Seventh Anniversary

This issue marks seven complete years of RCA ENGINEER communications. By the cooperative efforts of engineers and scientists in every division, *more than 600 professional papers* have been published in the RCA ENGINEER and thus made available corporate-wide to our engineering and research community.

Each paper published signifies that our engineers and scientists recognize the value and the professional nature of their work—and that RCA engineering and research activities accept the responsibility of making known their technical achievements throughout RCA. This truly professional objective goes beyond innovation and solution. It includes the equally significant job of recording *for others* the knowledge gained from successful endeavor, through RCA technical reports, engineering memoranda, symposia, and papers published in the RCA ENGINEER.

It is equally important that papers describing our research and engineering achievements be published in outside technical journals. Thus, our customers and potential customers can be informed of the great range of scientific competence and accomplishment of RCA.

The cumulative body of RCA technical knowledge is a priceless possession. Our ability to take maximum advantage of this determines to a great extent our position in the industry. As RCA continues to grow and diversify—technically, geographically, and organizationally—it becomes *ever more important* to intelligently document, disseminate, and use that knowledge. In this way we can efficiently transform RCA's collective skills and engineering know-how into new and improved products—and profits.

D. F. Schmit
Staff Vice President,
Product Engineering;
Research and Engineering,
Radio Corporation of America

RCA ENGINEER

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DEPARTMENTS

A TECHNICAL JOURNAL PUBLISHED BY **RADIO CORPORATION OF AMERICA,** PRODUCT ENGINEERING 2-8, CAMDEN, N. J.

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

Late in October 1942, a group of 125 RCA scientists and engineers—representing about 30 percent of RCA's total technical manpower—were transplanted from Camden and Harrison to new headquarters in Princeton, N. J. *RCA Laboratories was in business.* The business at hand was an all-out research and development effort in support of the United States' bid for victory in World War II. From its beginning until the end of World War II, RCA Laboratories' research was concentrated on television, tubes, radar, antennas, communications, and acoustics. The major emphasis was on research and development leading to the construction, testing, and evaluation of complete electronic *systems.* The role of electronics, under the pressure of war, expanded greatly during these years. Electronic technology advanced in a matter of months over ground that would normally have required years to cover—in many cases pushing the limits of existing scientific knowledge.

The return to peace generated new pressures on indus-

The Engineer and the Corporation

RCA LABORATORIES

Dr. JAMES HILLIER, Vice President

RCA Laboratories
Princeton, N. J.

try to supply still newer goods and services after the austerity of the war years. Thus, the RCA Laboratories' research program, under the direction of Dr. Elmer W. Engstrom, was reshaped following the war to include an increasing emphasis on fundamental research. There was still a major effort on the development of complete *systems,* particularly television. It also was recognized that the increasing diversification of the electronics industry required both an increase in RCA's total research and development effort and coordination of the development effort with the individual product divisions. This led naturally to a trend in the Laboratories toward work on the more basic long-range projects.

Today, major emphasis in the Laboratories is on solving *fundamental* problems, while the majority of applied research and development projects are carried on in the product divisions. A large percentage of the Laboratories' research program is devoted to electronic materials and devices, the electronic "building-blocks" that permit the invention of new and improved electronic apparatus and systems. While the Laboratories no longer designs, develops, or constructs complete systems, it has broadened its technical base in support of the divergent activities and product lines of the RCA product divisions. At the same time, it has a responsibility to be alert to developments that occur elsewhere in electronics and to pursue and help utilize the potentialities of those developments that are significant to RCA.

RCA's gross business has increased seven-fold since 1942, and the quantity of its products and services to an even greater extent. An eighteen-fold increase in the number of scientists and engineers has been needed to support RCA's mounting business and product diversification. Thus, today, the approximately 300 scientists and engineers on the RCA Laboratories' staff represent approximately 4 percent of RCA's total technical strength and 0.2 percent of the technical manpower of the United States electronics industry. While chemists and metallurgists were rarities at the Laboratories in 1942, they now represent about 20 percent of the technical staff, with physicists and mathematicians accounting for another 35 percent. About half the staff members have doctorates, or roughly double the percentage in 1942. These changes in the makeup of Laboratories' personnel are indications of the shifting emphasis occurring in the research program and of its changing role relative to the Corporation and its product divisions.

RCA LABORATORIES ORGANIZATION

There are about 1200 people located at the David Sarnoff Research Center. RCA Laboratories accounts for slightly under 1000, which includes the research activities, Project Pangloss (a contract-supported communications project which is carried out by the Special Projects Laboratory), C Stellarator Associates (a group which works with Princeton University's project on controlled nuclear fusion), and the Laboratories Administration. The latter includes Accounts and Finance, Purchasing, Materials Control, Stores, Building and Grounds, Model Shop, Office Services, Engineering Services, Personnel, Public Relations, and Marketing, which provide support and services for the entire Center. In addition to RCA Laboratories personnel, the Vice President, Research and Engineering, and the Vice President and Technical Director, together with their staffs, the entire RCA Patents and Licensing activity, and approximately 120 technical personnel assigned to seven product-division applied-research groups are located at the David Sarnoff Research Center.

The research activities of RCA Laboratories are organized functionally into seven different laboratories, distinguished from one another chiefly by subject matter. The Laboratories' research and administrative organization is shown in Fig. 1; the largest laboratory has approximately 60 staff members.

RCA LABORATORIES RESEARCH PROGRAM

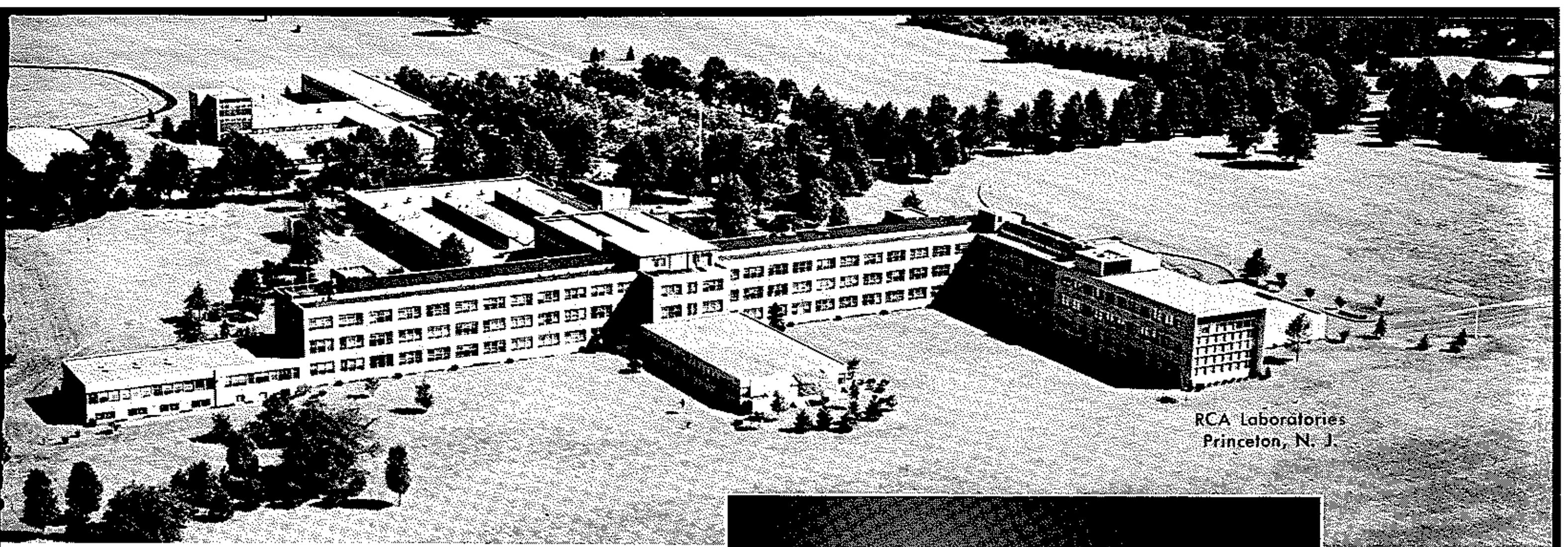
The continued growth of electronics, particularly the wide range of products it now encompasses, and the corresponding growth in the magnitude and scope of electronics research put a complete research program beyond the reach of any single corporation. This places a burden of selectivity on the RCA Laboratories' research program coupled with a sensitivity to technical developments both within and outside RCA. Moreover, the research program must be dynamic; it must be modified from time to time to provide continued technical advances in those areas of greatest business interest to the Corporation. The role that each of the seven research laboratories and the supporting Research Services Laboratory plays in facing this challenge is briefly described below.

Materials Research Laboratory

The Materials Research Laboratory is one of the largest of the laboratories, and includes small groups in Zurich, Switzerland, and Tokyo, Japan. It seeks to provide:

1) *materials* with superior properties for useful electronic devices;
2) *methods* for controllably and economically synthesizing materials, and for fabricating them into devices; and
3) *understanding* of the fundamental relationships between the preparations and constitutions of materials and their resultant properties.

The research program of the Materials Research Laboratory is chiefly directed to electronically active solids



essential to the devices that are vital in RCA's present and future apparatus and systems. Included are magnetic materials, phosphors, laser crystals, insulators, semiconductors, superconductors, photoconductors, photovoltaics, electron emitters, and thermoelectrics.

One of the recent advances in the Materials Research Laboratory is the development of a germanium-silicon alloy for thermoelectric power generation (Fig. 2). This material provides a high efficiency of conversion from heat to electricity in the temperature range from 300°C to at least 900°C. It is uniquely suited to outer-space applications, for it is the only efficient thermoelectric material that will operate in vacuum, without deterioration, for long periods of time at high temperature. The material was transferred from research to development and production at the Electron Tube Division, Harrison, in less than a year, with the help of contract support. The swift transfer from research to production is an excellent example of effective cooperation between technical teams from the Laboratories and a product division.

DR. JAMES HILLIER has been Vice President, RCA Laboratories, since early 1958. He is responsible for directing the research programs and administration of RCA Laboratories and for the direction of technical programs at Laboratories RCA, Ltd., at Zurich, Switzerland, and Laboratories RCA, Inc., Tokyo, Japan. In 1939 and 1940, while Dr. Hillier was a research assistant at the Banting Institute of the University of Toronto Medical School, he and a colleague, Albert Prebus, designed and built the first successful high-resolution electron microscope in the Western Hemisphere. Following this, Dr. Hillier joined RCA as a research physicist at Camden and then Princeton, where he designed the first commercial electron microscope to be made available in the United States. For his contributions to the development of the electron microscope as a vital tool of medical research, Dr. Hillier received an *Albert Lasker Award* in November 1960 from the American Public Health Association. Born in Brantford, Ontario, Dr. Hillier studied at the University of Toronto, where he received the BA in Mathematics and Physics in 1937, MA in Physics in 1938, and PhD in Physics in 1941. In 1953, he was appointed Director of the Research Department of Melpar, Inc., returning to RCA a year later to become Administrative Engineer, Research and Engineering. In November 1955, he was appointed Chief Engineer of RCA Industrial Electronic Products. In January, 1957, he returned to RCA Laboratories as General Manager, and was elected Vice President, RCA Laboratories, a year later. Dr. Hillier is a *Fellow* of the American Physical Society, the American Association for the Advancement of Science, and the Institute of Radio Engineers; a past President of the Electron Microscope Society of America; currently Vice President of the Industrial Research Institute; a Member of the Board of Directors of Industrial Reactor Laboratories, Inc.; and a Member of the American Management Association, and of Sigma Xi.

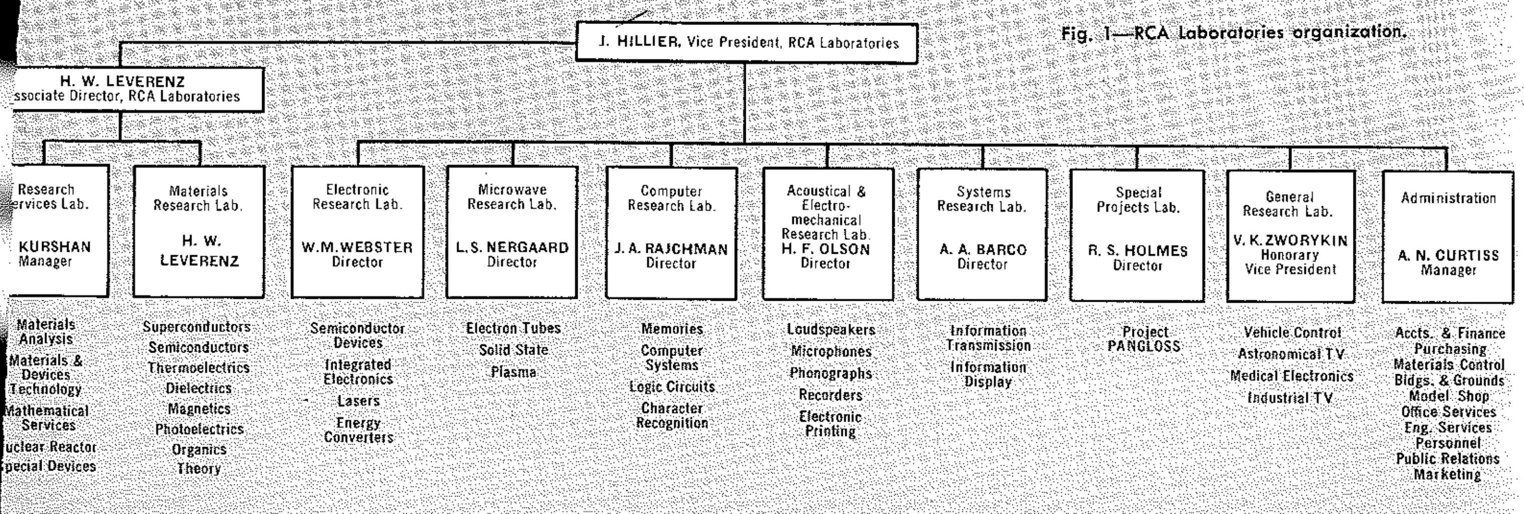


Fig. 1—RCA Laboratories organization.

A method for coating wires, ribbons, or other substrates with crystalline niobium tin was devised in 1961 in the Materials Research Laboratory. Niobium tin has outstanding properties as a superconductor, particularly its ability to remain superconductive in magnetic fields exceeding 100,000 gauss. It has, however, been difficult to prepare in a useful form. The new method, now being further developed by the Electron Tube Division, makes it possible to prepare lengths of wire or ribbon useful for the winding of superconductive magnets of extremely high field strengths.

Electronics Research Laboratory

The research program of the Electronics Research Laboratory is concerned broadly with three classes of electronic devices:

1) semiconductor devices, including integrated electronics,
2) energy-converter devices, and
3) quantum-electronic devices.

