig. 5 (deflector access time) is given by:

$$\tau = d/v \quad (2)$$

where d is the beam of dimension in the direction of acoustic wave motion (the scan direction) and v is the wave velocity. The total angular deflection, $\Delta\theta_T$, is related to the total change in the acoustic drive signal frequency, ΔF_T, by

$$\Delta\theta_T = \lambda\Delta F_T/v \quad (3)$$

If resolution is defined as the ratio of the total angular deflection to the angular spread of the optical beam due to diffraction, ϕ, the number of resolvable spots is given by

$$N = \Delta\theta_T/\phi \quad (4)$$

The diffraction-induced spread is proportional to the beam wavelength and inversely proportional to the beam dimension in the direction of scan, or

$$\phi = \alpha\lambda/d \quad (5)$$

where the constant of proportionality, α is determined by the intensity distribution of the beam and the resolution criterion used. For a uniformly intense rectangular beam ($\alpha = 1$), the number of Rayleigh spots that can be resolved in given by:

$$N = \tau\Delta F_T \quad (6)$$

which is the time-bandwidth product of the deflector.

Efficiency, which may be defined as the ratio of the intensity of the deflected beam to the intensity of the deflector output in the absence of acoustic interaction, is proportional to the interaction length over which Bragg scattering takes place and the level of the acoustic drive signal. It is desirable to propagate a single-phase acoustic wave in a nonvariable direction through the deflector. Since the input beam angle is fixed and the Bragg angle is frequency dependent, there is a limited frequency range over which efficient deflection is maintained. The optical beam will interact with different angular portions of a diverging acoustic wave at different frequencies. However, acoustic-wave divergence is increased by reducing the length of the transducer in the direction of interaction, requiring an increase in the acoustic drive power to maintain efficiency.

A major advantage of paratellurite over the previously used lead-molybdate material is that the Bragg angle changes very little over a broad acoustic frequency range. Therefore, very little acoustic-wave divergence is required and a long interaction length can be used. Additional characteristics of TeO_2 that make it an attractive deflector component are:

1) Low acoustic wave velocity, which means that a large angular deflection range can be achieved with a small optical aperture.

2) The Bragg condition is satisfied at acoustic drive frequencies below 100 MHz for all optical wavelengths of interest, and acoustic losses are tolerable in this frequency range.

3) Moderate acoustic drive signal levels introduce index of refraction changes that are sufficient to achieve high deflection efficiency.

4) The material is nonhygroscopic, and easily polished and handled. Growth is simplified by the small optical aperture requirements.

Acousto-optic deflectors for continuous film scanning

A sequential film scanner may be constructed using two beam deflectors configured as shown in Fig. 6. The electrical drive signals to the transducers are phased such that the output from one deflector reaches the trailing edge of the film as the beam from the second deflector starts to scan. In this fashion, continuous horizontal film scanning is accomplished with the output of each deflector scanning alternate tracks across the film. Vertical scan is accomplished by continuously moving the film. A linear fm ramp of decreasing frequency is continuously applied to each deflector. A fixed downward rate of frequency change ensures that the difference in acoustic frequency across the optical beam is constant. Also, the highest frequency within the optical aperture during the film-scan portion of the deflector cycle is always at the optical beam edge that is furthest from the transducer. This frequency distribution has the effect of creating a cylindrical lens that focuses the output of the deflector. The focal length of this virtual cylindrical lens is fixed for a constant film-scanning rate and is given by:

$$F = v^2 T_s/\lambda\Delta F_T \quad (7)$$

where T_s is the period of the drive frequency ramp.

The operating cycle for each deflector is the same except that one deflector is entering retrace when the other deflector is starting to scan the film. The film scan and retrace intervals for each deflector are equal to each other and to the deflector access time. Film scan is completed when the lowest fm ramp frequency reaches the optical beam edge nearest the acoustic transducer. Retrace commences immediately since the linear fm ramp applied to the acoustic transducer swings directly from its lowest to its highest frequency. During retrace, two deflected beams of reduced intensity are generated; one deflected above and one deflected below the film material. Retrace is completed and film scan commences when the highest acoustic frequency reaches the edge of the optical beam that is furthest from the transducer. At this time, the middle fm ramp frequency is present at the optical beam edge nearest

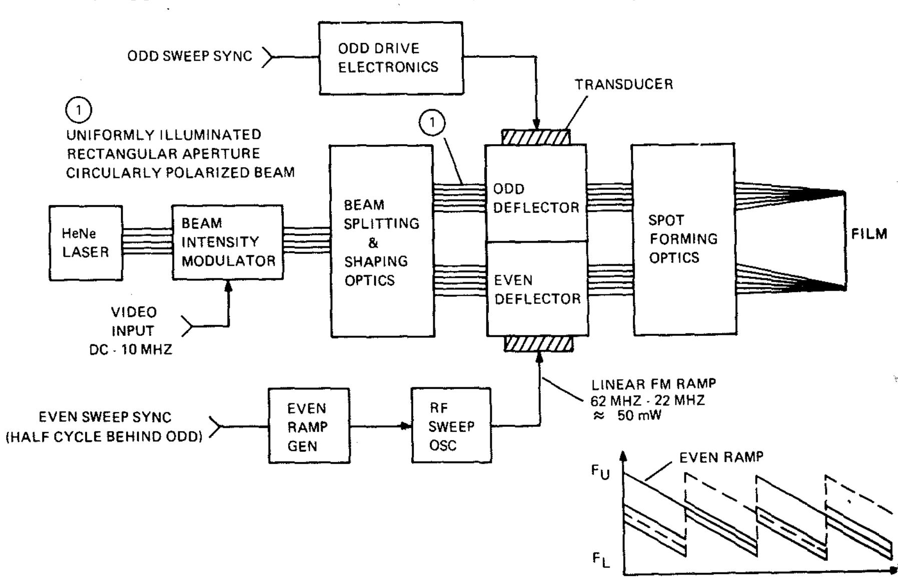

Fig. 6 — Continuous film scanner.

the transducer and the beam is deflected to a spot corresponding to a frequency halfway between the upper and middle ramp frequencies; One-fourth of the spots available from the deflector have already been used. A corresponding number of spots are lost after film scan and, therefore, half the resolvable spots available from each deflector are used to record on film.

Paratellurite material is optically active in that right-hand and left-hand circularly polarized light beams have different indices of refraction when they pass through it parallel to to the c-axis. The performance benefits of paratellurite over lead molybdate in moderate rate deflectors are largely based upon taking advantage of this property. A circularly polarized optical input properly oriented with respect to the acoustic shear areas in the material is used. It does not appear that the continuous power output of currently available laser diodes is sufficient to allow the beam to be passed through the polarizers and the deflector and still retain sufficient power to record at high rates on film. Therefore, the bit rate, scan rate, and scan-aperture dimension of the dual Bragg deflector will be determined, for now, for the circularly polarized output of a Helium Neon laser.

The acoustic frequency range over which a paratellurite deflector will deflect a circularly polarized 632.8-nm beam without the need for acoustic beam steering extends from about 22 MHz to 62 MHz.[7] The maximum continuous spot rate that can be recorded for this frequency range is determined by dividing the number of resolvable spots for each film scan by the scan interval. Since the number of spots is half that given by Eq. 6 due to retrace considerations, the maximum rate, R, is

$$R = 1/2\tau\Delta F_T/\tau$$
$$= \Delta F_T/2 \quad (8)$$

or 20 X 10^6 spots per second.

For the case where it is desired to place 500 Rayleigh spots on 16-mm film for each scan, the resolution of each deflector must be 1000 spots. The scan rate for each deflector is, therefore, 20 kHz and the deflector access time is 25μs. Since the velocity of the acoustic wave in paratellurite material is 0.62 X 10^5 cm/s, the optical beam dimension in the direction of scan is seen from Eq. 2 to be 1.55 cm. A finished crystal with an optical aperture of this size may be obtained without great difficulty from a boule of paratellurite material.

The 500-spot resolution on film is determined from Eq. 3 to be achieveable for an angular deflection range of 20 milliradians. The focal length of the virtual cylindrical lens formed by the sequential scan deflector operating mode is determined from Eq. 7 to be about 75 cm.

The acoustic drive power required to achieve a deflection efficiency in excess of 50% is about 50 mW. A variation of efficiency with deflection angle is inherent in the properties of paratellurite material. However, this variation, which consists primarily of a mid-band dip and roll off at the extremes of deflection, can be held to about 15% without the need for compensation shading in the optical system.

Conclusions

The first steps have been taken toward the development of a solid state optical recorder. These steps include: 1) the development of laser diodes that emit continuously at wavelengths in region of 700 nm, 2) the advent of extended red film, 3) the use of nonmechanical beam deflectors in laser recorders to preserve the time base of recorded data and 4) the use of a TeO_2 acousto-optic beam deflector as the horizontal line scanner in a tv-rate laser display.

Wideband modulation data taken by ATL indicate that laser diodes can be conveniently modulated up to 250 MHz for wideband film recording applications. The frequency response, distortion, spurious spectral component and noise data indicate that the quality of the modulated output is equal to or better than that achieved in the past using a gas laser and an external beam intensity modulator. It appears from the data taken to date that the exposure energy source requirement for 100-MHz wideband film recording systems is well satisfied by a laser diode of the type that has been tested, provided that the continuously emitted power is in the 10 to 15 mW region. Diodes with a lower continuous output power capability appear to be quite promising for use in 30-MHz signal and tv-rate direct image recording systems. Data is currently being taken to determine the characteristics of the record spot that can be formed from the diode output and the quality of film recordings that can be made.

A solid state film scanner relieves the tolerance problems that have been associated with multifaceted rotating mirror assemblies. Paratellurite is the most suitable acousto-optic material known for use in the solid state film scanner that has been described; to a major extent, it establishes the performance characteristics that have been cited.

Two acousto-optic deflectors are currently being fabricated by the RCA Laboratories for use by ATL. One of the deflectors will be installed in a tv-rate 16-mm film recorder to implement the horizontal film scanning function. A single deflector is sufficient for this application, since deflector retrace will take place during the 11.4-μs video signal horizontal blanking interval. A combination of continuous film motion and the vertical scan of a galvanometer will be used to record interlaced video frames.

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Acknowledgments

The authors thank Dr. H. Kressel, Mr. I. Ladany, and Mr. D. Gilbert of the RCA Laboratories for supplying technical advice and the laser diode samples; Dr. I. Gorog and Dr. J. Knox of the RCA Laboratories for supplying technical support on their beam deflector work; and Mr. R. Kenville and Mr. S. Corsover of the RCA Advanced Technology Laboratories for general technical consultation.

Five RCA technical staff members receive IEEE awards

The five RCA engineers cited herein have been honored for their professional achievements by the Institute of Electrical and Electronics Engineers. William L. Behrend, Dr. Erwin F. Belohoubek, and Dr. Karl H. Zaininger have been elected Fellows. This recognition is extended each year by the IEEE to those who have made outstanding contributions to the field of electronics. Dr. Harold B. Law is the 1975 recipient of the Lamme medal. This Award is given by the IEEE for meritorious achievement in the development of electrical or electronics apparatus or systems. Dr. Ralph E. Simon receives the 1975 Vladimir K. Zworykin Award which is presented by the IEEE each year for the most important technical contribution in the field of electronic television. This Award was presented to Dr. Simon and Dr. Eugene I. Gordon of Bell Laboratories, Murray Hill, N.J.

Lamme Medal

Harold B. Law — for outstanding contributions in developing color picture tubes, including the fabrication techniques which made color television practical

Dr. Law received the BS in Liberal Arts and the BS in Education, both in 1934, from Kent State University at Kent, Ohio. He received the MS and PhD in Physics from the Ohio State University, Columbus, in 1936 and 1941, respectively. Dr. Law taught elementary mathematics at Maple Heights, Ohio, in 1935-36 and at Toledo, Ohio, 1937-1939. He joined RCA at Camden, N.J., in 1941. In 1942 he transferred to RCA Laboratories at the David Sarnoff Research Center in Princeton, N.J., and became a Fellow of the Technical Staff in 1960. In 1962 he became Director of the Materials and Display Device Laboratory, a laboratory located at the David Sarnoff Reserarch Center, but affiliated with RCA Electronic Components and Devices. He has continued as Director of this Laboratory up to the present.