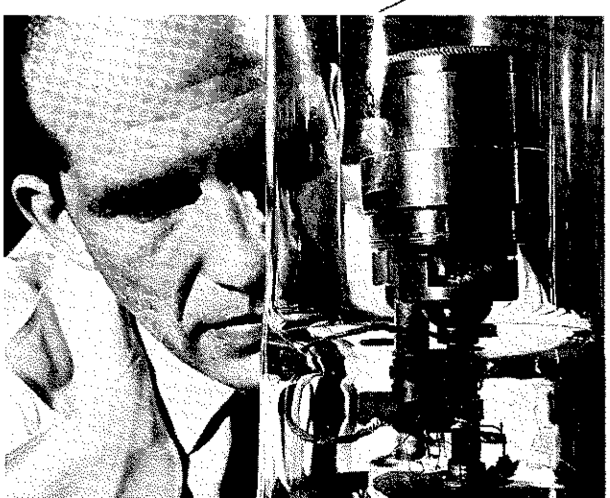
The major research effort on semiconductor devices and integrated electronics is concerned with active devices which show promise of being useful in large-scale networks where they can be fabricated and interconnected simultaneously and, therefore, economically. It is virtually certain that sometime in the future hundreds or even thousands of active electronic elements will be fabricated and interconnected in a single processing run. When this occurs, the cost for a given information-handling capability will be reduced significantly. To this end, transistor-like devices have been successfully deposited by evaporation of polycrystalline CdS.

The new evaporated CdS devices (Fig. 3) have electrical characteristics comparable to those of conventional transistors of four or five years ago, and further improvements are possible. The most significant aspect of this development is that the devices can be evaporated and interconnected using four evaporations in a single vacuum cycle. There are still a great many problems to be solved; for example, reproducibility. Research and development at RCA Laboratories, and at DEP Applied Research (Camden) and the DEP Surface Communications Systems Laboratory (New York), seeks a solution. In the meantime, other approaches, including unipolar transistors and organic semiconductors, are also the subject of research work in the Electronics Research Laboratory.

RCA Laboratories has had a modest, largely Government-supported effort on energy converters for some time. Much of this work has been instrumental in the establishment of programs in the component divisions and DEP. The Electronics Research Laboratory's present program on energy converters includes work on three of the major energy-conversion devices, and is in support of the increasing development efforts of the product divisions. The program includes work on thermoelectric and thermionic energy converters and on solar cells. Work on thin-film solar cells has provided devices with 4.5 percent efficiencies. The aims of this work are a significant decrease in cost per watt and a significant increase in watts per pound compared with single-crystal solar cells.

The Electronics Research Laboratory program on quantum electronics is relatively new, but is receiving increasing emphasis. The greatest effort is on optical masers (lasers) because of the great significance these devices may have for RCA's business.

Fig. 2—B. Abeles testing germanium-silicon thermocouple in a vacuum chamber.



Microwave Research Laboratory

The broad objective of the Microwave Research Laboratory program is to open the upper reaches of the radio spectrum to supply the additional wideband channels required for microwave relay links, space communications, and the interconnection of high-speed data-processing systems. To these ends, the research program seeks to devise amplifying devices whose contribution to system noise is small compared to the noise introduced by immutable external noise sources such as the earth, its atmosphere, and the galaxies; a second objective is to develop extremely-high-power RF sources capable of producing signals at a receiver which are large in comparison with the noise.

The program in the recent past on low-noise amplifiers included work on solid-state devices such as parametric and tunnel-diode low-noise microwave amplifiers, and on tubes such as the low-noise traveling-wave tube. The present program on solid-state devices has been extended to include amplifiers that use the Hall effect in semiconductors. These devices are nonreciprocal between input and output and thus exhibit the high degree of stability necessary for reliable communication systems. Work also continues on traveling-wave tubes with the aim of pushing the outstanding low-noise performance of this class of amplifier to its limit.

In the field of microwave power generation, an expanding program directed toward devices with improved performance at higher frequencies (above 10 Gc) includes studies of very dense electron beams required for millimeter-wave generation. It also includes work on plasmas (Fig. 4), particularly on devising means by which the high plasma densities required for millimeter-wave generation may be obtained, and on means for exciting oscillations in such plasmas. In addition, a research program is underway on crossed-field amplifiers, with the objective of finding high-gain mechanisms in these inherently efficient amplifiers.

Acoustical and Electromechanical Research Laboratory

The largest effort in the Acoustical and Electromechanical Research Laboratory is directed toward all aspects of the reproduction of sound and includes such diverse projects as the analysis and coding of speech, and the development of extremely high-fidelity phonograph systems. It also includes work on new and improved microphones (Fig. 5), loudspeakers, and solid-state audio circuitry.

The research program of this laboratory also includes work on the recording of video signals. It was in this laboratory that the "Hear-See" television recording and reproduction system was developed.

The Acoustical and Electromechanical Research Laboratory also has a program on electronic printing. It was here that RCA's Electrofax system was developed. Work on Electrofax continues for document and photograph reproduction applications and for computer printers, sup-

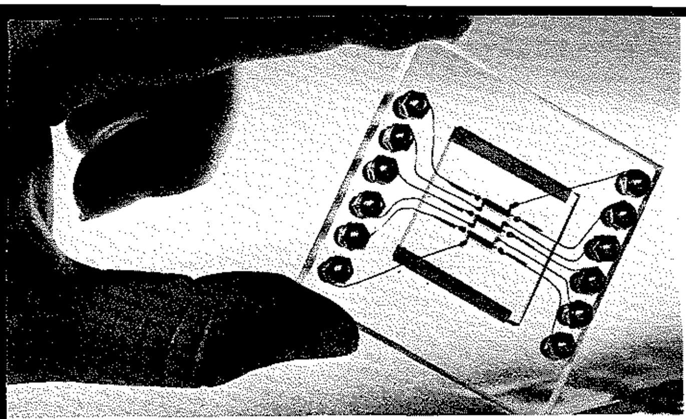


Fig. 3—Laboratory test unit containing three CdS thin-film devices made in special elongated form for experimental purposes.

plemented by additional work on slower-speed mechanical computer printers.

Computer Research Laboratory

Research on some aspects of computers has been conducted since the formation of RCA Laboratories. The computer program has been steadily enlarged, and in 1961, the Computer Research Laboratory was established as a separate entity. The activities of this laboratory are concentrated on memories, high-speed solid-state switching circuits, character recognition, and computer theory.

Research on memories is aimed at higher capacity and higher speeds and includes several approaches. Among these is a cryoelectric memory (Fig. 6) in which complete arrays of 10 x 10 bits have been demonstrated in the laboratory. Here, for the first time, there is the possibility of making an all-electronic random-access memory with a capacity comparable to that of electromechanical devices such as drums or tapes—but having access times measured in microseconds rather than seconds or minutes.

This Laboratory has also participated in a large Government-supported project aimed at 1000-Mc computers. Practical logic and memory circuits, using tunnel diodes developed originally in the Electronics Research Laboratory, have been operated at RCA Laboratories at very nearly this enormous speed (1000 times the speed of commercial computers at the time the contract was signed in 1957). The research phases of this contract were completed early in 1962, with RCA Electronic Data Processing continuing development work.

Programs are also underway in the Computer Research Laboratory on character recognition and on solid-state computer circuits for operation at the speeds anticipated for the next generation of computers. Foundations for future generations of computers are being sought in theoretical studies, including switching theory, system analysis, and artificial intelligence.

Systems Research Laboratory

The Systems Research Laboratory is engaged in research on information transmission and display, with emphasis on communications and television. New concepts in electronically active materials and in solid-state devices are being investigated for applications in circuitry.

In addition, there are research programs directed to the application of solid-state devices to home instruments, with emphasis on improved performance and increased reliability, and to the broad problem of devising more-versatile, simpler, and less-expensive devices for the display of visual information.

In the communications area, the emphasis is on reliable high-speed digital techniques. Modern statistical concepts are being employed using both analytical and experimental approaches to coding, modulation detection, decision processes, network realization, and adaption. Included is a program directed to the transmission of computer-type information on available telephone channels (Fig. 7).

General Research Laboratory

One part of the program of the General Research Laboratory is aimed at achieving complete electronic control of individual motor vehicles on a highway. The feasibility of such control has been demonstrated on a closed-loop track. The detector portion of the system has been marketed by RCA, and numerous test installations have been made for state and federal governments.

A program on medical electronics includes the development of passive sensors of several types which can monitor physiological information for recording or control.

In addition to the vehicle-control and medical-electronics programs, the General Research Laboratory is engaged in work on astronomical and industrial television. The former program is under the sponsorship of Princeton University and is for the development of a television system, including a balloon-borne transmitter for locating astronomical objects and permitting remote control of a telescope from the ground. The industrial-television program includes work with advanced components and techniques aimed at improving closed-circuit television.

Research Services Laboratory

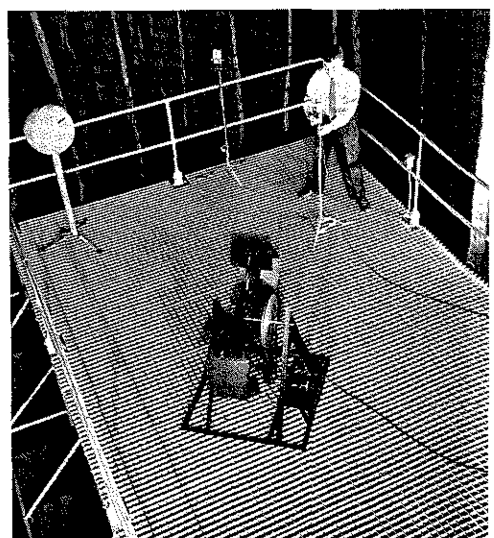
Direct technical support of the seven research laboratories is provided by the Research Services Laboratory, which is comprised of the following major groups: 1) Materials Analysis, 2) Nuclear Reactor, 3) Materials and Devices Technology, 4) Mathematical Services, and 5) Special Devices.

The *Materials Analysis* group has facilities for performing wet and spectrographic chemical analyses, plus equipment to perform x-ray diffraction, electron diffraction, and light and electron microscopy for the physical analysis of materials. In addition, a solids mass spectrograph (Fig. 8) is available which is capable of detecting impurities in the *parts-per-billion* range. This instrument has aided in the solution of problems presented by the Electron Tube Division and the Semiconductor and Materials Division.

The *Nuclear Reactor* group has its headquarters at Industrial Reactor Laboratories, Inc. (IRL, Fig. 9), within a short driving distance of RCA Laboratories. IRL is owned jointly by ten industrial companies, including RCA. The heart of the facility is a 5-Mw reactor equipped for neutron-activation and neutron-diffraction analyses,

Fig. 4—G. A. Swartz examining experimental RF plasma propulsion experiment.

Fig. 5—E. G. May readying experimental microphone for tests in RCA Laboratories free-field sound room.



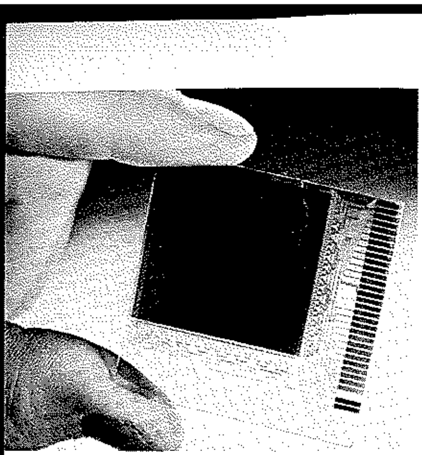


Fig. 6—Mechanical sample of 128 x 128 bit cryoelectric memory and addressing network.

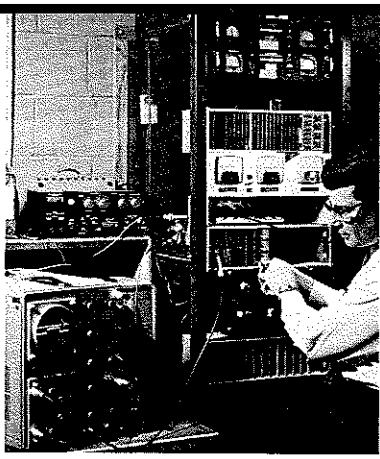


Fig. 7—J. J. Brandinger verifies feasibility of a novel digital communications technique in the Systems Research Laboratory.

isotope production, and studies of defects induced by neutron bombardment. In addition, a radiotracer facility is available at RCA Laboratories for low-level studies.

The *Materials and Devices Technology* group is equipped to fabricate and synthesize new devices and materials for the research programs of the Laboratories. To this end, it has all the major facilities needed for tube and transistor fabrication and materials synthesis. This group produced tunnel diodes in quantity for RCA Laboratories and the product divisions prior to the establishment of development and production facilities at the Semiconductor and Materials Division.

Mathematical Services' chief facility is a digital computer, with which it supports the RCA Laboratories research program in the areas of problem analysis and digital computation. In addition, the group carries out an independent research program in mathematical methods, numerical analysis, and programming research.

The *Special Devices* Group was established early in 1961 to supply small quantities of custom-made devices to advanced-development groups in the product divisions and at RCA Laboratories. The group calls on the special skills of groups at the Semiconductor and Materials Division, DEP, and RCA Laboratories to provide experimental devices not otherwise available.

AFFILIATED LABORATORIES OF THE PRODUCT DIVISIONS

RCA Laboratories has welcomed the establishment of an increasing number of division-supported applied-research and advanced-development groups at Princeton, including the following:

1) *Microwave Applied Research Laboratory,* Electron Tube Division
2) *Astro-Electronics Applied Research Laboratory,* Astro-Electronics Division, DEP
3) *Advanced Military Systems,* Defense Electronic Products
4) *Communications Advanced Development,* RCA Service Company
5) *Power Tube Applied Research Laboratory,* Electron Tube Division
6) *Conversion Devices Laboratory,* Electron Tube Division
7) *Home Instruments Advanced Development Laboratory,* RCA Victor Home Instruments Division

The establishment of these groups at the David Sarnoff Research Center has strengthened RCA's ability to move swiftly from research to product design. These groups have the advantage of being able to pick up new research results quickly. From RCA Laboratories' point of view, we welcome the opportunity to assist these groups. We also welcome the inevitable improvement in communication and cooperation provided by the daily contact of research and advanced-development personnel.

SPONSORSHIP OF PRODUCT-DIVISION APPLIED RESEARCH

This is the fifteenth consecutive year that RCA Laboratories has financed an Applied Research Program in the product divisions. The 1962 program totals 34 projects in six product divisions and RCA Victor Company, Ltd., Montreal. Projects are selected for support based on their profit potential to RCA, the probability of achieving technical success, and the technical and supervisory contribution Laboratories' personnel can make to the work.

Many of these applied-research projects have resulted in new products for RCA or major improvements in existing products. The results support our belief that the program helps bridge the gap between research and product development in RCA's manufacturing divisions. Communication and cooperation are improved by the frequent personal contact of Laboratories' and product-division personnel, and Laboratories' personnel benefit by the direct exposure to the needs and desires of the product divisions.

SUMMARY

RCA Laboratories, through steady growth, and through a gradual reshaping of its research program has kept pace with the greatly expanded technical and business interests of the Corporation. This has been accomplished by a steady shifting of responsibility for advanced development to the RCA product divisions along with an increased emphasis in the Laboratories on problems of a fundamental nature in an ever-widening area of scientific investigation.

RCA's vast business interests, coupled with the swift growth of electronics technology, is placing a tremendous burden on the company's pool of engineering and scientific talent. We are moving to meet our share of that burden—first, by concentrating on major technical advances in those areas of greatest business potential to RCA, and second, by providing means for more effective communication and cooperation between our staff members and the engineers and management of the product divisions.

Fig. 8—J. R. Woolston adjusts position of small quantity of material to be analyzed by mass spectrograph.