Dr. Law is a Fellow of the Institute of Electrical and Electronics Engineers, and a member of the American Physical Society and Sigma Xi.

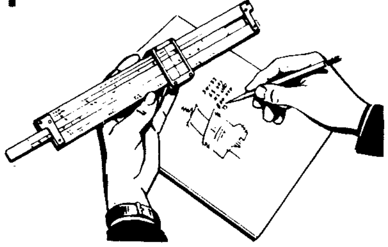
In 1946 he was given a joint award, with Dr. A. Rose and Dr. P.K. Weimer, by the Television Broadcasters Association. In 1955 he was presented the Vladimir K. Zworykin Television Prize by the Institute of Radio Engineers, and in 1961 received, with Dr. E.G. Ramberg, the David Sarnoff Outstanding Team Award, RCA's highest technical award. In 1966 the Consumer Electronics Group of IEEE presented Dr. Law their annual award for Outstanding Contributor to Consumer Electronics.

Zworykin Award

Ralph E. Simon — for the invention and leadership in the development of the silicon target camera tube and in the extension into new application

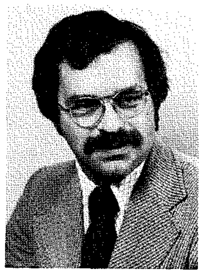
Dr. Simon received the BA in physics from Princeton University in 1952 and the PhD in physics in 1958. He joined the technical staff of RCA Laboratories in 1958 where he was engaged in fundamental studies of electron emission from semiconductors, photoconductivity, and surface physics. In April 1968, he was appointed Director of the Conversion Devices Laboratory. Dr. Simon joined RCA Electronic Components in Lancaster, Pa., in December 1969, where he is presently Manager of the Electro-Optics Operation of the Industrial Tube Division and is directly responsible for an Advanced Technology activity including the Electro-Optics Research Laboratory located at the David Sarnoff Research Center, a Material & Process Laboratory, and a Development Activity. In addition, he is responsible for all manufacturing, design, and application activities for the Electro-Optics Products which include silicon target camera, storage, and intensifier tubes; charge-coupled imagers; and photomultiplier tubes. Dr. Simon was a recipient of the David Sarnoff Award for Outstanding Team Performance in 1970, and is a member of Sigma Xi, the American Association for the Advancement of Science, and the American Physical Society.

Engineering and Research Notes



Expandable priority interrupt system

Michael J. Markulec, Jr.
Astro-Electronics Division
Princeton, N.J.



Multi-level priority interrupt systems allow any one of many devices to request and cause a processor to interrupt the program it is executing and to execute a program of higher urgency and then return to the original program.

Fig. 1 shows a block diagram of a priority interrupt logic semiconductor integrated circuit chip, PIL. This device is an eight-level priority interrupt system. The PIL is designed to receive interrupt requests from eight devices having priorities of zero through seven. They are in the form of seven interrupt requests and a block request. The block request indicates that any one of the eight devices is requesting service. It is always active for a single device system. This allows the PIL only to examine seven of the eight requesting devices to determine whether interrupt action should be taken. The integrated circuit includes a three-stage register containing the 3-digit code for the one of eight interrupt levels which is presently active. The priority level of a new interrupt request on the 7 input lines is translated by combinational encoders to a 3-digit code. The coded priority level of the new request is compared with the presently active level and two interrupt controls are provided to determine the status of the system. The "grant interrupt" signal, one of the output interrupt control lines, is active when the highest level request HLR is not equal to the current level active LA. The second output, LA > HLR, defines whether the current programming level active is greater than the highest level requesting. The code for the new level active will be stored in the three-stage register upon the receipt of a change level active CLA command and is made available at the level active code output lines. A fourth register stage is included in the integrated circuit to indicate whether one of the interrupt levels handled by the PIL is active. The interrupt control and level active code outputs are multiplexed with similar type inputs to provide the capability for expansion to more than an eight level interrupt system.

Two integrated circuits PIL_1 and PIL_2 are shown interconnected in Fig. 2 to illustrate that the system is expandable to include any desired number of interrupt requests. The system shown is a sixteen-level priority system numbering zero to fifteen, level fifteen having the highest urgency for service. The block request for each eight device section can be considered as an "*or*-ing" function of all eight requesting lines in that section. The higher priority block request is used as lock-out for the lower block inputs in the PIL_2 chip, thus a cascading chain can be formed of any number of PIL devices. The present level of programming for this sixteen-level system is visible at the level active code outputs (A_{out}, B_{out}, and C_{out}) in conjunction with the block active output (BA) of the PIL_2 device.

This expandable multi-level priority system offers great flexibility to the computer hardware designer.

Reprint RE-20-5-25| Final manuscript received June 17, 1974.

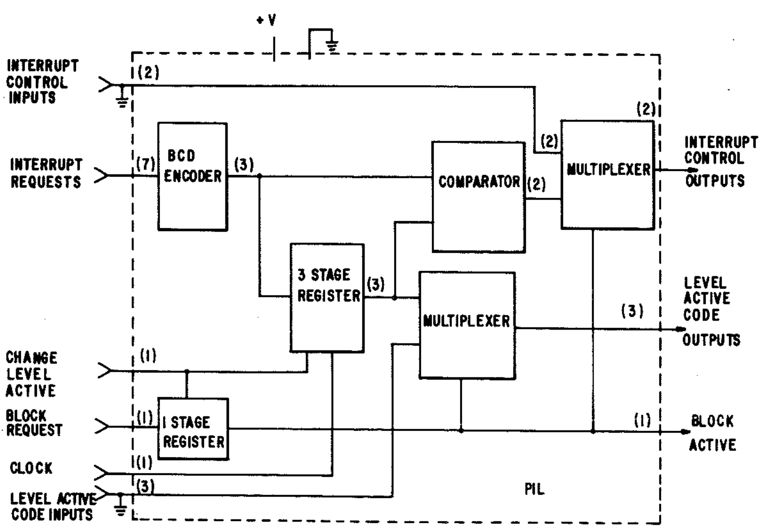


Fig. 1 — Eight-level priority interrupt system.

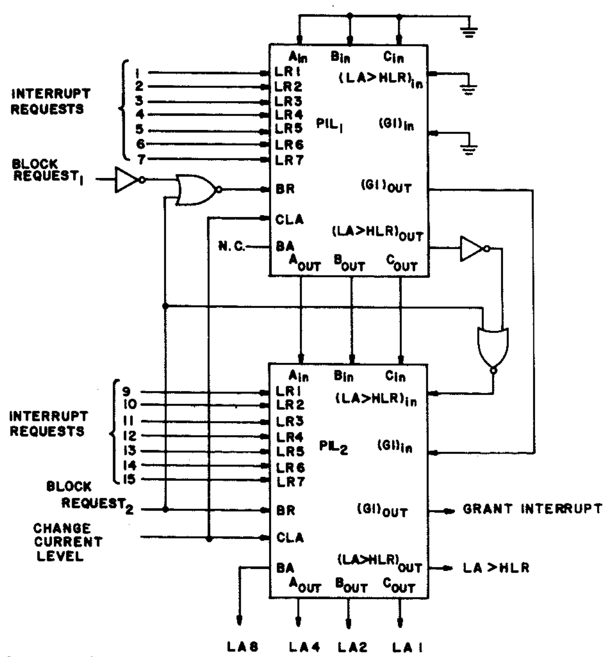
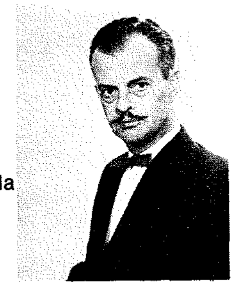


Fig. 2 — Sixteen-level priority interrupt system.

Quality control of seams for inflated structures



Edward L. Crosby, Jr.
TELTA Project
RCA Service Co.
Cape Canaveral Air Force Station, Florida

Inflated structures, in our case large balloons, are assembled from panels and gores of cloth or film-composite fabrics. To achieve acceptable production speed and uniformity of results, the joining of these fabrics is best performed by machine-sealing using a dielectric heat sealer. The adhesive component in the joint may be intrinsic to the fabric composite (as a coating), or it may be a discrete component (such as a strip of adhesive, sandwiched between the pieces of fabric to be joined). The heat generated by rf dissipated in the material causes the adhesive to fuse. The process involves three principal variables: temperature, time, and pressure. They are established, respectively, by the rf power setting of the machine, the dwell-time of the platens, and the force exerted by the top platen on the joint being made, which, in turn, rests on the fixed bottom platen.

The dwell time and pressure are easily controlled with sufficient precision. Temperature is subject to variation because of variations in dissipation factors of the various materials and because of temperature "pickup" *via* thermal conduction to the platens from the work. Variability of the material has never been a problem in our case because of the high quality of the materials and the controlled environment in the plant of the balloon manufacturing contractor.

However, with long seams which require a large number of "hits", excess platen temperature had been troublesome. The effective peak temperature would gradually rise to the point of transgressing the 488° F "transition" temperature of the polyester cloth in our fabric. At this temperature, a rapid and irreversible change takes place that results in a degradation of fabric tensile strength of 70% or more. The result was that the inflated balloon seams would split, the rupture occurring just beside the overlap where the material was weakest.

The problem was overcome by cooling the platens, and the quality was ensured by painting, along the inside seal-batten tape, two stripes of temperature-sensitive laquer known at Tempilaq®.[1] This laquer changes color and luster at a particular temperature, chosen for the application.

In our case, one stripe was formulated to change conservatively above the adhesive fusion temperature, and the other stripe to turn well below the critical transition temperature. The laquer stripes are applied to the tape using a striping machine in a separate operation.

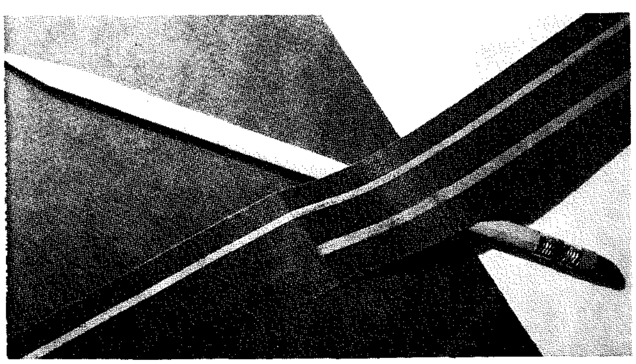


Fig. 1 — A sample, partly sealed, batten-tape seam viewed from the inside face, showing the striping and its response to a "good" seal.

In production assembly, the sealing variables are adjusted so that the low-temperature stripe *must* change appearance, indicating a fused bond, and the high-temperature stripe *must not*, thus indicating that the joint has not been "overcooked". Fig. 1 shows a sample coupon of balloon fabric from the inside with the sealed part of the tape showing one stripe, the unsealed showing two.

In our 200,000 ft^3 balloons, there is more than a mile of seam length. In current and future produciton, every inch is striped as described. It is a very effective QC method since the proof of quality is permanently evident on the work and may be visually checked at high speed by simple observation. One stripe, and one only, must be bright and clear along every seam.

1. The Tempilag stripe must be applied where the heat is applied (in the joint) for it to be representative of the temperature attained. Tempil Div., Big Three Industries, Inc., South Plainfield, New Jersey.

Reprint RE-20-5-25| Final manuscript received December 13, 1974.

Thermocompression indium wire bonding

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When fabricating infrared imaging arrays, we were faced with the problem of electrically contacting a delicate *(Hg-Cd)Te* detector element without overheating or mechanically damaging this very sensitive semiconductor material. Our solution to this problem may prove to be a useful technique for a variety of other applications.

Indium is inherently a good material to use in such applications because it is soft (much softer than *(Hg-Cd)Te* and most, if not all, other semiconductors of interest). In addition, indium can be thermocompression bonded to a wide variety of metals, semiconductors, and insulators with only modest amounts of heat (less than 100°C) and pressure. However, two practical difficulties usually discourage its use for this purpose. A clean indium surface is so "bondable" and will stick to itself so tenaciously that freshly prepared indium wire can not be wound-up on a storage spool and later unwound when it is needed. In addition, indium acquires an oxide coating during storage in air that makes bonding more difficult after storage times as short as one day. The most effective way of circumventing these obstacles is to use indium wire that is freshly prepared in the thermocompression bonding machine in short lengths that can be used immediately.

A very convenient method for preparing indium wire is by extruding it through a tungsten carbide capillary tip from a gold-wire ultrasonic bonding machine that has been formed into an extruding apparatus as shown in Fig. 1. Extruders for wire diameters from 1 to 5 mils have been made from used capillary tips and mounted in place of the gold-wire feed system in conventional thermocompression bonding machines. Consequently, when some indium wire is needed, the screw of Fig. 1 is simply tightened, the desired length of wire extruded, and the screw loosened to stop the process. The wire is then held by the extruder while being positioned for bonding by the mechanism of the thermal-compression bonding machine. The only precautions necessary during these operations being 1) not to tighten the screw of Fig. 1 too tightly and create sufficient internal pressure to rupture the tungsten carbide capillary tip; and 2) to attach (bond) the free end of the extruded wire somewhere and guide the wire during extrusion so it extrudes straight and any tendency to curl-up is prevented. Since indium does not stick to tungsten carbide, the actual bonding is done with a tungsten carbide rod that is heated to about 100°C and used to press the wire against the unheated surface to be bonded for about five seconds with just enough pressure to slightly deform it (which, in the case of indium wire, is not a large pressure). After a length of indium wire has been bonded to the two areas one wishes to connect together, it can be severed at the second bond by a shearing (or snow-plowing) motion of the tungsten carbide tip. The length of wire still attached to the extruder can then be used to make additional bonds until it gets so short that additional extrustion becomes necessary.

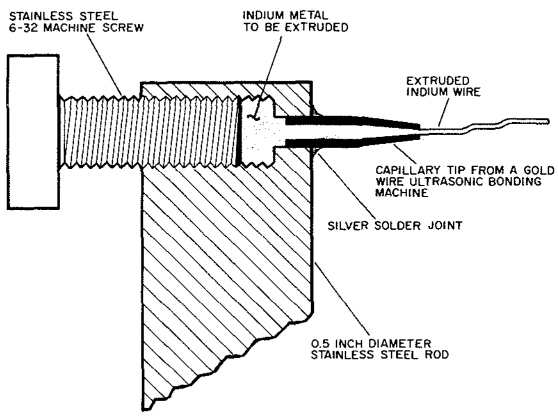

Fig. 1 — Cross-sectional view of an indium-wire extruder.

This technique has been used to connect small *(Hg-Cd)Te* infrared detector elements to their corresponding gold or copper metallization fan-out lines, to repair scratched or ever-etched regions in these fan-out lines and, in quite unrelated projects, to make temporary connections to the aluminum metallization of conventional integrated circuits and the gold metallization on experimental gallium arsenide microwave devices. In these applications, the real advantage of using indium wire bonding lies in the low temperatures and pressures involved and in the ease by which the wire can be bent to the second bond position without introducing any stresses on the substrate to which the first bond was made. Therefore, it is thought that this technique may be used in a number of unrelated applications where contacts to delicate substrates or structures are required.

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Universal electronic blown-fuse indicator circuit

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Cowley **Doty**

The indicator circuit (Fig. 1) can detect an open fuse in a fused supply or load circuit of the type operating in the range from 6 to 115 V, ac or dc. The indicator circuit utilizes an independent power source to enable the circuit to function regardless of whether current is flowing in the fused circuit. The indicator circuit also incorporates an automatic reset capability to prevent an erroneous indication in the event of transient

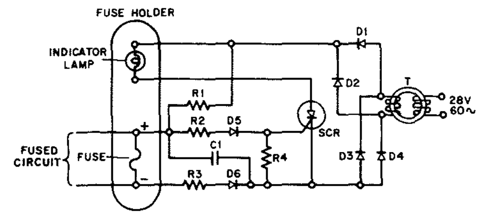

Fig. 1 — Universal electronic blown-fuse indicator circuit.

triggering, but which does not reset if the fuse is open. In the event a fuse does open, replacement of the open fuse automatically resets the circuit.

In the circuit diagram (Fig. 1), a toroidal coil T and diodes D1 through D4 provides a 28-V pulsating dc supply to operate the blown-fuse indicator circuit. The supply voltage is applied across an indicator lamp in series with the cathode/anode electrodes of an SCR. The supply voltage is also applied across a divider network: R1, R2, R3, a fuse and the gate/cathode electrodes of the SCR.

In normal operation (*i.e.*, a good fuse) the supply voltage across the series combination of R1, the fuse, and R3 develops a voltage drop of approximately 0.9 V across R3. This voltage is applied to the gate/cathode electrodes of the SCR by way of resistor R2 and diodes D5 and D6. However, this voltage is of insufficient magnitude to trigger the SCR due to the additional shunting resistance of R4. The only appreciable current flow in the circuit during normal operation is determined by the values of R1 and R3.

When the fuse opens, the supply voltage is applied across resistors R1 and R2 in series with the gate/cathode electrode of the SCR. The supply voltage then causes sufficient current to flow through the SCR gate/cathode junction to cause the SCR to trigger. When the SCR triggers, sufficient current flows through the lamp to cause it to light thereby indicating a blown fuse.

Capacitor C1 provides filtering and prevents transient triggering. However, by reason of the pulsating dc supply, the indicator circuit will reset itself if it should trigger from a transient—provided, of course, that the fuse maintains its continuity.

Resistors R1, R2, R3 and diodes D5 and D6 offer sufficient resistance to provide isolation and therefore prevent feed-back to the fused circuit when a fuse does open.

Reprint RE-20-5-25| Final manuscript received August 5, 1974.

Simple method for separating completed diodes from semiconductor wafers

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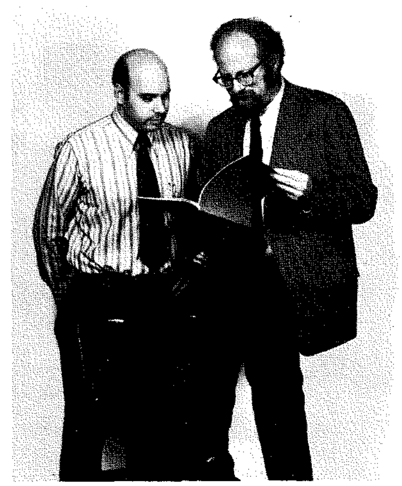
Princeton, New Jersey



Finding ways of cutting processed semiconductors into individual diodes or transistors is a major time-consuming activity for process designers. One problem, for instance, has been the separation of completed Trapatt diodes so they could be packaged. Many designers use techniques such as wire sawing, diamond sawing, etching, laser cutting, and scribe and break separation.

Problems associated with these methods, excluding the cost of the equipment involved in cutting, include low yields due to damage along the edges of the completed devices, as well as inadvertent fractures of the device itself.

Wire sawing requires a cutting medium such as oil, or a tenacious diamond mixture which retains the shavings on or near the device. In addition to metal contamination, the substance used presents cleaning problems.

Diamond sawing requires a large capital investment, without solving fine-line requirements (< 1 mil).

Etching introduces contaminants, which can ruin an otherwise good device. Etching is a lengthy process—often up to two hours—and the masking material seldom holds that long.

Scribe and break separation often causes damage due to breaks along lines not defined by the scribe. Unintentional breaks come about because the natural cleavage line to scribe line angle is too large.

An analysis of the methods and the review of their associated problems have led to an improved process for cutting a semiconductor wafer into individual devices of desired geometrical configuration.

A metal film is deposited on the support side of a semiconductor material. Photoresist is applied and processed, forming the device regions by a pattern of intersecting strips (Fig. 1). A layer of metal, such as copper or gold, is plated within each device region (Fig. 2). This forms a base for mounting or bonding in a package. The opposite side of the semiconductor wafer is selectively etched down to the metal film. The mechanics of etching diodes completes both the structure formation of the diode and material removal in one step. Different device structures could require a masking procedure.

Separation of each device takes place by fracturing the thin metal film along the strips of photoresist (Figs. 3 through 6). The presence of photoresist at this point is not required, and removal is possible prior to separation.

This process has increased device yields while saving the manhours normally required in the dicing operation.

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This work is supported in part by U.S. Army Electronics Command under Contract No. DAAB07-74-C-0180.

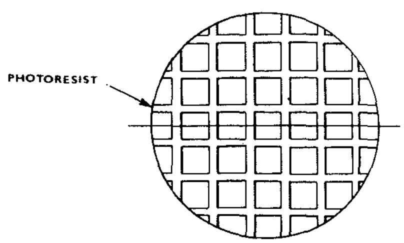


Fig. 1 — Photoresist defining the device regions. The type of photoresist used is dictated by the design requirement. AZ111 has been used successfully and, for forming a thick base, dynachem thick film resist has been utilized.

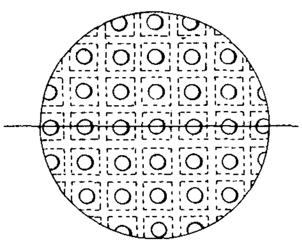


Fig. 2 — Alignment of each device within the defined regions.

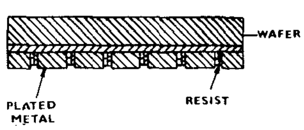


Fig. 3 — Plated heat sink with photoresist separators.

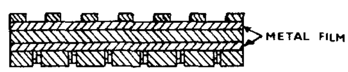


Fig. 4 — Wafer prior to etching for diode fabrication.

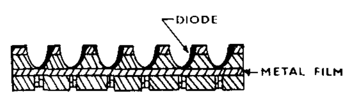


Fig. 5 — Completed wafer with diode formed above each heat sink ready for separation.

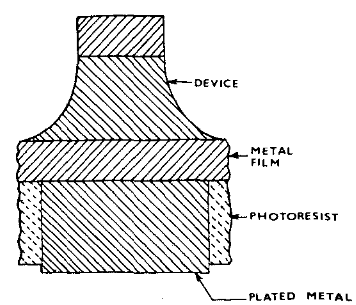
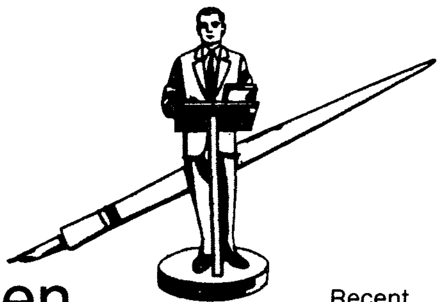


Fig. 6 — The separated device, in this example a diode.



Pen and Podium

Recent RCA technical papers and presentations

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Subject Index

Titles of papers are permited where necessary to bring significant keywords(s) to the left to easier scanning. Author's division appears parenthetically after his name.

SERIES 100 BASIC THEORY & METHODOLOGY

180 Management and Business Operations

organization, scheduling, marketing, personnel.

NSIA/OSD Symposium on CCDR (Panelist) — P. W. Coben (Staff, Cam) Washington, D.C., 11/4/74.

PRICE Parametric Cost Modeling Methodology — F. R. Freiman (GCASD, Cam) Design to a Cost Seminar, Pres. by Amer. Inst. of Indus. Engineers, San Francisco, Calif.; 11/20-22/74; *Proceedings*.

SYSTEMS ENGINEERING, Modern Concepts in — J. T. Nessmith (MSRD, Mrstn) Faculty and Graduate Students, University of Pennsylvania Department of Systems Engineering, Phila., Pa.; 12/3/74.

SERIES 200 MATERIALS, DEVICES, & COMPONENTS

210 Circuit Devices and Microcircuits

electron tubes and solid-state devices (active and passive); integrated, array and hybrid microcircuits, field-effect devices, resistors and capacitors, modular and printed circuits, circuit interconnection, waveguides and transmission lines.

MNOS MEMORY DEVICES, Effect of Radiation and Degradation on Retention Time in — G. J. Brucker (AED, Pr) 5th Semiconductor Interface Specialists Conference, Puerto Rico; 12/5/74.

240 Lasers, Electro-Optical and Optical Devices

design and characteristics of lasers, components used with lasers, electro-optical systems, lenses, etc. (excludes: masers).

GaAs LASER DIODE Pumped Nd:YAC Laser — L. C. Conant, C. W. Reno (ATL, Cam) *Applied Optics*, Vol. 13, No. 11, pp. 2457-2458, Nov. 1974.

OPTICAL PROCESSING of Wideband Data — R. F. Croce, G. T. Burton (GCASD, Burl) E/O Systems Design Conference, San Francisco, Calif.; 11/74.

245 Displays

equipment for the display of graphic, alphanumeric, and other data in communications, computer, military, and other systems, CRT devices, solid state displays, holographic displays, etc.