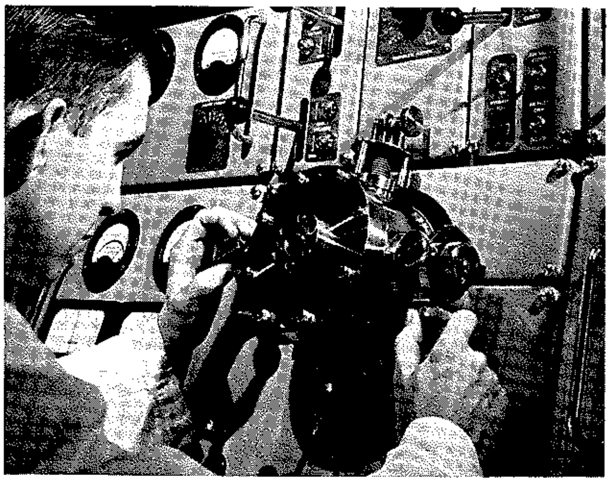
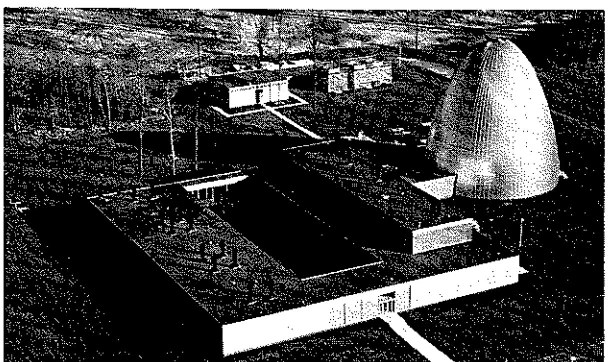


Fig. 9—Industrial Reactor Laboratories, Inc.



REGISTERED PROFESSIONAL ENGINEERS IN INDUSTRY

A Guest Editorial

J. C. WALTER (P.E.), Mgr.
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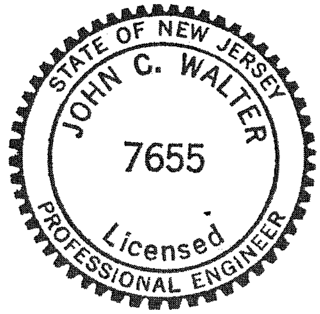
DEP, Moorestown, N. J.



As engineers *earn* professional status, the engineering community will attain its proper place among the established professions. Growing opinion in support of this precept is indicated by the considerable increase during the past decade in the number of engineers obtaining state *Professional Engineer* licenses. Other important factors influencing the increased rate of registration are the basic personal desire for identification as a professional and a growing public awareness of the important role of engineering—factors which emphasize to engineers in industry that individual recognition is essential to gaining identity as professionals.

GROWTH OF REGISTRATION

Today every State of the nation has a statute defining and governing the practice of engineering. *Over 40% of the engineering profession is registered under these laws.*

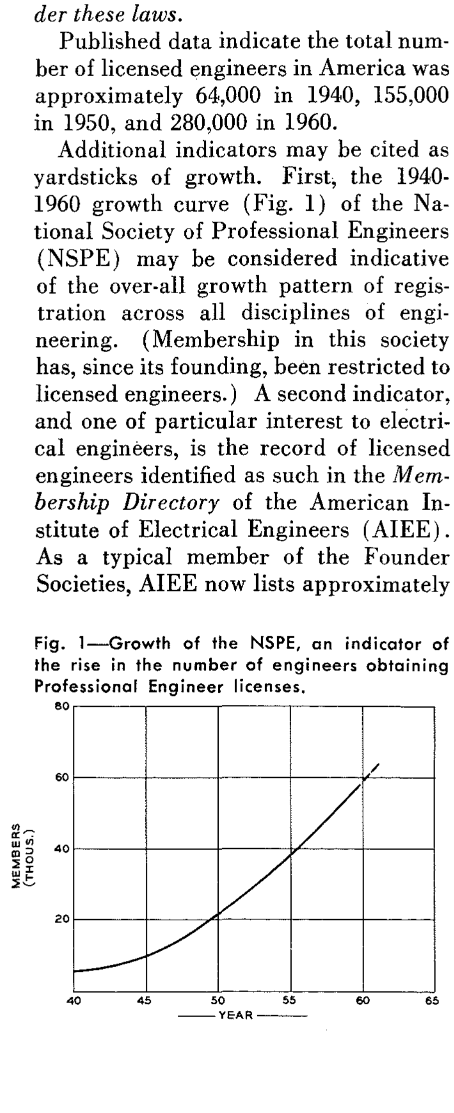
Published data indicate the total number of licensed engineers in America was approximately 64,000 in 1940, 155,000 in 1950, and 280,000 in 1960.

Additional indicators may be cited as yardsticks of growth. First, the 1940-1960 growth curve (Fig. 1) of the National Society of Professional Engineers (NSPE) may be considered indicative of the over-all growth pattern of registration across all disciplines of engineering. (Membership in this society has, since its founding, been restricted to licensed engineers.) A second indicator, and one of particular interest to electrical engineers, is the record of licensed engineers identified as such in the *Membership Directory* of the American Institute of Electrical Engineers (AIEE). As a typical member of the Founder Societies, AIEE now lists approximately 50 percent of its voting members as licensed PE's. Five years ago, this figure was approximately 25 percent.

The Founder Societies are the American Institute of Chemical Engineers (AIChE), American Institute of Electrical Engineers (AIEE), American Institute of Mining, Metallurgical and Petroleum Engineers (AIME), American Society of Civil Engineers (ASCE), and American Society of Mechanical Engineers (ASME).

A list of registered RCA engineers published in the Dec. '55 - Jan. '56 issue of the RCA ENGINEER contained but 80 names. A 1962 census shown in Fig. 2 lists upwards of 230. These figures are indicative only, since for example the 1962 census (Fig. 2) includes only those licensees who have personally forwarded their license data to the RCA ENGINEER for announcement in the *Engineering News and Highlights* section of the journal. The total number of PE's in RCA is therefore probably greater. In any case, there has been a considerable increase in numbers during the past six years.

Fig. 1—Growth of the NSPE, an indicator of the rise in the number of engineers obtaining Professional Engineer licenses.



JOHN C. WALTER, in addition to his engineering and management duties at RCA, has for many years supported registration of the individual engineer as a means of achieving public recognition of engineering as a profession. His activities in this field have included the initial organization and chairmanship of the Philadelphia Section AIEE Committee on Registration of Engineers, and authorship of a guest editorial "The Registered Professional Engineer" in the Dec. 1955 - Jan. 1956 RCA ENGINEER. He is a Member of the National Society of Professional Engineers, American Institute of Electrical Engineers, American Management Association, a Senior Member of the Institute of Radio Engineers, and a Naval Member of the American Society of Naval Engineers. Educated at the University of Notre Dame, he has completed graduate work, with honors, at the Industrial College of the Armed Forces and the Naval War College, and is a Captain in the ready reserve of the United States Navy.

ADVANTAGES OF REGISTRATION

At the present time, most engineers employed in industry are not required to be licensed, although if a company's products are applied to public works or projects involving the domain of public safety, the legal presumption is that such products have been approved by a licensed engineer.

The necessity and legal requirement for registration of consulting engineers and those whose engagements place them "in responsible charge" of public works should be obvious—an advantage to the professional because it protects him and his client. The engineer is free to act without fear of competition from unqualified persons, and his client is similarly safeguarded.

There are also certain advantages which devolve upon *the engineer in industry* through registration. Some of these are:

1) As a recognition factor; the license to practice engineering in the public domain constitutes public recognition of professional status.

2) The licensed engineer, by establishing publicly his professional qualifications, contributes in a positive manner toward enhancing public acceptance of engineering as one of the acknowledged professions.

3) Licensure is becoming increasingly important both to the employer and to the employee in legal actions. It is well to note that in the event of litigation most courts today recognize *only* licensed Professional Engineers as expert witnesses in engineering matters. This practice is based upon the principle that legal recognition can be accorded only to those witnesses whose professional status is established by public law. The advantage to

the registered employee is the small, but positive, element of his added worth to his employer.

4) At the practical working level, particularly in customer relations, the licensed PE is automatically established as a *persona grata* in technical matters. This entree is most valuable in establishing effective relationships with customer and vendor engineers and all those with whom negotiations are held at the technical level.

5) License in lieu of engineering degree. For the practicing engineer who is qualified by experience and acquired education but holds either no degree or one in an unrelated field, the opportunity to obtain a license by proving his capabilities and qualifications through formal State Board examinations provides a most important and unique means of establishing himself professionally. These exceptional cases are becoming more scarce, to be sure, but will probably never disappear altogether.

THE AIEE AND FUNCTIONAL UNITY PLANNING

There is current strong support for a plan whereby NSPE would represent members of the Founder Societies in professional and legislative matters, while technical matters in each discipline would continue to be administered by the individual technical societies. Known as the *AIEE Functional Plan*, the proposal has had wide publicity in *Electrical Engineering* and the *American Engineer* in recent years. It has already been approved in principle by the directorates of NSPE, AIEE, and ASME and will go to NSPE members for a vote in 1962. Adoption will require approval by a ⅔ majority.

Among other things, the proposed changes in the NSPE constitution and bylaws would create three classes of membership: *Professional Engineer Member*, *Member*, and *Junior Member*. Nonregistered engineers could thus be admitted to Member grade in NSPE during an interim period (three years) provided they belong to one of the Founder Societies in a grade for which that society requires registration for admission in the future. The nonregistered engineer holding the member grade in NSPE would have all the rights and privileges of a Professional Engineer Member, except that of holding office in the national society.

Full implementation of the plan would eventually result in PE registration becoming a requirement for membership grades qualifying for election to office in the Founder Societies.

Noah Hull, past President of NSPE, gives the following as advantages of the new member grade in NSPE:

"1) It will encourage recognition of registration by the Founder Societies and other technical groups. The requirement for registration for admittance to the highest grade of membership in these societies will establish registration as the goal of every young engineer.

"2) It will give further meaning to the NSPE policy of encouraging every engineer to be a member of both his technical society and his professional society. This additional grade of membership will permit many eminent engineers to support the organization's concern with the two major elements of this professional development—his technical concerns and his professional concerns.

"3) It will assist NSPE to do a better job in professional areas by: a) permitting these additional leaders of the profession to participate in the professional programs and decisions of NSPE; and b) permitting NSPE to count among its members a broader cross-section of the leaders of the profession."

Mr. Hull's remarks are quoted directly from his article sponsoring the member grade in NSPE which was published in the January 1962 issue of the *American Engineer.*

AIEE-IRE MERGER

Another development which, when accomplished, may further stimulate registration is the proposed merger of AIEE and the Institute of Radio Engineers (IRE). This proposed consolidation of both into a single organization is well along, and if approved by a ⅔ vote of AIEE and IRE membership this summer (as it very likely will be) will probably take effect in 1963.

Assuming this merger takes place, and should NSPE adopt the AIEE Functional Plan, then those whose present grade in IRE is Senior Member would presumably be eligible to apply for Member grade in NSPE during the three-year interim period previously mentioned. The merged AIEE-IRE would thus, in effect, be part of the family of Founder Societies, as the AIEE is now. The combined AIEE-IRE would total approximately 150,000 members—the largest engineering society in the world. Implementation of both the Functional Plan and the AIEE-IRE merger should certainly stimulate registration, since registration would then become a prerequisite to attainment of the highest grade of membership in the Founder Societies.

SOME OTHER INFLUENCES

Departments and agencies of the Federal Government are encouraging registration as a means of promoting professional recognition for qualified engineers, both civilian and military. The U.S. Army Corps of Engineers is sponsoring review courses for prospective licensees and encourages the display of PE licenses at engineer's duty stations. The U.S. Navy Bureau of Yards and Docks, responsible for public works and civil engineering within the Naval Shore Establishment, displays a roster of its registered engineers in the foyers of its National and District headquarters buildings.

RCA and many other companies have employee benefit plans which pay the tuition for review courses taken by engineers preparing for State Board examinations. This provides an opportunity for the prudent engineer to obtain his license while still employed as an engineer in industry, thus preparing himself for possible future self-employment or for responsible engagements in consulting work for his employer.

HOW TO GET A PE LICENSE

A majority of the States have adopted more or less uniform registration requirements based upon a Model Law recommended by NSPE, the Engineer's Joint Council (EJC), and other professional organizations. New Jersey has an excellent registration law that is exemplary of the highest recommended standards.

The model law suggests the title of *Professional Engineer* for all types of engineering, although many States still use specialty titles (Electrical, Mechanical, etc.). An accelerated transition to the PE title would help foster public recognition of engineering as a professional entity. Its justification is the fact that all engineering disciplines are built upon a common foundation of basic scientific principles and natural laws.

There are two ways to attain registration under the model law. The first method permits the recent graduate to sit for a written examination in Basic Engineering Sciences, Part I, and Structural Design, Part II; and upon successful completion thereof to become registered as an Engineer-in-Training (EIT). After having acquired the requisite number of years of responsible engineering experience he becomes eligible for examination in the final element, Part III, Major Field of Engineering, i.e., Chemical, Civil, Electrical, Mechanical, etc.

The second method is the direct application by those engineers who have already acquired the necessary experience in engagements of increasing professional responsibility. Such qualified applicants may sit for all three phases of the examination.

In either case the final issuance of a Professional Engineer license by the State is contingent upon the recommendations of the Board of Examiners after due consideration of all qualifying factors, which include the applicant's moral and ethical characteristics as well as his technical proficiency and evidence of professional development.

The apparent objectives of the statutory licensing requirements provide a clear reply to the popular question as to why an examination is required for engineers already having a recognized degree. There are fundamental differences between a showing of formal education successfully completed and authorization by the people of the State to practice a profession involving their health, safety and welfare. This distinction has been recognized and accepted by other professions, such as law and medicine, which also require examinations for a State license to practice.

Finally, an examination prescribes a standard for all—a mechanism whereby the individual is granted a right by the people of the State through the legally constituted voice of the people under law.

Engineers interested in registration should request information on statutory qualification requirements directly from the appropriate State Board of Engineering Examiners, whose address may be obtained by request to the Department of Public Law and Safety, Division of Professional Boards, State Capitol. In New Jersey, the State Board of Professional Engineers and Land Surveyors is presently located at 1100 Raymond Boulevard, Newark 2, N. J.

CONCLUSION

The inference to be drawn from current trends seems clear enough: Every qualified engineer sincerely interested in enhancing public acceptance of engineering as an acknowledged profession owes it to himself and to his colleagues to publicly establish his qualifications as a Professional Engineer by obtaining his PE license without delay.

The roster of Professional Engineers (Fig. 2) employed throughout RCA is included here as a token of recognition of their individual efforts in support of their profession.

Fig. 2—A list of RCA registered professional engineers, prepared from past listing in "News & Highlights." If you are licensed, and your name does not appear below, please send the information to the RCA ENGINEER, 2-8, Camden.