HOLOGRAPHIC Movies — W. J. Hannan (PBD, PBG) Optical Society of America, Orlando, Fla.; Dec. 14, 1974.

250 Recording Components and Equipment

disk, drum, tape, film, holographic and other assemblies for audio, image, and data systems.

SOLID STATE OPTICAL RECORDING, Progress Report on — R. F. Kenville (ATL, Cam) Electro-Optical Systems Design Conf., San Francisco, Calif.; 11/5-7/74; *Proceedings*.

VIDEO TAPE, Dimensional Stability of Magnetic — K. Sadashige (CCSD, Cam) *Journal of the Society of Motion Picture and Television Engineers* (Letter to the Editor); February 1975.

VIDEO TAPE RECORDER, Design and Manufacturing Considerations for a New Quadruplex — G. S. Moskovitz, J. R. West (CCSD, Cam) SMPTE Winter TV Conference, San Francisco, Calif.; 1/24-25/75.

280 Thermal Components and Equipment

heating and cooling components and equipment, thermal measurement devices, heat sinks.

COOLING Cordwood Modules for Vacuum Environments, Design Guide to — E. D. Veilleux (GCASD, Burl) *IEEE Transactions on Parts, Hybrids, and Packaging*; Dec. 1974.

SERIES 300 SYSTEMS, EQUIPMENT, & APPLICATIONS

310 Spacecraft and Ground Support

spacecraft and satellite design, launch vehicles, payloads, space missions, space navigation.

ATMOSPHERE EXPLORER Spacecraft System — R. deBastos (AED, Pr) AIAA 13th Aerospace Sciences Mtg., Pasadena, Calif.; 1/20-22/75.

315 Military Weapons and Logistics

missiles, command and control.

Communications command and control (Chairman) — D. Shore (MSRD, Mrstn) AIAA Remotely Piloted Vehicle Technology Meeting; 11/12-14/74; David Momthan Air Force Base, Tucxon, Ariz.

RPV Command and Control Demonstration System Incorporating Anti-Jam Communications — C. S. Sorkin (MSRD, Mrstn) AIAA Remotely Piloted Vehicle Technology Meeting - 11/12-14/74, David Momthan Air Force Base, Tucson, Arizona.

320 Radar, Sonar, and Tracking

microwave, optical, and other systems for detection, acquisition, tracking, and position indication.

MULTIPATH CORRECTION, Experimental Results of the Complex Indicated Angle Technique for — D. D. Howard, S. M. Sherman, J. J. Campbell, D. N. Thomson (MSRD, Mrstn) *IEEE Transactions on Aerospace and Electronic Systems*, Vol. AES10, No. 6, Nov. 1974, pp. 779-787.

RADARS, Instrumentation Applications of Pulse Doppler Tracking — R. D. Mitchell, J. T. Nessmith, G. M. Sparks (MSRD, Mrstn) TTCI Ad Hoc Working Group 102 (Tri-Parte Group), Naval Research Lab., Washington, D.C., 12/3/74; *Tri-Parte Group Proceedings*.

325 Checkout, Maintenance, and User Support

automatic test equipment, (ATE), maintenance and repair methods.

FLEET VEHICLE Maintenance, Diagnostic Equipment for — J. M. Laskey (GCASD, Burl) Automatic Testing '74, Brighton, England; 11/74.

JET ENGINE ACCESSORIES, ACCESSORIES, Automatic Test System for — G. E. Kelly, Jr. (GCASD, Burl) Automatic Testing '74, Brighton, England; 11/74.

340 Communications

industrial, military, commercial systems, telephony, telegraphy and telemetry, (excludes: television, and broadcast radio).

MODEM Design for Minimum Error Rate Optimize Binary PSK — B. E. Tyree (GCASD, Cam) *Electronic Design News*, Vol. 19, No. 4; July 20, 1974.

PABX Using Low-Power LSI Devices, An Advanced Technology — P. H. Bennett (GCASD, Cam) *Telephony Magazine*, pp. 40-43, Nov. 1974 issue.

345 Television and Broadcast

television and radio broadcasting, receivers, transmitters, and systems, television cameras, recorders, studio equipment.

CAMERA, A Multi-Purpose Electronic — J. J. Clarke (CCSD, Cam) 9th International TV Symposium & Technical Exhibition, Montreaux; May 23-29, 1975.

CARTRIDGE FILM PROJECTOR Into Telecine Islands, Integrating the TCP-1624 — A. E. Jackson, A. H. Lind, H. G. Wright (CCSD, Cam) 9th Annual SMPTE Winter TV Conference, San Francisco, Calif.; 1/24/75.

365 Computer Programming and Applications

languages, software systems, and general applications (excluding: specific programs for scientific use).

USER'S MANUAL, PSA Program — P. G. Anderson (MSRD, Mrstn) for general distribution

380 Graphic Arts and Documentation

printing, photography, and typesetting; writing, editing, and publishing; information storage, retrieval, and library science.

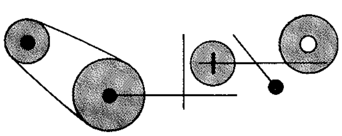
FIRE Photography - An Aid to Investigation — C. W. Asbrand (GCASD, Burl) Conference of Evidence Technicians, Dedham, Mass.; 11/74.

Author Index

Subject listed opposite each author's name indicates where complete citation to his paper may be found in the subject index. An author may have more than one paper for each subject category.

Patents Granted

to RCA Engineers



Astro-Electronics Division

Storage System for Two Phase Fluids — D. L. Balzer and R. J. Lake, Jr. (AED, Pr.) U.S. Pat. 3854905, December 17, 1974

RCA Limited

Cascade Amplifier using Complementary Conductivity Transistors — L. R. Avery (RCA Ltd, England) U.S. Pat. 3857105, December 24, 1974

Government Engineering

Article Labeling and Identification System — J. F. Schanne (ATL, Cam.) U.S. Pat. RE28285, December 31, 1974

Electromagnetic and Aviation Systems Division

Fixed Format Video Data Display Employing Crossed-line Pattern Format Delineation — W. L. Ross (EASD, Van Nuys) U.S. Pat. 3858198, December 31, 1974

Parts and Accessories

Rotator System including a Remote Drive Motor and a Local Indicator-Control Motor — B. H. Buckley (P&A, Deptford) U.S. Pat. 3860859, January 14, 1975

RCA Service Company

Tethered Balloon Refueling System — E. L. Crosby, Jr. (Sv. Co., Patrick AFB) U.S. Pat. 3834655, September 10, 1974;Assigned to U.S. Government

RF Hazard Detector — L. D. Johnson (Sv. Co., Cherry Hill) U.S. Pat. 3863149, January 28, 1975; Assigned to U.S. Government

Computer Systems

Combined Check-out Counter and Canopy Therefor — T. C. Abrahamsen and J. D. Zaccai (Sys. Dev., Marlboro) U.S. Pat. D234037, January 7, 1975

Commercial Communications Systems Division

Color Amplitude Correction in Plural Transducer Signal Playback Systems — K. Sadashige (CCSD, Cam.) U.S. Pat. 3852808, December 3, 1974

PWM Multiplex System — W. L. Hurford (CCSD, Cam.) U.S. Pat. 3855419, December 17, 1974

Reel Mounting Apparatus — W. A. Dischert (CCSD, Cam.) U.S. Pat. 3857526, December 31, 1974

Consumer Electronics

Tape Cartridge Player Mechanism — G. D. Pyles (CE, Indpls.) U.S. Pat. 3852818, December 3, 1974

Programming System for a Motor-Driven Television Receiver Tuning Apparatus — J. C. Marsh, Jr. (CE, Indpls.) U.S. Pat. 3855535, December 17, 1974

Transistor Oscillator with Diode in Feedback Circuit providing Amplitude Stabilization — D. J. Carlson (CE, Indpls.) U.S. Pat. 3855550, December 17, 1974

Circuit Breaker with Ambient Temperature Compensation — H. Rhee (CE, Indpls.) U.S. Pat. 3855562, December 17, 1974

Video Amplifier Circuit for use with Synchronous Detectors — J. B. George (CE, Indpls.) U.S. Pat. 3862361, January 21, 1975

Government Communications and Automated Systems Division

Magnetic Reed Sensor Suitable for use in Ignition Timing Systems — L. R. Hulls (GCASD, Burlington) U.S. Pat. 3852664, December 3, 1974

Missile and Surface Radar Division

Lens Fed Antenna Array System — B. F. Bogner (MSRD, Mrstn.) U.S. Pat. 3852761, December 3, 1974

Square Root of Sum of Squares Approximator — J. A. Lunsford (MSRD, Mrstn.) U.S. Pat. 3858036, December 31, 1974

Laboratories

Holographic Thermoplastic Memory System — R. A. Gange, E. M. Nagle and C. C. Steinmetz (Labs, Pr.) U.S. Pat. 3851948, December 3, 1974

Amplifier using a Negative Resistance Semiconductive Device Operative in the Anomalous Mode — A. Rosen and J. F. Reynolds (Labs, Pr.) U. S. Pat. 3852680, December 3, 1974

Electron Beam Recording Process — D. L. Ross and L. A. Barton (Labs, Pr.) U.S. Pat. 3852771, December 3, 1974

Switchable Video Amplifier — D. P. Dorsey, W. E. Rodda, and K. B. Bahrs (Labs, Pr.) U.S. Pat. 3854006, December 10, 1974

Process for Depositing Electrically Conductive Indium Oxide Coatings on a Substrate — J. Kane (Labs, Zurich, Switz.) U. S. Pat. 3854992, December 17, 1974

Dual Bias Controlled Storage Tubes — D. P. Dorsey and W. E. Rodda (Labs, Pr.) U.S. Pat. 3855497, December 17, 1974

Carrier Injected Avalanche Device — H. Kawamoto (Labs, Pr.) U.S. Pat. 3855605 December 17, 1974

Semiconductor Injection Laser with Reduced Divergence of Emitted Beam — H. Kressel, H. F. Lockwood, and F. Z. Hawrylo (Labs, Pr.) U.S. Pat. 3855607, December 17, 1974

Solid State Switch using an Improved Junction Field Effect Transistor — L. S. Napoli and R. H. Dean (Labs, Pr.) U.S. Pat. 3855613, December 17, 1974

Semiconductor Devices and Methods of Making the Same — L. S. Napoli and W. F. Reichert (Labs, Pr.) U.S. Pat. 3861024, January 21, 1975

Permanent Holographic Recording Medium — R. A. Gange (Labs, Pr.) U.S. Pat. 3861914, January 21, 1975

Method of Electrolessly Plating a Metal to a Body which includes Lead — A. F. Arnold (SSTC, Som.) U.S. Pat. 3856565, December 24, 1975

Method for Making Beam Lead Device — L. S. Napoli and J. J. Hughes (Labs, Pr) U.S. Pat. 3856591, December 24, 1974

Sensors having Charge Transfer Recycling Means — P. K. Weimer (Labs, Pr.) U.S. Pat. 3856989, December 24, 1974

Microwave Acoustic Delay Line — H. Huang (Labs, Pr.) U.S. Pat. 3857113, December 24, 1974

Method of Electroless Metal Deposition — A. F. Arnold (SSTC, Som) U.S. Pat. 3857733, December 31, 1974

Tuneable Thin Film Inductor — J. I. Gittleman and L. M. Zappulla (Labs, Pr.) U.S. Pat. 3858138, December 31, 1974

Color Encoded Hologram Playback Apparatus — I. Gorog (Labs, Pr.) U.S. Pat. 3858239, December 31, 1974

Harmonic Radar Detection and Ranging System for Automotive Vehicles — H. Staras and J. Shefer (Labs, Pr.) U.S. Pat. RE28302, January 14, 1975

Etching Solution for Silver — F. Okamoto (Labs, Res. Tokyo, Japan)

RF Sputtering Apparatus and Method — J. L. Vossen Jr. (Labs, Pr.) U.S. Pat. 3860507, January 14, 1975

Semiconductor Mounting Devices made by Soldering Flat Surfaces to each other — A. J. Stoeckert and J. M. Hunt (SSTC, Som.) U.S. Pat. 3860949, January 14, 1975

Electronic Components

Fabrication of Dark Heaters — J. R. Hale (EC, Lanc.) U.S. Pat. 3852105, December 3, 1974

Thyristor Devices — J. M. S. Neilson and H. Weisberg (EC, Mountaintop) U.S. Pat. 3855611, December 17, 1974

Electrode Support Strap — P. L. Nestleroth (EC, Lanc.) U.S. Pat. 3857058, December 24, 1974

Tunable Solid State Local Oscillator — A. Presser (ECD, Pr.) U.S. Pat. 3848201, November 12, 1974; Assigned to U.S. Government

Method of Making a 111-V Compound Electron-Emissive Cathode — A. H. Sommer (EC, Pr.) U.S. Pat. 3858955, January 7, 1975

Stable Bonded Barrier Layer-Telluride Thermoelectric Device — T. R. Krebs (EC, Hrsn.) U.S. Pat. 3859143, January 7, 1975

M-Type Microwave Signal Delay Tube — E. F. Belohoubek (ECD, Pr.) U.S. Pat. 3863100, January 28, 1975

Solid State Division

Current Mirror Amplifiers — O. H. Schade, Jr. (SSD, Som.) U.S. Pat. 3852679, December 3, 1974

Fabrication of Liquid Crystal Devices — H. Sorkin (SSD, Som.) U.S. Pat. 3853391, December 10, 1974

Push-Pull Transistor Amplifier with Driver Circuits Providing Over-Current Protection — A. J. Leidich (SSD, Som.) U.S. Pat. 3855540, December 17, 1974

Current Proportioning Circuit — A. J. Leidich (SSD, Som.) U.S. Pat. 3855541, December 17, 1974

Circuit, Such as CMOS Crystal Oscillator, with Reduced Power Consumption — R. C. Heuner and R. P. Fillmore (SSD, Som.) U.S. Pat. 3855549, December 17, 1974

Detector Employing a Current Mirror — M. B. Knight (SSD, Som.) U.S. Pat. 3857047, December 24, 1974

Optical System — F. Caprari (SSD, Som.) U.S. Pat. 3860335, January 14, 1975

High Frequency Voltage-Variable Capacitor — R. H. Dawson (SSD, Som.) U.S. Pat. 3860945, January 14, 1975

Dates and Deadlines

As an industry leader, RCA must be well represented in major professional conferences . . . to display its skills and abilities to both commercial and government interests.

How can you and your manager, leader, or chief-engineer do this for RCA?

Plan ahead! Watch these columns every issue for advance notices of upcoming meetings and "calls for papers". Formulate plans at staff meetings—and select pertinent topics to represent you and your group professionally. Every engineer and scientist is urged to scan these columns; call attention of important meetings to your Technical Publications Administrator (TPA) or your manager. Always work closely with your TPA who can help with scheduling and supplement contacts between engineers and professional societies. Inform your TPA whenever you present or publish a paper. These professional accomplishments will be cited in the "Pen and Podium" section of the *RCA Engineer*, as reported by your TPA.

Calls for papers —be sure deadlines are met

Ed. Note: Calls are listed chronologically by meeting date. Listed after the meeting title (in bold type) are the sponsor(s), the location, and deadline information for submittals.

SEPT. 2-5, 1975 — **European Electronic Circuit Techniques** (IEE, IEEE UKRI Section et al) Univ. of Kent, Canterbury, UK **Deadline info:** (abst) 4-15-75 **to** IEE, Conference Dept., Savoy Pl., London W. C. 2R OBL England.

SEPT. 22-24, 1975 — **Int'l Congress on Instrumentation in Aerospace Simulation Facilities** (AES) Canadian Gov't Conf. Ctr., Ottawa, Ont., Canada **Deadline info:** (abst) 4-25-75 **to** E. S. Hanff, Nat'l Res. Council of Canada, Montreal Rd., Ottawa, Canada K1A OR6.

SEPT. 28 - OCT. 1, 1975 — **Joint Power Generation Technical Conference** (PE, ASME, ASCE) Portland Hilton Hotel, Portland, Oregon **Deadline info:** (ms) 5-15-75 **to** W. F. Cantierei, Diamond Pwr. Specialty Corp., Box 415, Lancaster, OH 43130.

OCT. 7-9, 1975 — **Data Communications** (C, Comm., ACM) LeConcorde, Quebec, Canada **Deadline info:** (ms & s) **to** W. W. Chu, 3732 Boelter Hall, Univ. of Calif., Los Angeles, Calif. 90024.

OCT. 22-23, 1975 — **Eighth Annual Connector Symposium** Cherry Hill, New Jersey **Deadline info:** (abst) 4-21-75 **to** Papers Chairman, Eighth Annual Connector Symposium, Post Office Box 1428, Camden, NJ 08101.

NOV. 3-5, 1975 — **Conversion of Refuse to Energy Int'l Conference** (IEEE EQC, USERC, ASME et al) Montreux, Switzerland **Deadline info:** (A&S) 3-31-75 **to** Fritz Wedmer, ETH , Sonneggstrasse 3, CH8006, Zurich, Switzerland

NOV. 10-13, 1975 — **Sensing Environmental Pollutants** (EQC, et al) Stardust Hotel, Las Vegas, Nev. **Deadline info:** (abst) 4-30-75 **to** Henry Freiser, Univ. of Ariz., Dept. of Chemistry, Tucson, Ariz. 85721.

NOV. 30 - DEC. 4, 1975 — **ASME Winter Annual Meeting** Regency Hyatt Hotel, Houston, Texas **Deadline info:** (abst) 3-1-75 (ms) 5-1-75 **to** Program Chairman: Robert W. Graham, Lewis Research Center, M.S. 301-1, 21000 Brookpark Road, Cleveland, OH 44135.

DEC. 10-12, 1975 — **Decision and Control - Adaptive Processes** (CS) Hyatt Regency Hotel, Houston, Texas **Deadline info:** (ms) 4-1-75 **to** J. B. Pearson, Dept. of EE, Rice Univ., Houston, Texas 77001.

Dates of upcoming meetings —plan ahead

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.

APRIL 7-10, 1975 — **Satellite Communication Systems Technology** (IEE, IEEE UKRI Section et al) London, England **Prog info:** IEE, Conference Dept., Savoy Place, London WC2R OBL England.

APRIL 7-11, 1975 — **Secondary Flows in Turbomachines** (ASME, Dartmouth College and Von Karman Inst., Belgium) Iowa State University, Ames, Iowa 50010 **Prog info:** Prof. George K. Serovy and Dr. Ted H. Okiishi, Mechanical Engineering Dept., Iowa State Univ., Ames, Iowa 50010.

APRIL 8-10, 1975 — **IEEE International Convention (Intercon)** (IEEE) Coliseum & Americana Hotel, New York, NY **Prog info:** J. Goebel, Motorola Inc., 9401 W. Grand St., Franklin Park, IL 60131.

APRIL 14-17, 1975 — **Int'l Magnetics Conf. (INTERMAG)** (MAG, IEE, Inst. of Physics) Imperial College, London, England **Prog info:** E. C. Snelling, Mullard Res. Labs., Redhill, Surrey RH1 5HA, England.

APRIL 15-17, 1975 — **Advances in Automatic Testing Technology** (IERE, IEEE UKRI Section et al) Univ. of Birmingham, Birmingham, Eng. **Prog info:** Conference Dept., IERE, 8-9 Bedford Sq., London WC1B 3RG, UK.

APRIL 20-23, 1975 — **International Circuits & Systems Symposium** (CAS) Marriott Motor Hotel, Newton, Mass. **Prog info:** H. B. Lee, MIT Lincoln Labs., 244 Wood St., Lexington, Mass. 02173.

APRIL 21-23, 1975 — **Radar International Conference** (AES, Washington Section) Washington, DC **Prog info:** Merrill Skolnik, Naval Res. Lab., Code 5300, Washington, DC 20375

APRIL 21-25, 1975 — **Electrical and Electronic Engineers in Israel (IEEE Israel Section) Tel-Aviv Prog info:** Technical Committee, 9th Conv. of Elec/Elec. Engineers in Israel, POB 29234, Tel-Aviv, Israel.

APRIL 22-24, 1975 — **Reliability Software Int'l Symposium** (C, R, ACM et al) International Hotel, Los Angeles, CA **Prog info:** James King, IBM Res., POB 218, Yorktown Heights, NY 10598.

APRIL 23-25, 1975 — **Optical Computing International Symposium** (C) Mayflower Hotel, Washington, DC**Prog info:** David Cassasent, Carnegie-Mellon Univ., Dept. of EE, Pittsburg, PA 15213.

APRIL 28-30, 1975 — **Scientific Journals** (PC) Cherry Hill, NJ **Prog info:** C. W. N. Thompson, Northwestern Univ., Evanston, IL 60201.

MAY 3-8, 1975 — **77th Annual Meeting & Exposition** (ACS) Sheraton-Park Hotel and Shoreham Americana, Washington, DC **Prog info:** The American Ceramic Society, Inc., 65 Ceramic Drive, Columbus, OH 43214.

JULY 14-18, 1975 — **Third Intersociety Transportation Conference** (ASME) Hyatt Regency Hotel, Atlanta, GA **Prog info:** Paul Drummond, Meetings Dept., ASME, 345 E. 47th Street, New York, NY 10017.

SEPT. 17-19, 1975 — **Third ASME Design Automation Conference** (ASME) Statler-Hilton Hotel, Washington, DC **Prog info:** Dr. Miles A. Townsend, Mechanical Engineering, Box 1710, Station B, Vanderbilt University, Nashville, Tenn. 37235.

SEPT. 23-25, 1975 — **1975 Joint Materials Conference** (ASME) Sheraton-Cleveland Hotel, Cleveland, OH **Prog info:** Conference Chairman, Frank A. Stevens, Bituminous Coal Research, Inc., Monroeville, PA.

Engineering News and Highlights

Electronic Components reorganized

A major realignment of the RCA Electronic Components organization to reflect changing trends in the industry was announced recently by **William C. Hittinger**, RCA Executive Vice President.

Joseph H. Colgrove has been appointed Division Vice President and General Manager, Picture Tube Division. This new Division will include the activities that pertain to picture tubes in the former Entertainment Tube Division as well as the former Electronic Components Staff activities of finance, industrial relations, technical planning, and news and information. Mr. Colgrove had been Division Vice President and General Manager, Entertainment Tube Division. He will report directly to Mr. Hittinger.

Paul B. Garver has been appointed Division Vice President and General Manager, Distributor and Special Products Division. This new Division will include the activities that pertain to receiving tubes in the former Entertainment Tube Division; the former Electronic Components Distributor Products, and Product Distribution and Traffic organization units; and the RCA Parts and Accessories organization. Mr. Garver had been Division Vice President and General Manager, RCA Parts and Accessories. He also will report directly to Mr. Hittinger.

Dr. Ralph E. Simon has been appointed Division Vice President, Electro-Optics and Devices. This new organization encompasses the activities that formely comprised the Industrial Tube Division. The name has been changed to be more descriptive of the products of this unit. Mr. Simon had been Manager, Electro-Optics Products Operation. Electro-Optics and Devices will become part of the RCA Solid State Division which is headed by Vice President and General Manager **Bernard V. Vonderschmitt** who reports to Mr. Hittinger.

Awards

Commercial Communications Systems Division

Herman R. Henken, Manager of Commercial Marketing Services received RCA's first Design Advancement Award for "his constructive participation in the planning and implementation of design improvement programs and the consistent design quality of the graphic material produced under his direction."