E. Ackerlind, EE-870, *Calif.*
H. D. Albrecht, PE-6261, *N. J.*
R. W. Allen, PE-7826, *N. J.*
A. R. Alter, PE-3440-E, *Pa.*
R. J. Ansell, EE-12002, *Ohio*
F. F. Appleton, M&S-E-4023, *Mo.*
J. J. Ayres, PE-7820, *N. J.*

J. S. Baer, ME-2843, *Iowa*
H. F. Baker, PE-8113, *N. J.*
R. H. Baker, ME-9114, *Calif.*
R. Beagles, EE-780, *Calif.*
E. D. Becken, PE-21033, *N. Y.*
G. L. Beers, PE-6970, *N. J.*
R. F. Bailey, PE-10521, *Ill.*
H. J. Benzuly, PE-8645, *N. J.*
R. Bergay, PE-11805, *N. J.*
F. C. Blancha, PE-6013, *N. J.*
A. C. Blaney, EE-1987, *Calif.*
O. N. Bowen, PE-11678, *N.J.;* EE-8351, *Ind.*
W. H. Brearley, Jr., PE-989, *Wash., D. C.;* PE-7645, *N. J.;* PE-025173, *N. Y.;* PE-17250, *Ohio;* PE-11357, *Pa.*
H. A. Brelsford, PE-5538, *N. J.*
R. Bricker, ME-9803, *Calif.*
F. W. Brill, PE-6673-E, *Pa.*
L. A. Brockwell, PE-25174, *N. Y.*
P. Bronckhurst, ME-8197, *Calif.*
E. L. Brown, PE-EE3643, *Calif.*
Dr. G. H. Brown, PE-11889, *N. J.*
I. Brown, EE-1536-E, *Pa.*
J. M. Brumbaugh, EE
J. B. Bullock, PE-8639, *N. J.*
G. B. Bumiller, PE-37788, *N. Y.*
G. B. Bumiller, PE-37788, *N. Y.*
J. R. Bumke, PE-7550, *Ind.*

E. F. Cahoon, PE-11509, *N. J.*
M. J. Campanella, PE-8858, *N. J.*
J. B. Cecil, EE-E697, *Neb.*
H. H. Chapman, EE-20793, *Ohio*
A. E. Chettle, PE-6596, *N. J.*
O. W. Child, PE-62-18130, *Ill.*
C. L. Christian, Jr., PE-A-8908, *N. J.;* EE-33839, *N. Y.*
J. S. Class, PE-6583-E, *Pa.*
A. W. Comins, EE-11808, *Pa.*
D. A. Comninos, PE-10857, *N. J.*
R. W. Conner, EE-2586, *Calif.*
R. W. Cox, ME-6212E, *Pa.*
G. B. Cranston, ME-11919, *Pa.*
D. R. Crosby, PE-8401, *N. J.*
R. P. Crowner, PE-6879, *Ind.*
W. C. Curtis, EE-901, *Ala.*
A. N. Curtiss, PE-7304, *N. J.*

S. Davidson, PE-7964, *N. J.*
Mrs. J. L. Deckert, PE-7944, *N. J.*
J. DeLuna, PE-19635, *Ohio*
C. G. Dietsch, PE-14233, *N. Y.*
J. S. DiMauro, PE-A-7656, *N. J.*
J. W. Donato, PE-7140E, *Pa.*
J. D. Duffin, PE-8653, *N. J.*
R. P. Dunphy, PE-2283, *Wash., D. C.*
L. P. Dymock, PE-7417E, *Pa.*
H. R. Dyson, PE-5946, *N. J.*

J. E. Eiselein, PE-6215, *N. J.*

C. Felheimer, PE-1617, *Ala.*
J. L. Folly, ME-14153, *Pa.*
J. M. Forman, PE-11347, *Pa.*
C. Formicola, PE-35120, *N. Y.*
F. H. Fowler, Jr., PE-3206, *Wash., D. C.;* PE-20943, *N. Y.*
W. H. Freund, EE-7498, *Pa.*
F. A. Fuhrmeister, ME-13543, *Pa.;* PE-5797,*N. J.*

J. Gallup, PE-8353, *N. Y.*
J. German, PE-8825, *N. J.*
R. D. Gillen, PE-10070, *N. J.*
J. C. Goldsmith, PE-11334, *N. J.*
R. W. Greenwood, EE-15496, *Pa.*
A. C. Grimm, EE-12399, *Pa.*
O. B. Gunby, EE-3417, *Calif.*
R. F. Guy, PE-3873, *N. J.*

L. B. Hall, PE-7084, *Ind.*
G. A. Hamilton, PE-7435E, *Pa.*
C. Hart, EE-11501, *Pa.*
H. Hartmann, PE-9027, *N. J.*
H. R. Headley, PE-5794E, *Pa.*
J. R. Hendrickson, Sr., PE-4661-E, *Pa.*
L. C. Herman, EE-3071-E, *Pa.*
R. Herman, PE-9841, *N. J.*
P. G. Herold, MnE-E-658, *Mo.*
J. I. Herzlinger, PE-6095, *N. J.*
C. E. Hittle, ME-10001, *Calif.*
D. B. Holmes, PE-7152, *N. J.*
D. W. Honeycutt, Land Sur., *N. C.*
D. W. Hudgings, PE-62-4675, *Ill.*
D. G. Hymas, EE-9830, *Can.*

A. F. Inglis, PE-168, *Wash., D. C.*

J. C. Johnson, PE-2275-E, *Pa.*

S. L. Katten, ME-1740-E, *Pa.*
J. W. Kauffman, ME-4572E, *Pa.* PE-2233-E, *Pa.*
F. T. Kay, PE-11053, *N. J.*
F. L. Kelly, ChfE-B-30633; ME-1207, *Pa.*
B. P. Kerfot, PE-8449, *N. J.*
J. Kimmel, EE-9271, *Pa.*
G. W. K. King, PE-6590, *Mich.;*
E. L. Klein, PE-3563, *Wash., D. C.*
D. L. Klein, PE-3563-M, *Va.*
M. J. Kozak, PE-12050, *N. J.*
L. J. Krawitz, EIT-302, *N. J.*
I. D. Kruger, PE-6262, *N. J.*
G. H. Kunstadt, PE-6471, *Mass.*
G. A. Kunz, EIT, *Pa.*
R. M. Kruzrok, PE-36940, *N. Y.*

H. J. Laiming, PE-6245, *N. J.*
K. D. Lawson, ME-23182, *Ohio*
M. B. Lemeshka, CE-13361, *Pa.*
E. Leshner, PE-5804E, *Pa.*
R. J. Linhardt, PE-8241, *N. J.;* PE-28339, *N. Y.*
J. E. Love, PE-5758, *N. J.*
K. S. Lewison, PE-27728, *N. Y.*
H. Levine, PE-11612, *N. J.*
M. L. Levine, PE-6257-E, *Pa.*
H. H. Licht, AE-7627, *Pa.*
S. W. Liddle, PE-7671, *Ind.*
J. J. Liggett, PE-9325, *N. J.*
A. L. Lucarelli, ME-11877, *Pa.*
W. Lyons, PE-25871, *N. Y.*

G. F. Maedel, PE-17003, *N. Y.*
A. J. Mannino, PE-1317, *Dela.*
J. A. Markoski, ChE-12146, *Pa.*
H. S. Markstone, ME-10865, *Pa.*
W. A. McLendon, PE-1839, *Fla.*
T. Mead, ME-6560, *Calif.*
W. F. Mecker, PE-23710, *N. Y.*
M. E. Meer, PE-36986, *N. Y.*
R. Mendelson, PE-27175, *N. Y.*
L. I. Mengle, PE-3778E, *Pa.*
R. L. Meisenheimer, PE-8648, *N. J.*
C. Michas, PE-14416, *N. Y.*
C. R. Monro, PE-10782, *N. J.*
H. R. Montague, PE-34731, *N. Y.*
E. Montoya, Jr., PE-6584, *Ind.*
J. B. Moore, PE-20360, *N. Y.*
I. K. Munson, EE-2321, *Wash., D. C.*
C. H. Musson, PE-11606, *N. J.*
D. N. Myers, PE-2812-E, *Pa.*

C. Nakrosis, EIT, *N. J.*
A. G. Nekut, EE-10276, *Pa.*
J. Nestory, EIT-6532, *Ind.*
E. Nickl, ME-9376, *N. J.*
H. H. Nishino, PE, *Calif.*
G. V. Nolde, EE-630, *Calif.*

D. K. Obenland, PE-12739, *Ill.*
D. J. Oda, EIT-2080, *Ind.*
D. H. O'Herren, PE-7704, *Ind.*
J. W. O'Neil, PE-11044, *N. J.*
C. C. Osgood, ME-651, *Maine*
J. Osman, PE-3731, *Ind.*

J. F. Page, PE-8876, *N. J.*
S. R. Parker, PE-28390, *N. Y.;* PE-8091, *N. J.*
L. Parnes, PE-37503, *N. Y.*
P. G. Pecorara, ME-2981, *Ariz.*
A. W. Peterson, PE-500, *Mass.*
J. F. Petri, PE-A-10431, *N. J.*
J. L. Pettus, ME-4252, *Calif.*
W. R. Percivale, PE-11018, *N. J.*
L. Pessel, PE-5247, *Pa.*
W. J. Poch, PE-9232, *N. J.*
D. O. Price, ME-6203E, *Pa.*
E. M. Pritchard, PE-6607, *Mass.*
R. S. Putnam, PE-8893, *N. J.*

J. L. Quinn, EE-10677, *Pa.*

T. C. Reeves, ME-2332-E, *Pa.*
D. G. Rosenzweig, PE-7433E, *Pa.*
C. M. Ryerson, PE-2105, *Wash., D. C.*
Dr. M. I. Radis, PE-2172-E, *Pa.*
D. Roda, PE-7990E, *Pa.*

R. E. Salventer, Jr., PE-7373, *Ind.*
V. A. Schlenker, PE-10863, *N. Y.;* EE-3111, *N. J.*
L. J. Schnobeck, PE-9943, *N. J.*
E. N. Scott, PE-8853, *N. J.*
I. Scott, ME-14398, *Pa.*
H. R. Seelen, PE-11493, *N. J.*
F. Stephensen, PE-5839, *N. J.*
H. A. Stern, PE-22704, *Ohio*
H. Shay, PE-34731, *N. Y.*
H. J. Siegel, PE-21548, *N. Y.;* ME-3148, *Fla.*
H. S. Siesel, PE-9803, *N. J.*
S. S. Silberg, PE-10792, *N. J.*
K. Singer, ME-1973, *Calif.*
C. M. Sinnett, PE-11472, *N. J.*
J. Silverman, PE-19627, *N. Y.*
J. Smith, EE-4155, *Calif.*
E. Smuckler, EE-4506, *Calif.*
I. Sofen, EE-4697, *Calif.*
K. Solomon, EIT, *Wash., D. C.*
S. S. Spiegel, PE-10310, *N. J.*
E. E. Spitzer, EE-11809, *Pa.*
W. Stonaker, PE-A-10092, *N. J.*
T. H. Story, PE-7836, *N. J.*
P. J. Stadnyk, PE-10497, *N. J.*
T. E. Swander, PE-19667, *Ohio*
L. Swartz, ME-14343, *Pa.*
F. H. Symes, CE-3127, *Ind.*

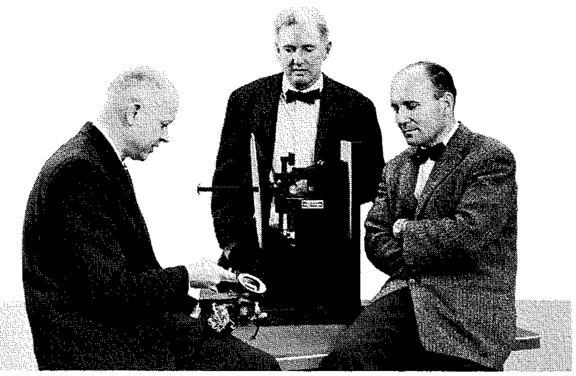
D. M. Taylor, PE-11242, *N. J.*
W. J. Tejral, PE-10605, *N. J.*
E. S. Thall, PE-8568, Prov. of Ont., Can.
A. J. Torre, PE-7950, *N. J.*

A. Vose, EE-4844, *Calif.*

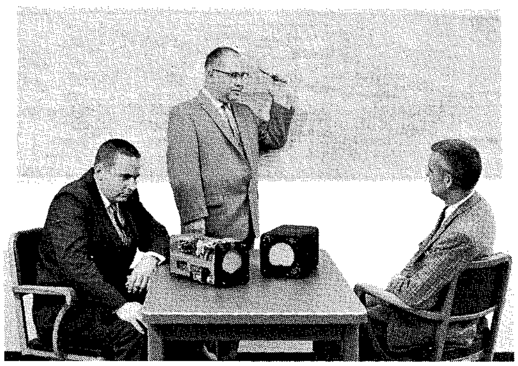
S. Wald, PE-5611, *N. J.*
J. M. Walsh, PE-24590, *N. Y.*
M. A. Walsh, PE-19800, *N. Y.*
J. C. Walter, PE-7655, *N. J.*
H. B. Walton, PE-5063, *Pa.*
H. Waters, ME-8154, *Calif.*
R. Walton, CE-E-6393, *Mo.*
H. R. Wege, PE-8159, *N. J.*
M. R. Weingarten, ME-12069, *Pa.*
R. A. Welke, PE-1163, *N. Y.*
G. Wells, PE-7417E, *Pa.;* PE-11586, *N. J.*
B. F. Wheeler, PE-8083, *N. J.*
E. G. Widell, PE-8433, *N. J.*
F. W. Widmann, PE-8131, *N. J.*
G. H. Williams, PE-7768, *N. J.*
S. H. Winkler, PE-36579, *N. Y.*
H. S. Wilson, PE-10302, *Ont.*
E. Witkin, PE-2491-E, *Pa.*
A. Wohlgemuth, PE-7920, *N. J.;* PE-26839, *N. Y.*
P. W. Wolverton, PE-5548, *Ind.*
C. H. Wright, PE-11877, *N. J.*

A. D. Zappacosta, PE-11206, *N. J.*

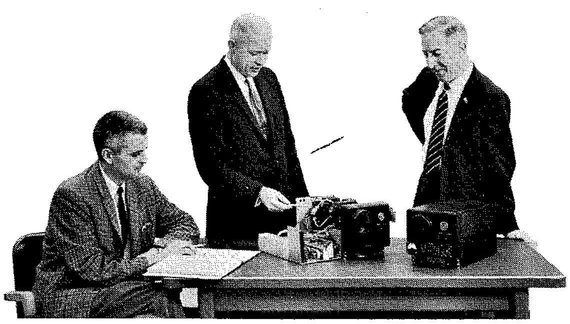
TWO NEW LIGHTWEIGHT AIRBORNE WEATHER RADARS



Weather radar design engineers inspect a partially assembled AVQ-55 antenna (left) and a complete AVQ/20 antenna (center). (L to r): Lloyd Bonney, responsible for receiver-transmitter, mixer-duplexer, pulse modulator, and antenna waveguide design; Bob Sale, responsible for antenna design; and Don Malkin, responsible for AVQ-20 stabilization circuit design.



An AVQ-55 Indicator (left) and an AVQ-20 Indicator (right), with (l to r): Dave Montgomery, responsible for AFC and indicator circuit design; George Brode, responsible for over-all indicator and low-voltage power supply design; and Bob Moses, responsible for over-all AVQ-55 and AVQ-20 electrical design.