Missile and Surface Radar Division

Duard L. Pruitt, Principal Member, Engineering Staff in the Signal Processing Engineering Activity, received the 1974 Technical Excellence Award at the Annual TE Awards Dinner held on February 28 at the Sheraton Poste Inn in Cherry Hill. In all sixteen quarterly TE winners were honored. Quarterly awards were presented to:

First —**John Drenik, H. DeAlton Lewis** and **Joseph Strip.**

Second—**James W. Cole, Harry C. Irion III, Joseph J. Mark, Stephen R. McCammon, Richard J. Smith** and **Pruitt.**

Third—**John Fogleboch, Bernard J. Matulis, A. Merrit Sheeder, Ralph L. Stegall** and **Don N. Thompson.**

Fourth—**Edward J. Butterfoss** and **Isaac A. Schottenfeld.**

Meadow Lands

"People...Productivity..Profit" was the theme of the annual Meadow Lands Technology Seminar where several key engineers were cited for their outstanding achievements in 1974:

Bill Behrend, Broadcast Transmitter Engineering

Dick Colbaugh, Custom Systems Engineering

Bill Duris, Broadcast Transmitters Engineering

Chuck Filbey, Mobile Products Engineering

Chuck Kocher, Leader, Technical Publications Staff

Greg O'Neill, Mobile Broadcast Engineering

Joe Pierce, Mechanical Engineering Staff

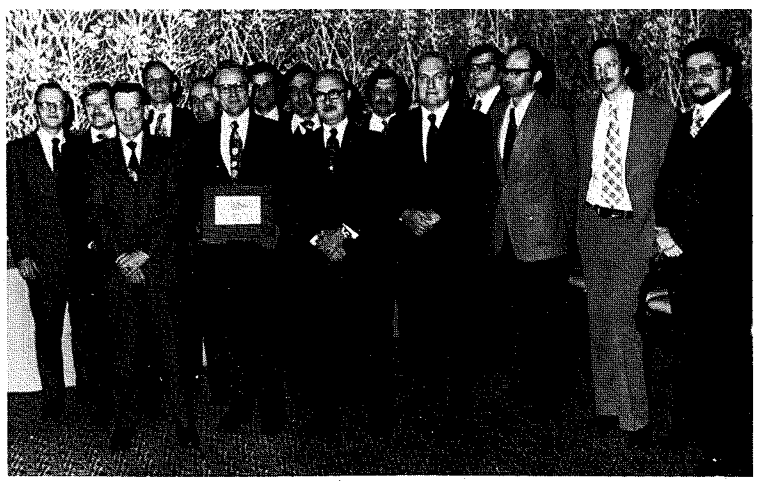
Joe Springer, Manufacturing Engineering.

Ken Weaver, Manufacturing Engineering

RCA Laboratories

Forty-one scientists on the RCA Laboratories staff have received Achievement Awards for outstanding contributions to electronic research and

Duard L. Pruitt (center) holds the 1974 Technical Excellence Award he received at annual TE Awards Dinner. Max Lehrer (left) Div. V.P. and General Manager and Joseph C. Volpe, Chief Engineer, congratulate all sixteen award winners.



MSRD's 1974 TE WINNERS (l to r) — Edward J. Butterfoss, John Drenik, A Merritt Sheeder, Isaac A. Schottenfeld, Joseph Strip, Duard L. Pruitt, Richard J. Smith, H. DeAlton Lewis, Max Lehrer, John Fogleboch, Joseph J. Mark, Bernard Matulis, Harry Irion III, Stephen R. McCammon and Joseph C. Volpe. James W. Cole, Ralph L. Stegall and Don N. Thompson were unable to attend dinner.

Nine Meadow Lands Award Winners from left to right are: Kenneth Weaver, Joe Peirce, William Behrend, Richard Colbaugh, Joe Springer, Greg O'Neill, Charles Kocher and Charles Filbey. Milan Duris is not pictured.

engineering during 1974.

Carmen A. Catanese, for the development of a rugged, reliable electron multiplier of simple construction.

John F. Corboy, Jr., for the design and implementation of apparatus and procedures for scaled-up heteroepitaxial growth of silicon on sapphire.

Thomas L. Credelle, for the demonstration of a low-loss electron guide.

Eduard Luedicke, for contributions to signal-to-noise characterization in color-television receivers.

Barry S. Perlman, for the development of computer-aided device characterization and circuit-design techniques.

William Phillips, for the discovery and development of techniques for the fabrication of high-performance optical waveguides.

Martin Rayl, for the invention and development of novel solid-state particle and gas detectors.

John R. Sandercock, for the concept and practical realization of a multiple focused tandem interferometer with contrast and sensitivity orders of magnitude higher than previously possible.

William C. Schneider, for leadership in the realization and transfer of advanced silicon-on-sapphire technologies.

Fred W. Spong, for development of a high-sensitivity, high-resolution optical recording material.

Carl W. Benyon, Jr., Kenneth M. Schlesier, and **Joseph M. Shaw,** for a team effort on the study and evaluation of dielectrics for CMOS/SOS devices and circuits.

Phyllis B. Brannin and **Gerald S. Lozier,** for a team effort in the identification of a family of materials that promote the deposition of improved phosphor screens.

Robert R. Demers, Joseph Guarracini, William H. Morewood, John H. Reisner, Jr., and **George H. N. Riddle,** for a team effort resulting in improvements in the mechanisms and the optics of electron-beam recordings.

Karl F. Etzold, Bernard Hurley, Reuben S. Mezrich, and **David H.R. Vilkomerson,** for a team effort leading to novel concepts and implementations of acoustic imaging devices.

Doris W. Flatley, Richard J. Hollingsworth, and **Murray H. Woods,** for a team effort in the research and development of MNOS/SOS electrically alterable read-only memory arrays.

Irwin Gordon, Rabah Shahbender, and **Frank S. Wendt,** for a team effort in the development of new ferrite materials and devices.

David D. Holmes and **Richard J. Klensch,** for a team effort in the reduction of arc effects in television receivers.

Arthur Kaiman, Richard H. Roth, Burnett H. Sams, and **Allen H. Simon** for a team effort in the development of a multiprocessor software system for television broadcast automation.

Michael D. Lippman, Angelo R. Marcantonio, Anthony D. Robbi, Paul M. Russo, and **Chin Tao Wu,** for a team effort leading to imaginative applications of microprocessors.

Staff Announcements

Management Information Systems

DuWayne J. Peterson, Staff Vice President, Management Information Systems has announced the following appointments in the RCA Staff Management Information Systems organization: **Franz Edelman,** Director, Business Systems and Analysis; **Warren J. Ferriter,** Director, Computer Systems Planning; and **John T. O'Neil, Jr.,** Director, Information Services.

SelectaVision

William C. Hittinger, Executive Vice President has announced the organization of the RCA "SelectaVision" VideoDisc Project as follows: **Richard W. Sonnenfeldt** is appointed Staff Vice President, "SelectaVision" VideoDisc Operations and will act as Mr. Hittinger's deputy in the direction of this Project.

Mr. Sonnenfeldt will have direct responsibility for — **John F. Biewener,** Staff Vice President, "SelectaVision" Business Planning and Control; **Gordon W. Bricker,** Director, "SelectaVision" Product Management; and **Donald S. McCoy,** Staff Vice President, "SelectaVision" Engineering and Manufacturing.

Mr. Sonnenfeldt will have functional responsibility for and provide business direction to — **Donald P. Dickson,** Staff Vice President, "SelectaVision" Disc Marketing Development and **Thomas J. McDermott,** Staff Vice President, "SelectaVision" Programming Development.

Messrs. Dickson and **McDermott** will continue to report directly to **George C. Evanoff,** Vice President, Corporate Development. **Mr. Evanoff** will continue to report to me for his "SelectaVision" assignment.

Mr. Sonnenfeldt will have responsibility for liaison with the RCA Licensing activity, RCA Laboratories, and other related RCA activities as they pertain to the "SelectaVision" VideoDisc Project.

Government and Commercial Systems

Irving K. Kessler, Executive Vice President has announced the responsibility for the activities that formerly comprised the Central Engineering organization of Government Engineering is transferred to the organization of the Chief Engineer, Government Communications and Automated Systems Division.

Irving K. Kessler, Executive Vice President, Government and Commercial Systems, has announced that **Andrew F. Inglis,** in addition to his present responsibilities as Division Vice President and General Manager, Commercial Communications Systems Division, will assume responsibility in an acting capacity for the Electromagnetic and Aviation Systems Division.

Andrew F. Inglis, has announced the organization of Electromagnetic and Aviation Systems Division as follows: **W. Robert McKinley,** Manager, Van Nuys Operations; **Ramon H. Aires,** Chief Engineer, Engineering; **Bobby J. Fletcher,** Manager, Government Systems; **James F. Gates,** Manager, Special Programs; **Charles L. Gordon,** Manager, Custom Terminals; **Robert M. Hinkel,** Plant Manager, Van Nuys Plant; **W. Robert McKinley,** Acting, Materials; **W. Robert McKinley,** Acting, Rapid Score; **Robert B. Moses,** Manager, Operations Control; **James L. Parsons,** Manager, Product Assurance; **Robert W. Stephens,** Manager, Industrial Relations; **Andrew F. Inglis,** Acting, Aviation Equipment Department; **Linden L. Carter,** Manager, Aviation Programs; **William P. Doyle,** Manager, Product Support; **George A. Lucchi,** Manager, Aviation Engineering; **John P. Mollema,** Director, Marketing; and **Richard C. Quinlan,** Manager, Avionic Systems Programs.

Government Communications and Automated Systems Division

F. Donald Kell, Manager, Information Processing and Recording Systems has announced the organization as follows: **F. Donald Kell,** Acting Manager, Classic Bulldog Program; **E. Frank Bailey,** Manager, Project Management; **John R. Bonaccorsi,** Manager, Engineering Design; **Zack J. Hester,** Administrator, Engineering Field Support; **Herbert E. Strauss,** Manager, Processing Systems; **B. Fred Wheeler,** Manager, Systems Engineering; **C. Robert Thompson,** Manager, Recording Systems; **J. Sidney Griffn,** Manager, Technology and Systems; **Donald T. Hoger,** Admin., Technical Projects Coordination; **Charles R. Horton,** Manager, Aerospace Information Systems; **Richard E. Jansen,** Manager, Airborne Programs; **G. Thomas Rogers,** Manager, Instrumentation Programs; **Irwin Spetgang,** Manager, Engineering Services; and **Charles F. Valenti,** Administrator, Engineering Budgets and Manpower Requirements.

Edmund J. Westcott, Manager, Product Effectiveness has announced the organization as follows: **Harvey R. Barton,** Manager, Product Effectiveness Analysis; **Donald C. Bowen,** Manager, Product Safety and Field Assurance; **John J. Davaro,** Manager, Product Assurance; and **Richard M. Dunlap,** Manager, Producibility Assurance.

Government Engineering

Harry J. Woll, Division Vice President, Government Engineering has announced the appointment of **William W. Thomas** as Manager, Engineering Documentation and Standards.

Paul E. Wright, Director, Advanced Technology Laboratories has announced the organization of Advanced Technology Laboratories as follows: **Richard F. Kenville,** Manager, Applied Physics

Laboratory; **David A. Gandolfo,** Leader, Electron Devices; **Donald G. Herzog,** Leader, Optics and E-O Systems; **Martin L. Levene,** Leader, Advanced Mechanics; **Benjamin Shelpuk,** Leader, Thermal Systems; **Jack J. Rudnick,** Manager, DOT Program; **Gerald M. Claffie,** Leader, Development and Testing; and **Jack J. Rudnick,** Acting, Information Processing.

Consumer Electronics

Jay J. Brandinger, Division Vice President, Television Engineering has announced the Television Engineering organization as follows: **Clyde W. Hoyt,** Manager, Safety and Reliability; **Thornley C. Jobe,** Chief Product Development Engineer; **Eugene Lemke,** Manager. Deflection, Power and Component Supply Development; **Robert J. Lewis,** Chief Engineer, Black and White Television Product Design and Special Projects; and **John M. Wright,** Chief Product Design Engineer.

Elliott N. Fuldauer, Manager, Production Planning has announced appointment of **Joe D. Andrews** as Manager, Development Programming and Control.

David E. Daly, Division Vice President, Product Planning and Industrial Design has announced the appointment of **Stephen H. Morrall** as Director, Television Product Planning and Development.

Thornley C. Jobe, Chief Product Development Engineer has announced the Product Development Engineering organization as follows: **Jack Avins,** Manager, Integrated Circuits Development - Somerville; **Gilbert C. Hermeling,** Manager, Tuners and Remote Digital Systems; **David J. Carlson,** Manager, Remote Control and Digital Systems; **George W. Carter,** Manager, Tuner Development; **Thornley C. Jobe,** Acting Manager, Device and Components Measurement Lab.; **R. Kennon Lockhard,** Manager, Signal Processing; **Eugene E. Janson,** Manager, Project Development/Signal Processing.

Clyde W. Hoyt, Manager, Safety and Reliability has announced the organization of Safety and Reliability as follows: **Ronald J. Buth,** Manager, Technical Relations; **Edward J. Evans,** Manager, Safety Administration and Records; **John Stark,** Manager, Reliability Engineering; and **Lucius P. Thomas,** Manager, Safety Engineering and Testing.