L to r: AVQ-55 receiver-transmitter with hinged-down panel for easy accessibility, and the AVQ-20 receiver-transmitter. The engineers are (l to r): Bob Moses, responsible for over-all AVQ-55 and AVQ-20 electrical design; Lloyd Bonney responsible for receiver-transmitter mixer duplexer, pulse modulator, and antenna waveguide design; and Basil Rowlands, responsible for over-all system integration and coordination, and IF pre-amplifier design.

Transistors and solid-state techniques are used to gain improved reliability, size, weight, and power consumption in these two new radars for commercial aircraft. They represent the state of the art in this type of equipment, and reinforce a product line of commercial-aircraft electronic equipment in which RCA is an industry leader.

A. VOSE, Staff Engineer

*Aviation Equipment Dept.**

Data Systems Division

DEP, Los Angeles, Calif.

THE PHENOMENAL SUCCESS of the AVQ/10 and AVQ/50 weather radars[1,2] in the commercial-airline and business-aircraft field has resulted in RCA becoming one of the three *leading manufacturers of electronic equipment for commercial aircraft.* Although the Aviation Equipment Department is expanding its line by the addition of two new items (the AVQ/60 ATC transponder beacon and the AVQ/70 distance measuring equipment), weather radar continues to be its most important product in quantity sale and dollar volume.

In our rapidly changing electronic industry, advanced components and techniques plus new customer requirements frequently make last year's model at least "old hat," if not obsolete. Because of the appearance of newly developed competitive equipment using modern components and techniques — and because the popular AVQ/50 and AVQ/10 represent weather-radar designs 6 and 7 years old—a change in design was neces-

* Prior to a reorganization in 1961, this Aviation Equipment engineering group in Los Angeles was a part of the former Industrial Electronic Products operating unit.

AUBREY W. VOSE, graduated from the General Course in Communications Engineering at RCA Institutes, New York, in 1939. He joined Westinghouse Electric in 1940 as Test Equipment Designer, transferring to the Engineering Department in 1942 where he worked on the design of the SCR-584, AN/APS-6 and other ground and airborne radar systems. In 1946 he did consulting work in the airborne radar and guided missile field for General Electric, Convair Aircraft and Lockheed Aircraft and helped develop a small lightweight airborne radar for commercial airline use. In 1948, he joined the Houston Corporation, first as a consultant, later as Assistant Chief Engineer, and was instrumental in the redesign of the AN/APS-42 airborne radar, making it sary to maintain RCA's position as leader in this radar field. The newly developed AVQ/20 and AVQ/55 weather radars represent the ultimate in the present-day state-of-the-art for such equipment. Solid-state devices are utilized to produce practical, reliable, and economical radars for commercial airlines, business aircraft, and general aviation use.

DESIGN CONCEPT

Airborne weather radar has become an essential, even a mandatory, tool in the commercial aviation industry since its unveiling in 1955. However, the initial glamour and wide-open market is gone, with increased competition allowing the user more freedom of choice for his particular requirements.

It is no easy task to set forth specific design advantages that might result in an equipment capable of cornering the present and future commercial airborne weather radar market. Rather, the AVQ/20 and AVQ/55 weather-radar systems are based on an integrated design concept that will provide, with no sacrifice in over-all performance, the best possible advantages in all of the following features considered essential in the design and use of airborne electronic equipment today:

1) economy in manufacture and final cost,
2) economy and ease of installation,
3) ease of maintenance and low-maintenance cost,
4) great reliability,
5) low-power consumption,
6) small size, and
7) low weight.

After careful evaluation, X-band (9375 Mc) was selected as the most suitable operating frequency for both the AVQ/20 and AVQ/55. Since RCA has long been considered the main proponent of C-band (5400 Mc) for weather radar, this decision warrants further explanation:

With the effects of turbulence becoming greater at the high speeds of jet aircraft, it appears more desirable to avoid storm areas completely rather than penetrate them. Thus, it is essential to obtain the maximum usable radar range, with *usable radar range* defined as the point at which targets can be resolved clearly enough to determine: 1) whether targets are in fact thunderstorms and 2) whether adequate space exists between them to permit a safe flight. X-band provides about a 2-to-1 superiority over C-band in angular resolving power for a given antenna reflector size, as well as a 1.8-to-1 advantage in range performance for a given water-droplet size, assuming no intervening rain.

Intervening rain reduces the range superiority of X-band until at rain densities of 200 mm/hr-miles (20 continuous miles of 10 mm/hr rainfall),[3] C-band range performance becomes equal; however, this condition rarely exists at the lower altitudes and should be even less evident at the higher jet altitudes with the correspondingly less-dense air and lower moisture content.

Advances in microwave techniques since the inception and design of the AVQ/10 apply to all radar operating frequencies; but the X-band region, as always, has been used as the proving ground. As a result, the new techniques and components that already exist for this frequency band are not as readily available for C-band application. *There can be little argument* that choice of X-band over C-band has resulted in equipment of smaller size, less weight, lower cost, and less power consumption. In fact, from the standpoint of antenna size alone, a choice of C-band operation for the AVQ/20 and AVQ/55 would definitely prohibit their use in numerous smaller business and executive type aircraft.

COMPATIBILITY WITH USER REQUIREMENTS

An economical system for the integrated design concept of the AVQ/20 and AVQ/55 weather radars must also provide a degree of compatibility that meets the requirements of both the airline and business and executive aircraft users. Through the extensive use of solid-state devices and techniques, the final packaging configuration meets these requirements.

To provide compatibility, the radar system consists of three basic units: *receiver-transmitter, antenna,* and *indicator*. In manufacture, these basic units are essentially common to both weather-radar equipment systems; so, when the basic units reach the end of the production line, an AVQ/20 or an AVQ/55 may be obtained by the interchange of a limited number of subassembly units. The economy of such a design is at once apparent through high-quantity purchases, stocking of fewer parts, simplified inspection and testing, and common replacement parts.

How well the design concept goals are met can best be shown by the comparison of the AVQ/20 with its predecessor, the AVQ/10 (Table I).

RECEIVER-TRANSMITTER

The receiver-transmitter is the common unit, or heart, of the radar system. Besides being a junction point for incoming power, the receiver-transmitter (RT) converts the power to the appropriate form and levels and passes it on to the other two units; the RT is the only unit of standard size, being a short ¾ ATR

acceptable for military use. Mr. Vose came to RCA in 1950, along with other Houston personnel when RCA purchased the AN/APS-42 contract from Houston Corporation. Since joining RCA, he has held the positions of Administrator of Systems Activities and Staff Engineer. In 1953 Mr. Vose was responsible for the design of an experimental 5.6 airborne weather radar for evaluation by United Air Lines. This work led to the product design of the present RCA AVQ/10 C-Band Weather Penetration Radar and AVQ/50 X-band Weather Avoidance Radar. Mr. Vose received the *RCA Award of Merit* in 1956 for his work in this field. Mr. Vose is a Registered Professional Engineer in the State of California.

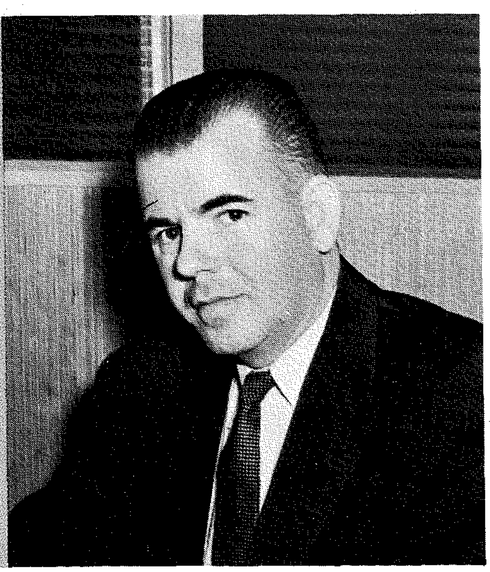


Table I — General Characteristics of the AVQ/20 and AVQ/10

Characteristic	*AVQ/20*	*AVQ/10*
System Complement	3 major units	5 major units
Tubes and Transistors	8 tubes, 73 transistors	51 tubes, no transistors
Over-all weight	45 lb.	125 lb.
Primary Power	275 v-a at 400 cycles 30 watts at 27.5 v-DC	850 v-a at 400 cycles 30 watts at 27.5 v-DC
Operating Frequency	9375 ± 40 Mc	5400 ± 30 Mc
Operating Altitude	35,000 ft. (Ant. 50,000 ft.)	16,000 ft. (Ant. 45,000 ft.)
Type Presentation	180° PPI	360° PPI
Ranges	30–90–180 miles	20–50–150 miles
Power Output	20-kw peak	75-kw peak
Pulse Width	2.0μsec	1.8 μsec
System Noise Figure	9 db	12 db
Antenna Beamwidth	3.5° with 24″ reflector plus csc^2 operation	7° with 22″ reflector
Antenna Scan Rate	20 looks/min, sector	15 rpm, continuous
Antenna Stabilization	line-of-sight, pitch and roll	line-of-sight, pitch and roll
Duplexer	Ferrite duplexer and load isolator	Standard duplexer isolator optional
Selling Price	approx. $8,500	approx. $11,000

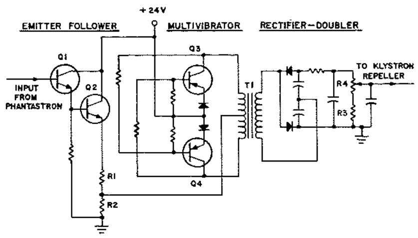


Fig. 1—The AFC repeller supply.

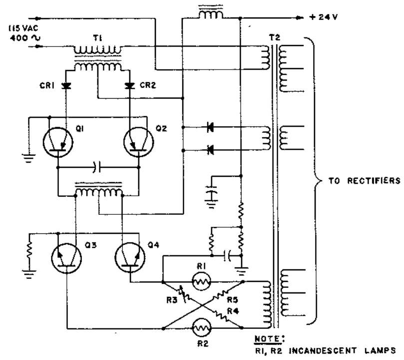


Fig. 2—The AVQ-20 power supply.

(air transport radio) configuration. As in the AVQ/10 and AVQ/50, the RT houses the IF preamplifier, AFC unit, mixer-duplexer, and modulator. In addition, the low-voltage power supply is included in the RT of the two new weather radars. A choice of this power supply plus the local oscillator tube and front panel determines whether the RT is for use with the AVQ/20 or AVQ/55. Except for the transistorized AFC unit and low-voltage power supply, the RT is a low-power version of the AVQ/10 and AVQ/50 with an improved system noise-figure to make up for the lower level of transmitter output power.

AFC UNIT

Application of transistors to the weather-radar AFC circuitry of the diode-phantastron type is quite straight-forward until the AFC output must be applied to the klystron repeller. Here, because of the inherently low impedance and operating level of the transistors, a somewhat unorthodox, yet direct, scheme is used to avoid "floating" the AFC sweep or control voltage on the repeller DC voltage supply. With this method, it is both feasible and desirable to derive the repeller supply directly from the AFC system. Thus, the 400-cycle rectifier, filter, and associated voltage-regulator elements are eliminated.

Functionally, this is accomplished by a modulation technique (Fig. 1) wherein the amplitude of a saturating-transistor multivibrator is varied at a low-frequency rate by the sweep-lock output of the AFC unit. The resulting square wave is then stepped up in a toroidal transformer and reconverted to DC in a full-wave, voltage-doubling rectifier for application to the klystron repeller. Filtering requirements are minimized by operating the multivibrator at about 2600 cycles.

AFC REPELLER-SUPPLY CIRCUIT

As shown in Fig. 1, the sweep-lock DC from the AFC phantastron is applied to the input base of a compound emitter-follower consisting of transistors *Q1* and *Q2*; thus, an input impedance of at least 60,000 ohms is presented, loading is minimized, and reaction from the multivibrator back to the phantastron is prevented. The output of the compound emitter-follower is effectively in series with the DC supply voltage, and because of common impedance *R2*, amplitude modulation of the multivibrator occurs. The values of *R2* and *R1* determine respectively the nominal DC voltage across the repeller power-supply output and the effective variation of this voltage with change of input level.

Transistors *Q3* and *Q4* constitute an astable resistance-coupled multivibrator delivering a maximum peak-to-peak square-wave output of 46 volts across the primary of *T1*. The nominal free-running frequency of this circuit is 2600 cycles, with essentially a 50-percent duty cycle for either transistor. Transformer *T1* is a toroidal unit having a square-loop hysteresis core for DC-to-DC converter application. Operating conditions of the multivibrator are such that collector saturation occurs and, over the dynamic range of interest, the peak-to-peak square-wave voltage across the secondary of *T1* is essentially a linear function of the DC input to the base of transistor *Q1*. After rectification and filtering, a maximum of —220 volts DC is available across load resistors *R3* and *R4*; the mode set potentiometer *R4* permits variation of this voltage down to —105 volts DC to accommodate either the 2K25 klystron used in the AVQ/55 or the VA203B klystron used in the AVQ/20.

LOW-VOLTAGE SUPPLY

As indicated earlier, two low-voltage power supplies are used, one for the predominantly DC-powered AVQ/55 and the other for the predominantly AC-powered AVQ/20. An interesting method of regulation is used in the AVQ/20 supply to overcome line-variation effects on modulator-trigger phase, klystron mode shift, and klystron anode voltage. The DC voltage variations causing these effects could have been individually stabilized by regulation with zener diodes, but only at additional complexity and cost plus

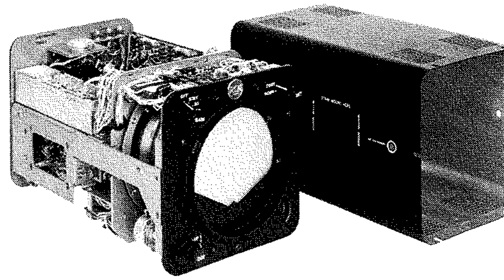


Fig. 3—Front view of the AVQ-55 indicator showing operating controls and 120° sector display.

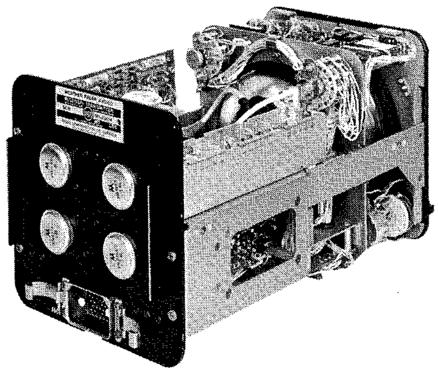


Fig. 4—Rear view of the AVQ-55 indicator showing the transistor circuitry and IF strip in foreground.

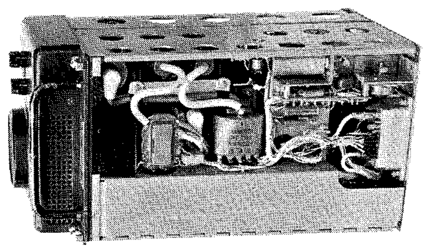


Fig. 5—Bottom view of the AVQ-55 receiver-transmitter showing the high-voltage modulator component.

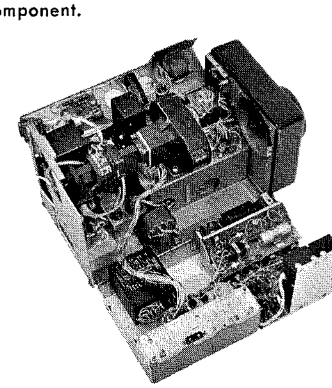


Fig. 6—Side view of the AVQ-55 receiver-transmitter showing hinged construction. AFC unit and low-voltage power supply are in foreground, magnetron and mixer-duplexer in center, and IF preamplifier in background.