Eugene Lemke, Manager, Deflection, Power Supply and Component Development has announced the organization of Deflection, Power Supply and Component Development as follows: **Jerrold K. Kratz,** Manager, Components and Materials; **Fred Brown,** Manager, Electro-Magnetic Shop; **Robert E. Hurley,** Manager, Materials Engineering; and **James A. McDonald,** Manager, Deflection and Power Development Engineering.

Robert J. Lewis, Chief Engineer, Black and White Television, Product Design and Special Projects has announced the organization as follows: **Robert D. Flood,** Manager, Testing Methods and **Robert J. Lewis,** Acting Manager, Systems Evaluations and Competitive Analysis.

John M. Wright, Chief Product Design Engineer has announced the Product Design Engineering organization as follows: **John M. Ammerman,** Manager, Chassis and Package Development - Mechanical; **Melvin W. Garlotte,** Manager, Package Development; **Eldon L. Batz,** Manager, Resident Engineering - Bloomington; **John A. Konkel,** Manager, Instrument and Chassis Project Engineering; **Paul C. Wilmarth,** Manager, Project Engineering; **Dale E. Roeschlein,** Manager, Vendor Contacts and Approvals; **Gerold L. Roth,** Manager, Instruments - Mechanical; **George W. Yost,** Manager, Engineering Services; **Cecil D. McGinnis,** Manager, Engineering Model Shop.

Roy H. Pollack, Vice President and General Manager, Consumer Electronics has announced the organization as follows: **James M. Alic,** Division Vice President, Finance; **Harry Anderson;** Division Vice President, Manufacturing Operations; **William E. Boss,** Division Vice President, Marketing; **Jay J. Brandinger,** Division Vice President, Television Engineering; **Keith U. Clary,** Division Vice President, Industrial Relations; **W. Thomas Collins,** Director, Consumer Affairs; **David E. Daly,** Division Vice President, Product Planning and Industrial Design; **Francis V. McCann,** Director, News and Information; **Roy H. Pollack,** as Acting, International and Acting, "SelectaVision" Tape Products.

Global Communications, Inc.

Howard R. Hawkins, Chairman of the Board and Chief Executive Officer, RCA Global Communications, Inc. has announced the Executive Committee elections: **Eugene F. Murphy,** President and Chief Operating Officer; **Eugene D. Becken,** Chairman of the Executive Committee of the Board of Directors; **Robert J. Angliss** also is appointed Executive Vice President, Services and Marketing. In this capacity, Mr. Angliss will continue his responsibility for Services and will assume the responsibility for Leased Facilities.

Philip Schneider also is appointed Executive Vice President, Satcom System. In this capacity, Mr. Schneider will have the total responsibility for the continuing development of the Satcom Communications System, including planning, design and production/construction of both space and earth segments. In addition, he will have the total responsibility for implementation of and marketing for the Satcom System.

Mr. Hawkins also announced the following: **Stephen D. Heller,** President, RCA Alaska Communications, Inc. and **Edwin W. Peterson,** Executive Vice President, Financial and Business Development, RCA Global Communications, Inc.

Philip Schneider, Acting, Engineering and Special Systems has announced the Engineering and Special Systems as follows: **Alexander A. Avanessian,** Director, Advanced Switching Projects; **Samuel N. Friedman,** Manager, Advanced Systems; **Stephen L. Latargia,** Manager, Facilities Engineering; **Solomon J. Nahum,** Manager, Construction and Engineering Services; **Robert D. TinWin,** Manager, International Satellite Projects; **Charles R. Whelan,** Manager, TDRSS Project.

Philip Schneider, Executive Vice President Satcom Systems has announced the organization as follows: **Harold W. Rice,** Vice President, Special Project; **A. William Brook,** Director, Systems Engineering and Facilities Planning; **John Christopher,** Director, Spacecraft Engineering and Production; **Dennis W. Elliott,** Director, Busines Planning and Control; **James H. Walsh,** Director, Earth Station, Radio and Construction Engineering and **Philip Schneider,** Acting, Marketing

Research and Engineering

Nathan L. Gordon, Director, Systems Research Laboratory has announced the appointment of **Joseph P. Bingham** as Head, TV Systems Research.

Promotions

Astro-Electronics Division

D. T. Conklin from Jr. Engineer to Assoc. Engineer (J. Staniszewski, AED, Hghtsn.)

S. Malyszka from Assoc. Engineer to Engineer (A. Aukstikalnis, AED, Hghtsn.)

R. J. Mancuso from Jr. Engineer to Assoc. Engineer (W. Metzger, AED, Hghtsn.)

A. L. Stern from Assoc. Engineer to Engineer (C. Hume, AED, Hghtsn.)

D. W. Upmal from Jr. Engineer to Assoc. Engineer (G. Barna, AED, Hghtsn.)

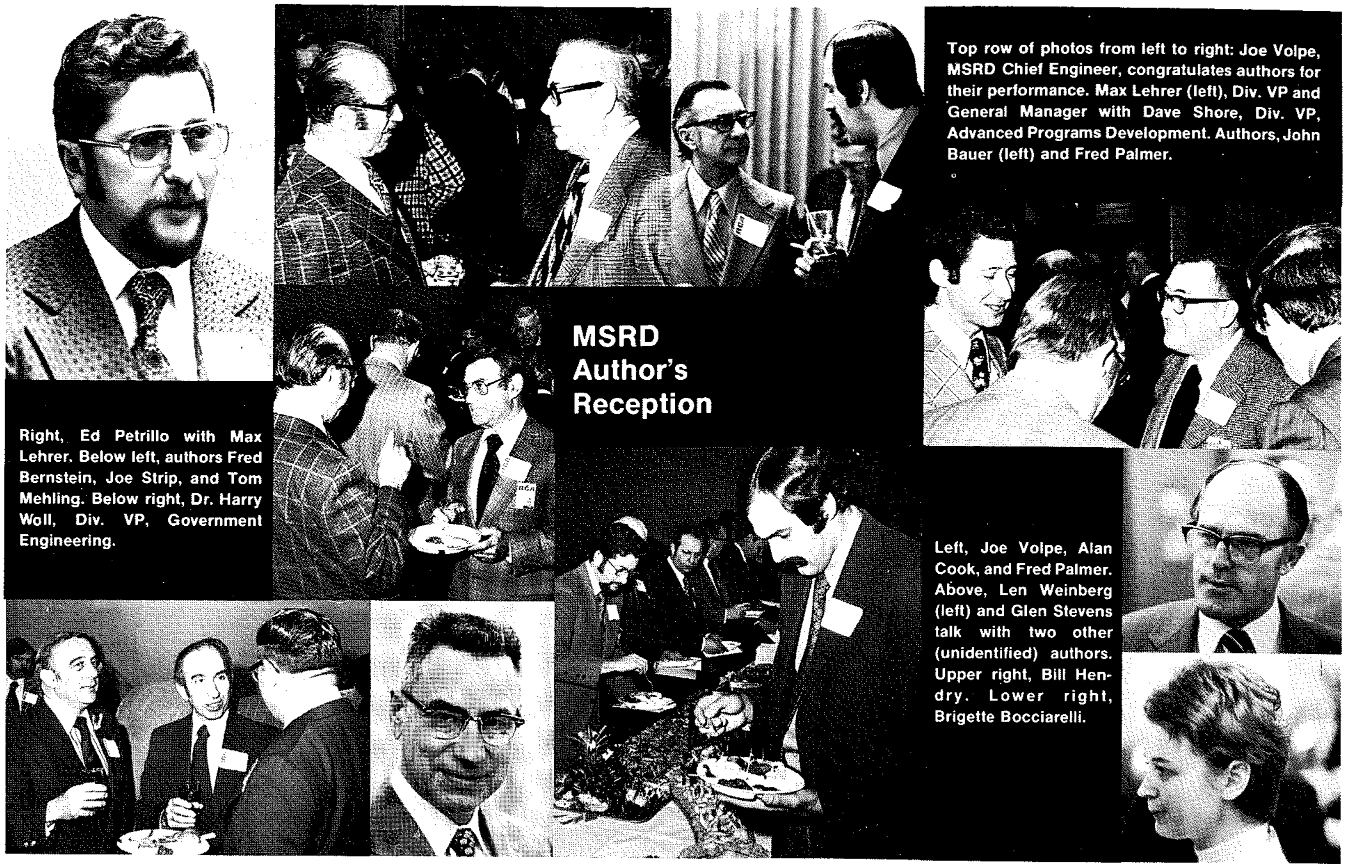
E. A. Zier from Assoc. Engineer to Engineer (M. Perchick, AED, Hghtsn.)

Missile and Surface Radar Division

D. Bennis from Mbr. Engrg. Staff to Sr. Mbr. Engrg. Staff (E. T. Hatcher, Systems Software, Mrstn.)

H. Boardman from Ldr. Sys. Engrg. to Mgr., Project (L. J. Schipper, ORTS Project, Mrstn.)

S. Buckman from Ldr. Des. & Dev. Eng. to Admr. Tech. Proj. Coord. (J. Seligman, AN/TPQ 27 Program, Mrstn.)



MSRD Author's Reception

Top row of photos from left to right: Joe Volpe, MSRD Chief Engineer, congratulates authors for their performance. Max Lehrer (left), Div. VP and General Manager with Dave Shore, Div. VP, Advanced Programs Development. Authors, John Bauer (left) and Fred Palmer.

Right, Ed Petrillo with Max Lehrer. Below left, authors Fred Bernstein, Joe Strip, and Tom Mehling. Below right, Dr. Harry Woll, Div. VP, Government Engineering.

Left, Joe Volpe, Alan Cook, and Fred Palmer. Above, Len Weinberg (left) and Glen Stevens talk with two other (unidentified) authors. Upper right, Bill Hendry. Lower right, Brigette Bocciarelli.

Ninety-three engineers were honored recently at Missile and Surface Radar Division's authors' reception. This reception, hosted by **Joseph Volpe,** Chief Engineer, was the eighth in a series that started in 1966 to honor engineers who have presented or published papers, received patents, or earned doctoral degrees.

In congratulating the MSRD authors, Mr. Volpe called attention to the pressures and motives underlying a professional publication:

"The urge is in all of us to let the world know about some of the exciting things we're doing, and the pressures of self image, corporate image, and obligation to the technical community provide additional impetus for authorship. But beyond the initial motivation lies the real struggle: the work of writing the paper or preparing the presentation or the patent disclosure. Frustrations in the form of time limitations, distractions, and administrative roadblocks combine with one's innate inertia to subvert or delay many of our best efforts.

"That's why my feeling of pride is mixed with awe when I look at the volume of our output of professional papers and presentations, as well as patents."

J. Cabo from Project Adm. to Admr. Operations Review (P. J. Dwyer, Program Adm. AEGIS, Mrstn.)

H. Cox, Jr. from Mbr. Engrg. Staff to Sr. Mbr. Engrg. Staff (E. T. Hatcher, RT Comp Prog., Mrstn.)

J. Guzik from Mbr. Engrg. Staff to Sr. Mbr. Engrg. Staff (J. C. Kulp, Software Analysis, Mrstn.)

E. Hathaway from Sr. Mbr. Engrg. Staff to Ldr. Engr. Sys. Proj. (L. J. Schipper, Comp. Program Dev., Mrstn.)

D. Herman from Ldr. Engrg. Sys. Proj. to Mgr., Project (L. J. Schipper, SM-2 Integ. Project, Mrstn.)

W. Hilpl from Project, Adm. to Adm., Proj. Admin. (P. J. Dwyer, System Test, Mrstn.)

S. Lang from Sr. Mbr. Engrg. Staff to Ldr., Sys. Engrg. (L. J. Schipper, System Design, Mrstn.)

J. Lunsford from Assoc. Mbr. Engrg. Staff to Mbr. Engrg. Staff (H. J. Halpern, Signal Processing Synthesis, Mrstn.)

R. Lyszak from Mbr. Engrg. Staff to Sr. Mbr. Engrg. Staff (E. T. Hatcher, RT Comp. Prog. Des., Mrstn.)

J. Mark from Mbr. Engrg. Staff to Sr. Mbr. Engrg. Staff (E. T. Hatcher, Systems Software, Mrstn.)

D. Mercer, Jr. from Ldr., Engrg. Sys. Proj. to Mgr., Adv. Prod. Engrg. (H. Grossman, Production Planning, Mrstn.)

I. Rosen from Project Adm. to Adm, Proj. Admin. (P. J. Dwyer, Integrated Logistics Support, Mrstn.)

H. Seppanen from Princ. Mbr. Eng. Staff to Ldr. Engrg. Sys. Projects (R. A. Baugh, ORTS Control, Mrstn.)

M. Stoll from Mbr. Engrg. Staff to Sr. Mbr. Engrg. Staff (M. Korsen, Input/Output Buffer Design, Mrstn.)

H. Sykes from Mbr. Engrg. Staff to Sr. Mbr. Engrg. Staff (S. A. Steele, Comp. Prog. Support, Mrstn.)

RCA Service Company

R. W. Caldwell from Sys. Service Engineer to Mgr., FORACS Project (R. S. Maloney, FORACS, Puerto Rico)

D. L. Hill from Engineer to Ldr., Engineers

(K. F. Wenz, Telemetry Commun., Patrick Air Force Base, FL)

J. R. Moore from Operations Support Engineer to Mgr., Range Measurement Lab. Operations (G. N. Berube, Range Measurement Systems, Patrick Air Force Base, FL)

RCA Alaska Communications, Inc.