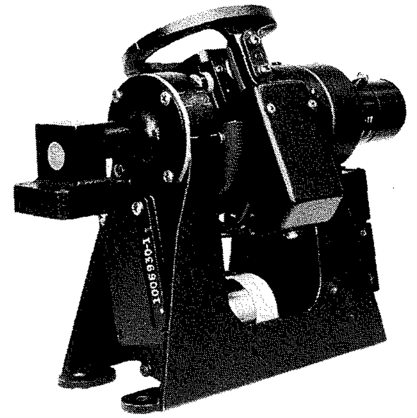


Fig. 7a—The AVQ-55 antenna less feed and reflector.

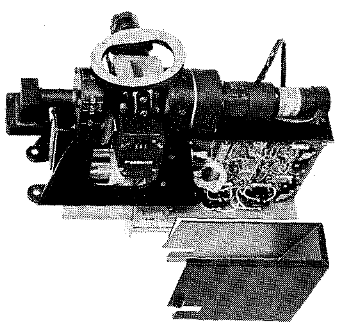


Fig. 7b—AVQ-20 antenna, less reflector and feed, but showing integration of transistorized plug-in stabilization chassis.

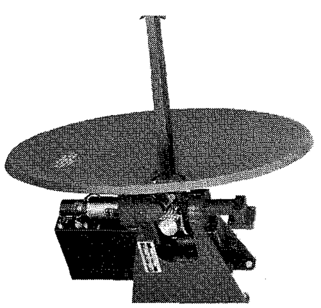


Fig. 7c—AVQ-20 complete antenna assembly with 18-inch reflector and feed.

substantial loss in over-all efficiency. A simpler and more direct approach involved feedback control of the 115-volt AC source through a buck-boost arrangement using a voltage-phase–sensitive network. Fig. 2 shows a simplified schematic of this method.

Referring to Fig. 2, transformer *T1* has its low-impedance secondary directly in series between the 400-cycle line and main power transformer *T2*, which is wound with a nominal 107-volt primary. Transistors *Q1* and *Q2* are configured for class-AB power amplifier operation and are driven from voltage amplifiers *Q3* and *Q4*. The voltage-phase–sensitive network consisting of *R1* through *R5* receives 400-cycle excitation from a separate winding on *T2* and contains two voltage-sensitive elements (actually small incandescent lamps) such that balance is obtained at a particular value of input voltage. Proportional 0° or 180° phased output voltages are provided respectively at input levels above or below the balance point. The error correction voltage is applied to *Q3* and *Q4* and (after suitable amplification) appears across the secondary of *T1* in proper amplitude and phase with respect to the 400-cycle line. Thus, the regulator compensates line voltage variations and is effective over an input range of 103 to 126 volts. The DC operating potentials for the control amplifier are derived from an unfiltered 24-volt source; after smoothing, this voltage is used elsewhere in the system. Diodes *CR1* and *CR2* protect transistors Q_1 and Q_2 against excessive inverse emitter-to-base voltages.

INDICATOR

Except for the PPI (plan position indicator) tube itself, the indicator is completely transistorized using 36 transistors and 29 diodes. The advantage of small size gained from using solid-state devices is emphasized by the fact that with the exception of the low-voltage power supply, the AVQ/55 indicator *alone* accommodates all of the circuitry formerly used in both the indicator and short ¾-ATR synchronizer of the earlier AVQ/50 weather radar system. In addition, the total heat dissipation within the new unit is well below 15 watts, providing satisfactory cooling without the use of an internal blower. Circuits incorporated into the AVQ/20 and AVQ/55 indicators are: High voltage power supply, sweep and gate generators, sweep amplifier, range mark generator, IF amplifier, iso-contour circuitry, and all operating controls.

ANTENNA

To cover the complete airborne weather-radar market, the basic antenna is designed for use as an unstabilized unit in the AVQ/55 system or, by addition of a transistorized stabilization amplifier chassis and several other components, as a stabilized unit in the AVQ/20 system.

The same line-of-sight stabilization method which proved so successful in present airline weather-radar equipment is used. However, contrary to original airline recommendations against use of vacuum tubes within the radome (enclosed nose) of the aircraft, complete transistorization of the stabilization system has allowed incorporation of these circuits into the antenna itself, greatly simplifying the installation and interconnecting cabling.

Sector scan has been used, with the scanned azimuth angle limited to 180° on the AVQ/20 and 120° on the AVQ/55. The mechanical design of the antenna is simplified, required installation space is minimized, and the present requirement for coating the aircraft antenna mounting bulkhead with microwave absorbent material is eliminated.

In addition to the normal pencil beam used for weather detection, a cosccant-squared beam has been provided with the 24-inch reflector of the AVQ/20 to take advantage of the improved ground-mapping capabilities of X-band operation. Switching from one beam to the other is accomplished electromechanically rather than by the older and more complex mechanical method. A selection of reflector and feed combinations is available which will allow use of both stabilized and unstabilized antennas in all but the very smallest of aircraft nose configurations.

CONCLUSION

Changing requirements in today's high-performance aircraft, both large and small, have placed increasing importance on reliability, size, weight, and power consumption of airborne electronic equipment. Transistors and solid-state techniques has made possible the development of these two new airborne weather radars for airline and general aviation use that represent the ultimate for these important features.

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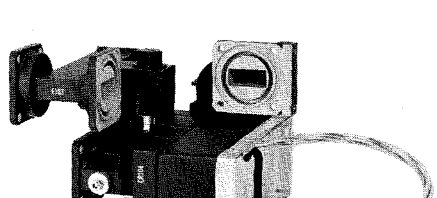

Fig. 8—AVQ-20/55 mixer assembly showing integration of IF preamplifier with mixer.

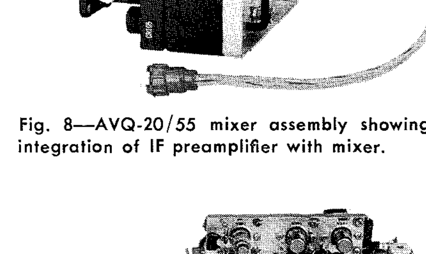

Fig. 9—AVQ-20/55 IF preamplifier design uses nuvistors to achieve a low noise figure (3 of the total of 8 tubes in the radar system).

IMAGE PROCESSING WITH DISTRIBUTED OPTO-ELECTRONIC SYSTEMS

Research with opto-electronic panels has demonstrated several image-processing transformations. For example, coupled panels can provide certain controlled modification of the input to a character-recognition system, where preprocessing is necessary so that a variety of character types can be handled. Because logic for such transformations is in the panels (panels have been made with over 10^5 elements) and operations are performed in parallel, processing speed is competitive with the time required to perform the same transformations on a digital computer—i.e., the nature of the opto-electronic panel itself provides a "natural program." Their unique properties for logic and simultaneous visual display suggest that many applications can be made as their technology improves.

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OPTICAL-FEEDBACK storage light-intensifier panels are capable of sufficient basic logic operations, namely threshold logic and negation, to perform any desired logic function. In addition, neighborhood interaction is easily obtained by cascading spaced storage panels or by optical operations on the input image. Line thinning of an alphabet character has been demonstrated using two spaced panels in cascade. This *natural program* (i.e. using the nature of the device itself) gives a thinned-character output in a time competitive with the time required by a high-speed digital computer to perform the same operation. The thinning operation, when allowed to progress far enough, will not only detect intersections, but also distinguish whether they are two-, three-, or four-way intersections. Several natural programs have been devised for motion detection, differing in degree of complexity and type of output. The simplest technique uses only one panel and displays leading edges of moving images.

The panels used are essentially two-dimensional, iterated arrays of simple elements, easily made with fabrication techniques largely based on refinements of spray painting processes. Panels containing 2.5×10^5 elements have been made, and present fabrication methods and equipment can be used to make panels having 7×10^5 elements or more.

IMAGE PROCESSING BY NEIGHBORHOOD LOGIC

In several proposed character-recognition systems aimed at accepting a wide variety of character shapes, various preprocessing schemes have been considered. The preprocessing has been directed toward character modification, needed because of a chosen particular set of recognition criteria or the specific nature of the analyzing means. Computer simulation programs to produce such smoothing as speck removal, notch fill-in, corner fill-in, hole fill-in, line thinning, etc. are reported in the literature.[1,2,3] The literature also contains references for electronic image processing; in these, various pulse shaping and integration schemes have been suggested and used in scanning systems.[4,5]

In a general sense, all smoothing operations reduce the over-all resolution of the system. The resolution is either uniformly degraded over the entire character field or within selected regions. Smoothing is thus a predetermined approach to destroy the fine structure of an image in such a way that certain requirements dictated by a specific analyzing method and recognition system design are met.

In a paper by Unger[6] describing a spatial computer aimed at the recogni-

The author, H. O. Hooks, checks light output from optoelectronic image-processing panel.

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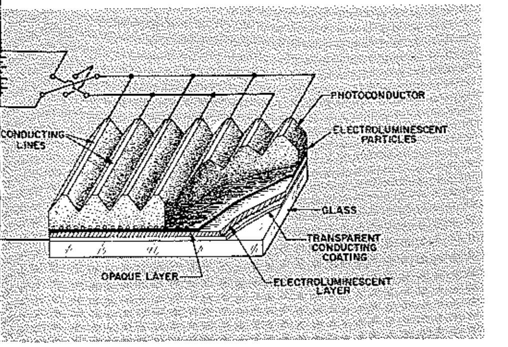


Fig. 1—Layer-type storage light amplifier and image-processing panel.

tion of alphanumeric symbols, smoothing is discussed using a neighborhood logic. In this scheme using neighborhood logic, the state of an elemental area is determined by its surround. The image is selectively modified according to a set of logic statements designed to produce a variety of image modifications such as speck removal, notch fill-in, corner fill-in, and hole fill-in. Smoothing functions are especially derived to adjust the character form to allow using character edge orientation as the method of analysis for recognition.

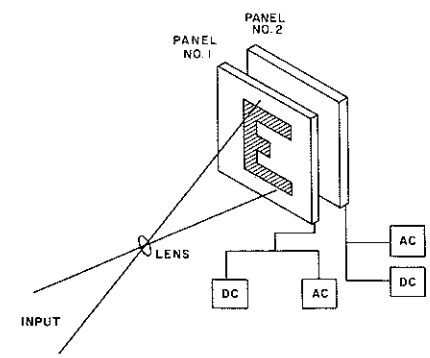
The behavior of two coupled storage light-intensifiers makes them suitable as a controlled means for performing certain explicit smoothing functions prior to character analysis in a character-recognition system. Such panels provide a distributed system capable of modifying character form without regard to character orientation and which operates simultaneously on all elements of the character field.

USE OF EL PANELS

The panels (Fig. 1) are of the layer type and consist of a photoconductor layer, an electroluminescent light feedback layer, an opaque layer to prevent output light feedback to the input, and an electroluminescent layer to produce light output.

These image-processing panels operate by using the photoconductor to control the current to the electroluminescent layers. Where the photoconductor is in the dark, no current flows to the electroluminor, leaving it dark. Where the photoconductor is illuminated, current flows and light is produced in both the output and feedback electroluminescent layers. The feedback light illuminates the photoconductor sufficiently to keep the current flowing after the input is removed. The light absorption of the photoconductor and its nonlinearity of current with electric field limit spreading of the image.

Fig. 2—Physical arrangement of panels for line thinning and smoothing.



The photoconductor allows more current to flow for a given light input if the electric field is unidirectional. The DC bias and interdigitated electrode permit the photoconductor to operate with unidirectional current while the electroluminor receives the required alternating field. Reversal of the polarity of this DC bias provides rapid erasure and is a step in the image reversal and motion detection operations.

OPTICAL COUPLING

If a panel is placed in close proximity to another panel each elemental area of the photoconductor layer of the second panel will be coupled optically to a region of the electroluminescent layer of the first panel (Fig. 2). The extent of the region will be proportional to the sensitivity of the photoconductor of panel No. 2 and the spacing between the panels, and will vary inversely with the intensity of the output light from the panel. Thus, the intensity of the light input at any point represents a weighted summation of a neighborhood.

The characteristics of these panels are such that a threshold amount of light must be impressed on the photoconductor before any appreciable output occurs from the electroluminescent layer in series with it. The properties of the photoconductor provide each elemental area with light integrating ability. The threshold and integrating function provides means for controlled image modification. The rate and extent of speck removal, line thinning, and hole and cavity dilation can be controlled by adjusting the output light level of the first panel and the exposure time. The processing can be stopped by removing the power from the first panel. The modified image will then be stored by the second panel for observation and analysis.

CHARACTER READING SYSTEMS

In several of the character-reading systems proposed in the literature,[2,3] the smoothing functions have been based on spatial quantization of the character (considering a white area as zero and a black area as one). The state of each elemental area is logically determined by formulating a Boolean expression utilizing the state of the eight neighboring elemental areas. A separate expression is derived for each type of modification desired. For example, referring to

A	B	C
D	X	E
F	G	H

Fig. 3—Cell nomenclature for nearest neighbor logic.

Fig. 3, speck removal would be accomplished by replacing the contents of cell X with:

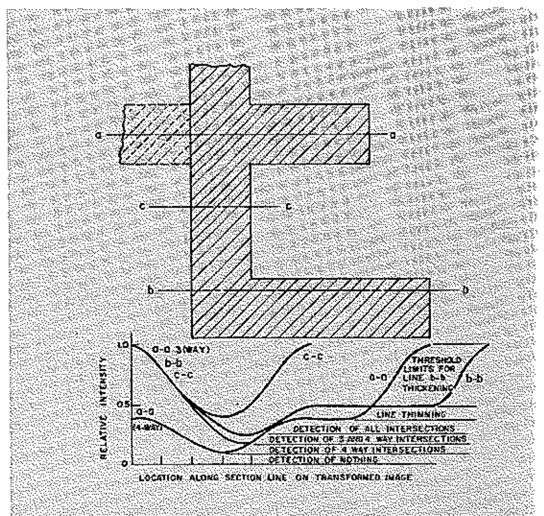
$$f = X[(A + B + D) \cdot (E + G + H) + (B + C + E) \cdot (D + F + G)]$$

The expression can be applied also to small bumps along straight lines, and applies to single isolated or paired cells only. Larger areas cannot be adequately treated without using continuity properties around isolated cells. This limitation does not apply to optically coupled storage light-intensifiers, since the size of the neighborhood can be as large as desired.

EXAMPLES OF IMAGE PROCESSING

To illustrate the processing of images using optoelectronic panels, let us use a simple imaging process cascaded with threshold selection. The imaging process can be described as a transformation whereby each point on the original is reproduced on the image as a uniformly illuminated disc, the illumination being proportional to the luminance of the original point. Fig. 4 illustrates this transformation for several sections through a constant-line-width character for the condition that the disk radius equals the line width. For these conditions the threshold ranges are indicated on the curves of intensity. Zero illumination from the character line is assumed. For a long range of high thresholds, line thickening is obtained; for a shorter range, line thinning is obtained at lower thresholds. At progressively lower threshold levels, all intersections, then

Fig. 4—Intensity distributions in image transformed such that a point on the original becomes a uniformly illuminated disk with radius equal to line width.



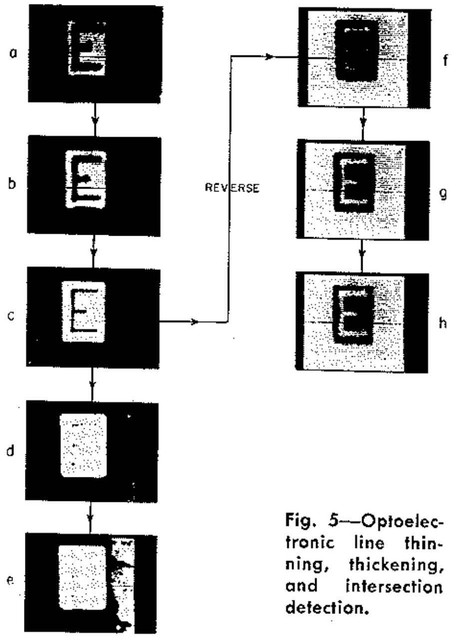


Fig. 5—Optoelectronic line thinning, thickening, and intersection detection.

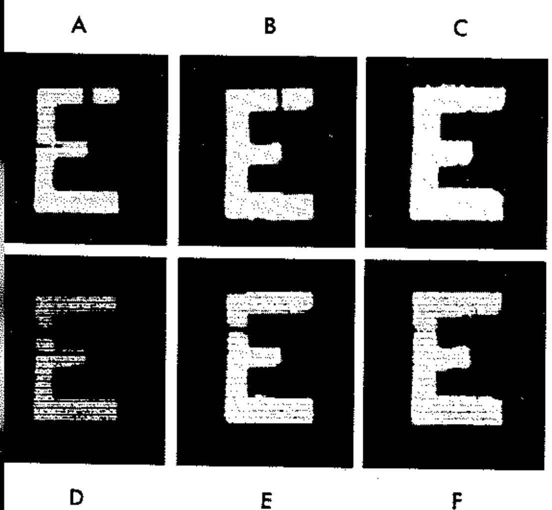
three- and four-way intersections, then four-way intersections only are displayed. Finally, with a near-zero threshold, no information is displayed — the whole display reaches white level.

One approximation of the point-to-disk transform is the spaced panel arrangement of Fig. 2. A better approximation is produced in the out-of-focus image of a good lens. The pictures of Figs. 5 and 6 were taken using the defocussed-lens image as the input.

Storage light-intensifier panels are capable of producing a reversed image, that is of converting a black image on a white background to a white image on a black background, or vice versa. Image reversal is accomplished by storing an image on a panel, removing the image, reversing the DC field across the photoconductor (Fig. 1) and momentarily flooding the photoconductor with uniform light.

Using these properties, several interesting image transformations are possible. Figs. 5a-5h illustrate line thinning (a,b,c), intersection detection (d,e), image reversal and line thickening subsequent to thinning (f,g,h). Figs. 5a,b,c,d, and e represent successive exposures to the defocussed input (that is, larger integated exposure) which can be equated to decreasing the threshold. Figs. 5f,g,h were obtained by reversing the DC bias after Fig. 5c and exposing successively to a uniform flood of light.

Fig. 6—Optoelectronic gap fill-in.



Using the image-reversal and speck-removal techniques results in a method for filling in holes and closing small gaps in the image. Let us assume, for example, a black image on a white background. The black regions contain holes which should be closed as removed. If a reversed image is produced, the holes will be converted to black specks surrounded by white areas. The exposure is allowed to progress until the specks are erased. When the specks are removed, the entire image is reversed to return it to its original sense, black on white.

To illustrate the hole-fill-in capability of opto-electronic image processing panels, a character with a gap was used as the input. A panel was given successive exposures to the defocussed image of the character (Figs. 6a-6f). Figs. a,b,c illustrate fill-in of a gap in a horizontal line; Figs. 6d,e,f illustrate the same for a gap in a vertical line.

Fig. 7 illustrates motion and new target detection obtained with an image processing panel (area moving target indicator). On the first frame, the whole image appears. The DC bias is reversed, and the next (displaced) frame is applied. The image of this frame appears only where there was no image on the first frame.

Fig. 8 illustrates the fimbriation, or outline, produced by overexposure of an image-processing panel. This effect is produced by fatigue of the photoconductor in the illuminated region except at the edges thereof where the exposure is less.

CONCLUSIONS

Opto-electronic panels using photoconductors and electroluminors as active materials have been used to demonstrate several image-processing transformations. Because the type of logic used for these transformations is easily achieved in image-processing panels and because the operations are performed in parallel, the transformations are accomplished in times comparable with the time required to do the same transformation in a high-speed digital computer. Thus for certain procedures, an apparent speed disadvantage of 10^5 is made up by making use of the nature of the device itself in what may be called a *natural program*.

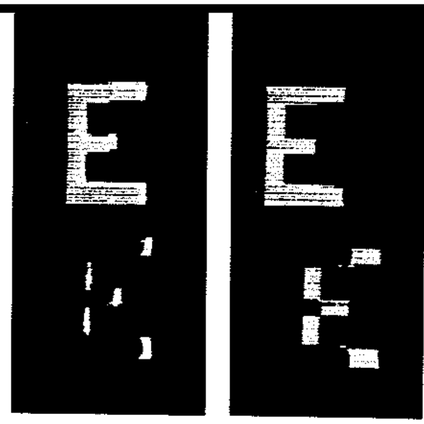


Fig. 7—Optoelectronic motion detection.

Many problems remain to be solved before opto-electronic panels can be used as adjuncts to high speed digital computers; however, their unique properties commend them to operations where a human observer must be informed or where the input is in the form of an optical image or both. In their present form, using only a part of the operations described above, these panels are being used as read-out devices. Other applications of image-processing panels should appear as their properties become more widely known.

ACKNOWLEDGMENTS

The contributions of E. C. Giaimo to the methods and practice of panel image processing and the able assistance of J. Murr in panel construction and testing are gratefully acknowledged.

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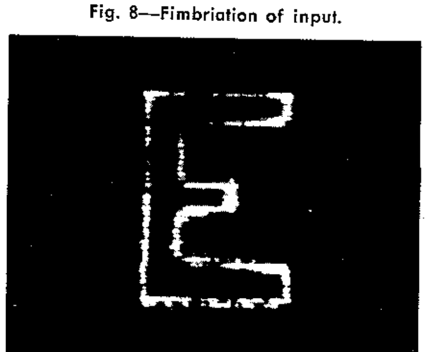
Fig. 8—Fimbriation of input.



WHITHER THE TUNNEL DIODE?

Ever since the tunnel diode made its appearance, considerable controversy has been evident with regard to its theoretical and practical importance. Time has now provided some meaningful engineering experience with the device. This paper evaluates the tunnel diode state-of-the-art, discusses application trends, and makes some significant comparisons between it and other devices. The result is a number of conclusions with regard to its practical position in the device arsenal.

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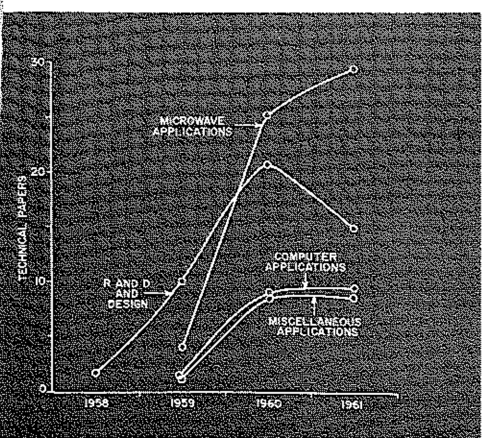
WHEN THE tunnel diode climbed aboard the electronics bandwagon in 1958, some optimists predicted that it would rise to such eminence that it might even replace the ubiquitous transistor. Another group, composed mostly of transistor engineers, predicted that the new "upstart" would rapidly wither away. Somewhat in the middle were those digital-applications men who thought that the tunnel diode would make a fine device for linear amplification—and the linear-applications men who thought that the device ought to be excellent for digital applications.

Who was right? Although the complete story has yet to be written, enough dust has settled to warrant a few general conclusions. First, the device will never equal the transistor in over-all, across-the-board importance. Second, the tunnel diode promises to be noteworthy in several important, but rather specialized, applications areas. One of these is the microwave amplifier, converter, and oscillator field. Another is pulse circuits requiring a threshold device of extremely high speed and very high stability. Still another is computers of such speed that no other device known can possibly switch fast enough to meet the circuit requirements. *The purpose of this paper is to justify these conclusions.*

Fig. 1—Number of papers published on tunnel-diode design and applications since 1958. (Data from all major electronic journals. The 1961 data is extrapolated from figures for the first nine months of the year. Figures are plotted at mid-year points.)



POPULARITY OF THE TUNNEL DIODE IN THE ELECTRONICS INDUSTRY

The number of technical papers published on a particular device or its applications is an approximate measure of interest in the device. Fig. 1 shows the number of technical papers published on tunnel-diode design and various applications since 1958. (A selected bibliography is included at the end of this paper.)

Interest in the R and D design of the device increased rapidly, reached a maximum in 1960, and has declined somewhat since then. This decline can be partly explained by the relative simplicity of the device and by the fact that semiconductor theory and practice was already so far advanced when the tunnel diode appeared.

Interest in microwave applications has increased rapidly and is still increasing —a significant illustration of the potentialities of the device in this application area. Fig. 1 indicates that perhaps the microwave field will be one of the most important applications of tunnel diodes. Interest in computer and miscellaneous applications, as evidenced by published papers, has leveled off at a considerably lower value.

Interest in the tunnel diode for general applications does not show the explosive, sustained growth tendencies experienced in the early years of transistor development.

Table I—Tunnel Diode Figures of Merit

Maximum Frequency of Oscillation:

$$F_{max} = \frac{1}{2\pi RC}\sqrt{\frac{R}{R_s} - 1}$$

Gain-Bandwidth Product:

$$G\Delta F = \frac{1}{2\pi RC}$$

*Switching Delay:

$$T_r \approx \frac{V_v - V_p}{I_p - I_v}\, C \approx \frac{C}{2I_p}$$

*Approximate, in nanoseconds when C is in picofarads; I_p, V_p are peak current and voltage; I_v, V_v are valley currents and voltages.

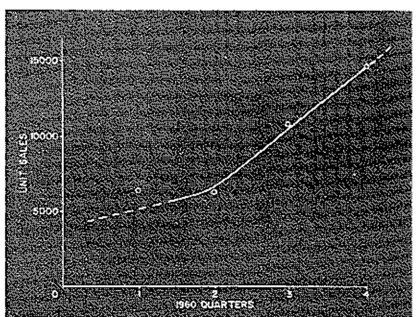
Fig. 2 shows the trend of unit sales during 1960. The rate of growth for the second half of the year is about 15,000 units per year. This rate will undoubtedly increase, but unit sales will probably never approach closer than within several orders of magnitude to transistor sales.

These data reinforce the conclusion that tunnel diodes will not approach the across-the-board applications volume of transistors. The discussion below of the basic technical difference between the tunnel diode and the transistor helps to explain the differences in applications interest.

GENERAL TUNNEL-DIODE CHARACTERISTICS

Fig. 3 shows the familiar volt-ampere characteristic typical of a germanium tunnel diode. The region of the characteristic between the "peak" and the "valley" displays a negative resistance, which makes it possible to convert power-supply energy into circuit energy and

Fig. 2—Trend of unit sales during 1960. (EIA figures; data not available for 1959 or 1961.)



thus to provide amplification, oscillations, etc. (A positive resistance merely converts power-supply energy into heat which leaves the circuit.)

Fig. 4 shows the generally accepted equivalent circuit of the device. In contrast, the more complicated transistor has evolved dozens of equivalent circuits which continue to provoke controversy between their various inventors.

Table I shows the basic figures of merit for the tunnel diode. In the relation for maximum frequency of oscillation, the magnitude of the negative resistance is used, but not the negative sign. The maximum value of this relation occurs when $R = 2R_s$; the expression then becomes:

$$f_{max} = \frac{1}{4\pi R_s C} \qquad (1)$$

Eq. 1 shows that the tunnel diode, like other p-n junction devices, is resistance-capacitance-limited in frequency response. The tunnel phenomenon, itself, is so fast that it need not be considered as a frequency limitation.

MAXIMUM OSCILLATION FREQUENCY

Fig. 5 shows the oscillation frequency of tunnel diodes and transistors as a function of a "critical" dimension which is a measure of the difficulty in constructing the device. For the tunnel diode, this critical dimension is the diameter of the p-n junction. For large-diameter junctions, R_s varies inversely and C directly as the junction area; thus, their product remains constant and the maximum frequency of oscillation remains constant.

For small junction diameters, however, spreading-resistance effects appear and the quantity R_s varies inversely as junction diameter, instead of as junction area. In the ideal case, when contact resistances and other spurious effects are absent, the variation of maximum oscillation frequency of a circular-junction tunnel diode with junction diameter can be represented by parallel lines for different doping densities in the material (Fig. 5). The more the material is doped, the lower is R_s and the higher the potential oscillation frequency. The actual frequency varies more slowly than the first power of doping density because of the effect of charge-carrier density on carrier mobility at high doping levels.

Oscillations have been observed in point-contact-junction tunnel diodes at frequencies close to 100 Gc. These results prove that the device has very high frequency capabilities.

Varactor diodes, which are p-n junction devices, have a frequency capability twice that given by Eq. 1. The factor of two compensates for the varactor's lower doping density. Consequently, both varactor and tunnel diodes with junctions of circular cross-section have very nearly the same maximum frequency capabilities.

The "critical dimension" shown for the transistor in Fig. 5 is the base width. Admittedly, collector and emitter diameters and other dimensions also affect frequency performance. However, these other dimensions only make the oscillation frequency approximately the same as, or less than, that shown in Fig. 5.

Regardless of the dimensions of a transistor, its geometry, or its material, there is a maximum frequency which cannot be exceeded. This limiting frequency is approximately represented in Fig. 5 by the vertical line at the high-frequency end of the transistor curve. This limitation is caused by the carrier transit-time delay in the collector depletion layer. The carrier drift velocity in all known semiconductors has an upper limit of about 6×10^6 cm/sec regardless of the applied field. This limiting (saturation) velocity is reached with fields of several kilovolts per centimeter. If the width of the depletion layer is reduced to shorten the carrier transit time, the electric field in this layer is increased and eventually reaches the breakdown field value, which is close to 2×10^5 v/cm for all semiconductors. If the collector voltage is reduced to decrease the electric field, the minimum allowable collector potential of about 0.5 volt is eventually reached. This value is approximately the minimum potential that allows the device to have a reverse-biased collector and thus operate as a transistor.

This combination of basic phenomena limits potential transistor frequency capabilities to about 30 to 50 Gc. It is doubtful that practical transistors will ever attain this limit. A value of about 10 Gc is possibly an attainable goal. Even this ambitious goal requires advances in microtechnology, plus the use of more idealized high-frequency semiconductor material, such as gallium arsenide, and probably also the application of the wide-bandgap emitter principle. Transistor oscillation capability is currently approaching 5 Gc.