J. B. Wilson from Engineering Assoc. to Supervisor, Field Installation (J. H. Hayes, Manager, Bush Communications Project, Anchorage)

E. S. Mack from Sr. Engineer to Mgr., Construction Engineering (K. J. Rourke, Mgr., Construction Installation Engineering, Anchorage)

Licensed engineers

When you receive a professional license, send your name, PE number (and state in which registered), RCA division, location, and telephone number to: *RCA Engineer,* Bldg. 204-2, RCA, Cherry Hill, N.J. New listings will be published in each issue.

Electronic Components, Lancaster

The following engineers participated in the thirty-week PE Review Course sponsored by the Lincoln Chapter of the Pennsylvania Society of Professional Engineers and have successfully passed the state PE examination.

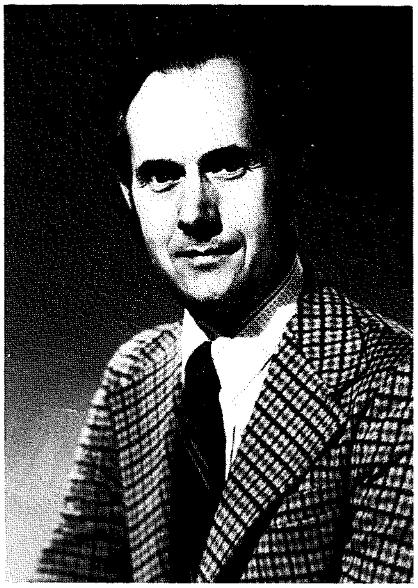
P.S. Augustine, EC, Lancaster, Pa.; PE-021425E, Pennsylvania
J.A. Eshleman, EC, Lancaster, Pa.; PE-021434, Pennsylvania
J.P. Jasinski, EC, Lancaster, Pa.; PE-021435E, Pennsylvania
D.R. Trout, EC, Lancaster, Pa.,; EC, Lancaster, Pa.; PE-021431E, Pennsylvania
H.J. Werntz, EC, Lancaster, Pa.; PE-021436E, Pennsylvania
J.R. Tomcavage, EC, Lancaster, Pa.; PE-021428E, Pennsylvania
H.H. Swope, EC, Lancaster, Pa.: PE-021426E, Pennsylvania

Electronic Components, Harrison

Willis F. Beltz, Manager Plant Engineering in the Microwave Activity received the New Jersey P.E. License No. 21933.

Degree granted

Jerome Schatz of RCA Global Communications, Inc., New York, N.Y., received the BS in Communications from the Empire State College of the State University of New York at Old Westbury, Long Island.



Sepich

Sepich is new TPA for Broadcast Systems

Arch Luther, Chief Engineer of Broadcast Systems, has appointed **William S. Sepich** Technical Publications Administrator for Broadcast Systems. In this capacity, Mr. Sepich is responsible for the review and approval of technical papers; for coordinating the technical reporting program; and for promoting the preparation of papers for the *RCA Engineer* and other journals, both internal and external.

Mr. Sepich received the BSME from the University of Pennsylvania in 1954 and the MSME from Drexel University in 1960. He joined RCA in 1954 as a design engineer on antenna pedestals in the Missile and Surface Radar Division in Moorestown, N.J. In 1960 he was promoted to Engineering Group Leader in that activity. In 1969, he was transferred to Camden where he is presently Manager, Engineering Technical Support for Broadcast Systems. He is a member of the American Management Association (AMA), IEEE, ASME, ADPA, and the SMPTE. He is also a registered Professional Engineer in New Jersey.

Stoeger and MacWilliams are new Ed Reps for Service Company

Merrill Gander, Technical Publications Administrator, RCA Service Company has appointed **Ray MacWilliams** and **Joe Stoeger** Editorial Representatives for the Service Company. Mr. MacWilliams will represent Government Services and Mr. Stoeger will represent Consumer Services. Editorial Representatives are responsible for planning and processing articles for the *RCA Engineer* and for supporting the corporate-wide technical papers and reports program.

MacWilliams (left) and Stoeger

Joseph E. Steoger, Mgr., Engineering Department, Consumer Services Division, started with RCA in 1942 as an Installation and Service Engineer. In 1945, he transferred to the Industrial Services activity where he was engaged in engineering activities relating to 16 mm. sound projectors and tv terminal and studio equipment. From 1950 to 1954, he assisted in special engineering projects—experimental automated color printing processes and later asssting Rex Isom on kine recording programs. In 1954 he was assigned to Computer Systems Service. In 1959 he was named Manager of Field Operations in the Technical Services Division of the RCA Service Company. In 1963 he was promoted to Manager of the EDP Computer Services Centers — Washington, San Francisco, Chicago, Philadelphia and Cherry Hill. In 1966 he transferred to the Consumer Services Division of RCAS as Quality Administrator and Manager, Special Engineering Programs. In 1971 he was promoted to Manager of the Engineering Department of the Consumer Services Division.

Raphael J. MacWilliams, Mgr., Marketing Services of the Government Services Division of RCA Service Company, directs the planning, writing, editing and production of contract proposals and marketing management communications, including reports, presentations, and brochures. He also coordinates Government Services activities relating to news and information, advertising, market planning, and market research. He joined RCA in 1962 as an engineering editor in the Marketing department of Government Services. Subsequently he served from 1966 to 1974 first as Manager, Proposal Writing and then as Manager, Writing Services. Mr. MacWilliams received the AB in English from Villanova University in 1951. In 1953 he received the MA in English from the University of Pennsylvania. He is a member of the Modern Language Association of America.

QSL's from Navassa Island

Last Thanksgiving, an expedition of MSRD engineers were making "ham" radio contacts from tiny, uninhabited Navassa Island. Navassa Island, which is a United States possession under the jurisdiction of the U.S. Coast Guard, is located 75 miles east of Jamaica, 30 miles west of Haiti, and 90 miles south of Cuba.

The six-man group comprised **Dr. S. B. Adler** (K2KA), **E.M. Brown** (W2PAU), **J.D. Duffin** (W2ORA), **W. Gallick** (K2FT), **A.R. Klotzbach** (W2FYS), plus Adler's 21-year-old son Frank (WB2BXV), a senior at Temple University. Ham radio enthusiasts are much like stamp and coin collectors; many are anxious to acquire communication confirmations (QSL cards) with as many rare areas of the globe as possible. Navassa Island qualifies as such a spot. Normally uninhabited, when someone does activate the island ham radio-wise, the airwaves are a beehive of activity while the effort is underway.

The group flew from Philadelphia to Kingston, Jamaica and then traveled approximately 125 miles by boat to Navassa. The initial attempt to reach the island on Saturday night, November 23, was thwarted by a severe storm at sea. The 65-foot chartered fishing boat was forced to return to a port in Jamaica, but did arrive successfully one day later.

Transferring a half-ton of supplies and equipment from the boat to a small dinghy, making a trip to the base of the island's only access ladder, and then hauling everything up on a hand line was tedious, and there was a constant danger of having the small boat smashed up against the undercut cliffs. Finally, all personnel and gear were safely on the island and the business at hand was begun. Antennas were erected, equipment was set up, gasoline motors generator sets were fueled and oiled and placed in operation. Navassa Island was on the air!

The group used the FCC-assigned call sign KC4NI and operated on all amateur frequencies from 1.8 through 28 MHz. Three stations were operated simultaneously, nearly 24 hours a day for our days. Operation ceased only when oor propagation conditions prevailed, or hen sudden rain storms drowned the otor generators.

he three 150-W transmitters were kept usy most of the time on the island, using th single-sideband (SSB) and CW. The C4NI group contacted amateurs in 62 untries, 49 of the 50 states (missed aska), and all continents. A breakdown the 7,320 contacts made by the opera- n is as follows:

quency (MHz)	28	21	14	7	3.5	1.8
SSB	718	533	1998	86	531	10
CW	9	443	1390	1216	308	79
Total	727	976	3388	1302	839	89

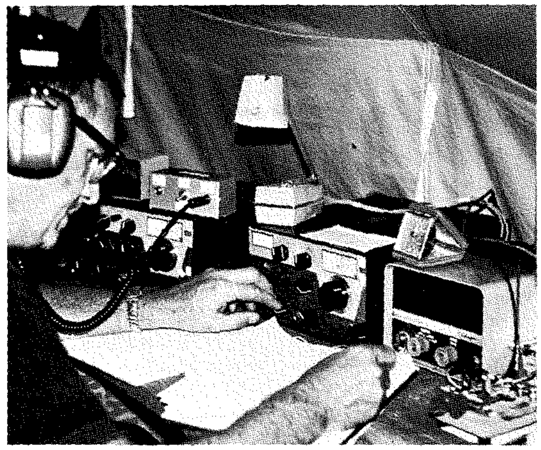
The island is very rugged; sheer cliffs 50- to 100-ft high ring the entire perimeter. The only possible landing spot is via a 30-ft wire rope ladder suspended from a cantilevered catwalk jutting from the side of a cliff. The six members of the group, plus over a half-ton of supplies and equipment, gained access to the island via this route.

A variety of antennas was used; paralleled dipoles for 3.5 and 7.0 MHz (common coaxial-cable transmission line) were erected at the cliff edge and sloped downward to the sea. A similar arrangement was used for 14 and 28 MHz, although used mainly on 14 MHz. A 262-foot dipole sloped up a hill served as the 1.8 MHz radiator. With vicious cactus everywhere, securing the hillside-end of the 1.8 MHz dipole was quite an experience! A multiband ground-plane antenna provided some redundancy with operational capabilities on 7.0 through 28 MHz. Completing the antenna complement was a three-element horizontal beam which was operated on 14, 21, and 28 MHz. Power was supplied by two motor generator sets: a 1750-W unit powered two stations and a 1000-W set powered the third. Although the three operating stations and most of the antennas were within a few hundred feet of each other, mutual interference was not troublesome, even when a CW station and an SSB station were operated simultaneously on the same band.

Even though we are presently in a low point in the sun-spot cycle, the maximum usable frequency did get above 28 MHz several times, which permitted over 700 contacts to be made on the 10-m band. The bread-and-butter band was 14 MHz; nearly half of the total contacts amassed were made on this band. Rugged limestone rock terrain rising abruptly behind the operating positions accounted for the difficulty encountered with stations in Europe and Africa. Stateside contacts were good; the first bounce off the salt water gave the KC4NI rf a real boost and the simple wire antennas were very effective in this direction.

The return trip was uneventful. Once back in Kingston, cold drinks, showers, and good food solved some of the discomforts of the previous week. The only chore remaining was to answer the thousands of requests for QSL cards. All cards received to date have been acknowledged, so the group is free to contemplate other rare spots for possible ham activity.

Miles Brown (left) and Joe Duffin (right, coveralls) with two Jamaican crew members erecting a tri-band beam antenna for 14-, 21-, and 28-MHz operation.



Amor Klatzbach monitoring 21 MHz CW.

Sy Adler is in the tent maintaining 7 MHz SSB communications with Jamaica.

Joe Duffin on 14 MHz SSB.

Editorial Representatives

The Editorial Representative in your group is the one you should contact in scheduling technical papers and announcements of your professional activities.

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*Technical Publications Administrators (asterisked * above) are responsible for review and approval of papers and presentations