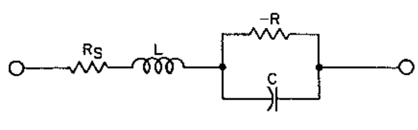


Fig. 4—Tunnel diode equivalent circuit, where R_s = dissipative series resistance; L = shunt capacitance; $-R$ = negative resistance; and C = p-n junction shunt capacitance.

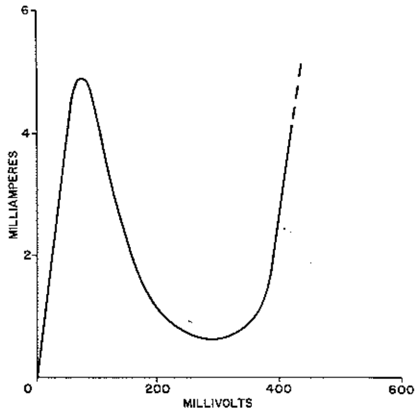


Fig. 3—Volt-ampere characteristics for a typical Germanium tunnel diode.

As shown in Fig. 5, therefore, tunnel diodes have a higher theoretical frequency capability than transistors. Furthermore, tunnel diodes have already been operated at frequencies higher than can possibly be reached with transistors, regardless of their design.

USEFUL POWER GAIN

As important as the upper frequency limit of a device is the useful power gain which can be obtained (Fig. 6).

The Fig. 6 curves for the tunnel diode assume the existence of a practical device capable of an upper frequency of about 100 Gc. At microwave frequencies below this value, the useful linear power gain is about 20 db. Higher gains are not practical because the tunnel diode is a two-terminal device and requires special circuits (circulators, isolators, and the like) to separate the input from the output signal. These circuits are not effective at gain levels higher than about 20 db because the loading conditions become critical. Also, because these circuits are not presently practical below about 500 Mc, the useful tunnel-diode gain falls below 10 db at lower frequencies. Even at such low gain levels, the high internal-feedback factor makes the device critically dependent upon circuit-loading conditions. In effect, the tunnel diode is forced to operate as a regenerative amplifier.

Another disadvantage of the tunnel diode for linear operation is its inability to handle large-amplitude signals. This disadvantage results from the shape of the volt-ampere characteristic (Fig. 3); the negative resistance is constant over only a limited range of current and voltage.

In digital operation, the signal across the tunnel diode's two terminals literally "doesn't know whether it is coming or going." As a result, special circuits are again necessary. The most successful approach appears to be the use of de-

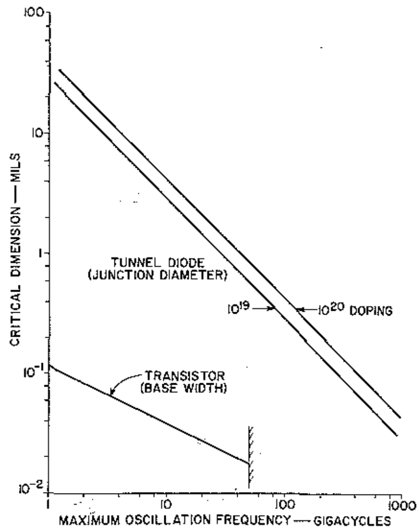


Fig. 5—Tunnel-diode and transistor frequency limits.

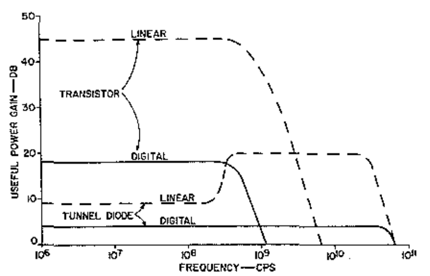
coupling diodes having volt-ampere characteristics which match those of the tunnel diode. The decoupling diodes which fit this requirement most closely are tunnel rectifiers (tunnel diodes with almost nonexistent peak currents).

Even when decoupling diodes are used, however, the tunnel diode is operated as a threshold device and the amount of logic stage gain is critically dependent upon very tightly specified device and passive-component parameters. For a stage gain of three, for example, the diode and component parameter values must be specified to 1 or 2 percent, a tolerance much tighter than those normally used for transistors. It should be remembered, however, that the tunnel diode is a much simpler device than a transistor and is not troubled by surface effects. Accordingly, 1 percent tolerances are easier to meet on tunnel diodes than on transistors.

Unfortunately, there is no simple way to "trade" frequency capability for logic stage gain. Consequently, the logic gain is low at all frequencies, as shown by the flat tunnel-diode useful gain curve for digital operation in Fig. 6.

The transistor curves in Fig. 6 assume an "ultimate" device having an upper

Fig. 6—Useful power gain of tunnel diodes and transistors.



frequency limit close to 10 Gc. As with lower-frequency transistors, the useful gain increases at frequencies below the upper operating limit. This gain, however, is limited in practice to about 45 db because the transistor, like the tunnel diode or any other electron amplifying device, has internal feedback which causes instability when gain is increased beyond some critical value. The transistor and the vacuum tube (unlike the two-terminal tunnel diode) are three-terminal devices which have very low, but not zero, internal-feedback factors. These devices can provide stable stage gains which are high enough for most applications. Furthermore, if higher gains are desired, stages can be cascaded, as in IF-amplifier strips or audio amplifiers. Cascading has not been feasible with the tunnel diode below microwave frequencies because the inherent instability of the regenerative type of operation is too great.

In digital operation of the transistor, the upper frequency limit is less than in linear operation. Digital operation involves very large swings of current and voltage for which the device design cannot be as effectively optimized as for small-signal linear operation. In particular, carrier-storage effects reduce operating speeds to values considerably slower than might be expected from consideration of only the RC time constants and transit-time effects encountered with small-signal operation. Nevertheless, the transistor has excellent input-output isolation and operates in a very straightforward manner in digital circuits. It provides ample gain to drive ten or more succeeding stages, usually without requiring device or passive-component tolerances tighter than about ± 10 percent. When a transistor is pushed to the limit of its switching speed in digital circuits, however, the component tolerances must be reduced in value.

As shown in Fig. 6, therefore, the transistor performs better than the tunnel diode in amplifiers and digital circuits for frequencies below about 0.5 to 1 Gc, except for special types of applications which will be discussed later. At very high frequencies, the tunnel diode can operate as an amplifier and switch, but the transistor cannot. At these very high frequencies, however, the tunnel diode must compete with such other devices as varactor diodes, masers, and vacuum tubes. At intermediate frequencies, from 0.5 to 5 Gc, the choice of tunnel diode or transistor depends on economics and special application requirements.

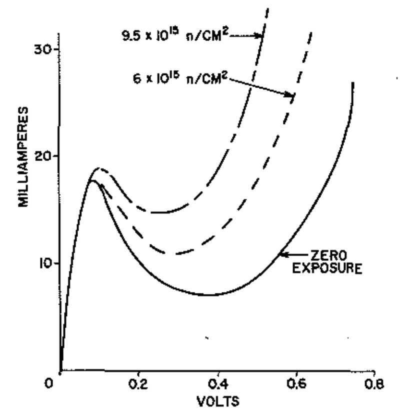


Fig. 7—Volt-ampere characteristics of a typical tunnel diode after fast-neutron exposure.

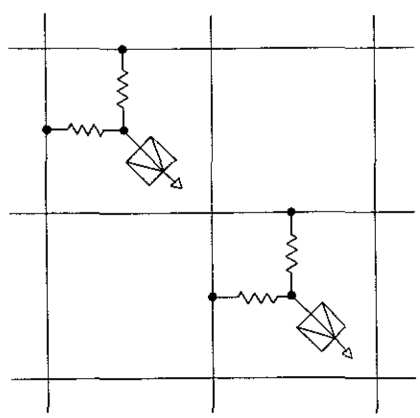
OTHER CONSIDERATIONS FOR TUNNEL-DIODE OPERATION IN LOGIC CIRCUITS

Despite its frequency limitations, the tunnel diode has some advantages for digital operation. For example, it has an unusually high degree of immunity to radiation effects such as might be encountered in space and in certain terrestrial applications (Fig. 7). In particular, the peak current is only slightly affected by radiation.

Another important advantage of a tunnel diode is its ability to continue operating while it is in the radiation field. In comparison with tunnel diodes, transistor operation is severely affected during exposure, and is only partly regained after the radiation has been removed.

Tunnel diodes also have the ability to operate at high speeds at very low power levels. For a computation speed corresponding to a stage delay of 50 nsec, the best transistor circuits dissipate about 50 mw per stage. A tunnel-diode stage might do the same job for about a hundredth of the power. The tunnel diode for this application would have a peak current of about 1 ma and a shunt capacitance of several picofarads. The tunnel diode can operate

Fig. 8—Tunnel-diode memory array.



at lower power because of its lower storage capacitance and lower operating voltages. Such economy of power is attractive not only for space application, where power is difficult to obtain, but also for equipment in which component packing density is high and heat dissipation is a problem.

Many circuits have been proposed for combining tunnel diodes and transistors in logic circuits to obtain the best features of both devices. The transistor, for example, would be used to provide isolation and stage gain; the tunnel diode would provide high-speed bistability. So far, no combination of the two devices seems to have been brought to the point of a finished design.

MEMORY APPLICATIONS

The bistability and high-speed capabilities of the tunnel diode suggest its possible application in high-speed memory systems. Fig. 8 shows how the diode would be connected between the x and y wires to achieve coincident operation.

Fig. 9 shows how tunnel-diode memories would compare with other types on the basis of bit capacity and cycle time. The term cycle time includes both *read* and *write* time. Tunnel-diode memories would have very high speeds compared to other memories, particularly the conventional ones using ferrite cores. However, because of a relatively high expense per bit, tunnel-diode memories are economically limited to relatively small sizes compared to ferrite memories. The tunnel-diode memory also requires a constant flow of power to maintain operation; this requirement further tends to limit its size.

As shown in Fig. 9, the tunnel diode shows considerable promise as a small, very-high-speed memory, such as might be used as a "scratch pad" in a high-speed computer. Single memory elements using tunnel diodes have displayed cycle times of a few nanoseconds. In a practical system, however, where drive circuits and other design problems have to be considered, the total cycle time becomes limited to the approximate values shown in Fig. 9.

MICROWAVE, NON-DIGITAL APPLICATIONS

The high internal feedback of tunnel diodes is an advantage for oscillator applications. Fig. 10 shows the present power-output capability of vacuum tubes, transistors, and tunnel diodes. The tube curve closely describes the capability of triodes, magnetrons, traveling-wave tubes, klystrons, and amplitrons. (In the equation describing this curve, $Pf^2 = 100$, P is the output power in kilowatts and f is the operating frequency in gigacycles; this relation was pointed out to the author by Dr. L. S. Nergaard of the RCA Laboratories.)

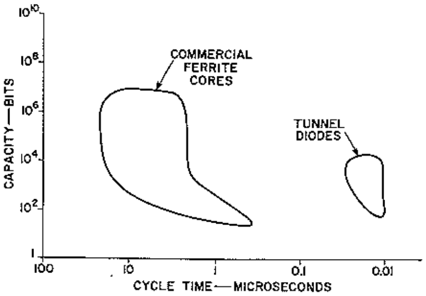


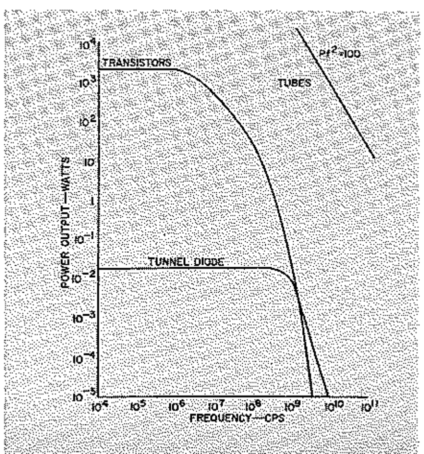
Fig. 9—Operating domains for ferrite and tunnel-diode memories.

The transistor curve approximately portrays the present state of the art. The low-frequency portion of the curve is determined by heat-dissipation problems. The high-frequency portion of the curve slopes downward because high-frequency response is obtained at the expense of a decrease in device size, with a consequent reduction in power-handling capability. A power-output capability of 1 watt at 1 Gc seems attainable.

Basically, tubes can handle more power than transistors at a high frequency because the power density is less. The greater charge-carrier velocity in tubes permits greater active volume for a given frequency capability. In addition, the greater coherence of charge-carrier motion in tubes makes distributed structures more feasible. Also, the lower dielectric constant of a vacuum reduces electrical capacitance for a given structural geometry.

The tunnel-diode curve also approximately portrays the present state of the art. Developmental units have attained power outputs approaching 10 mw at 1 Gc; this value is about equal to that attained by developmental transistors at this frequency. The present limitation in tunnel-diode power output is due to unavoidable series inductance. This problem will be alleviated when distributed structures can be fabricated. Theoretically, it should be possible to obtain output powers of a few watts at a frequency of several gigacycles.

Fig. 10—Oscillator-power-output capability for tubes, transistors, and tunnel diodes.



As a low-power microwave oscillator, the tunnel diode offers compactness, light weight, and simplicity. In addition, its power supply can be very compact and relatively simple in construction. Several types of tunnel-diode oscillators are now commercially available; they operate at several gigacycles with output powers approaching a milliwatt.

Fig. 11 shows the basic equivalent circuit for several important members of the two-terminal active-device family: tunnel diodes, parametric diodes, and masers. These devices include an input conductance G_g, a negative conductance $-|G|$, a shunt capacitance C, an inductance L to tune out C at the operating frequency, a shunt conductance G_c which represents circuit losses, and a load conductance G_L. The negative conductance in the tunnel diode results from tunneling phenomena; in the parametric diode, from the pump signal acting on the nonlinear capacitance; in the maser, from the energy emission caused by an overpopulation of atoms or molecules in the higher-energy levels due to absorption of energy supplied at the "pump" frequency. In all three devices, the power gain, the bandwidth, the gain-bandwidth product, and the noise factor are given by the expressions shown in Table II.

The noise figures for the maser and the parametric amplifier are reduced when the idler frequency W_i is higher than the signal frequency W_s. For lower noise and for improved stability, therefore, these devices are almost always operated as up-converters. The noise figure of the tunnel diode, however, does not involve frequency ratios, but results from current flow I_o across the junction; therefore, it involves shot noise. As a result, the tunnel diode has an advantage over the other devices for down-converter operation, which is frequently more convenient than up-conversion.

The first attempts at using tunnel diodes as down-converters led to noise figures of a few db and power gains of 10 to 20 db; however, the operation was critically dependent upon circuit loading. In more recent circuits, the diode is biased on a positive-resistance portion of its characteristic rather than

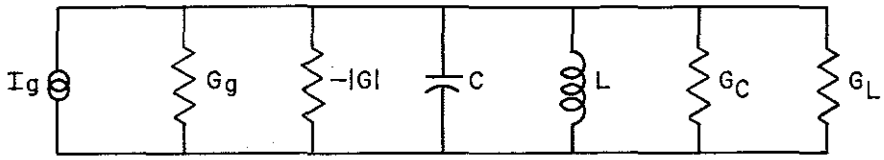


Fig. 11—Basic equivalent circuit for several two-terminal devices. (See also Table II.)

in the negative-resistance region. Large-amplitude signals from the local oscillator are then used to sweep the diode into the negative-resistance region of the characteristic. This type of operation provides circuit stability, power gains close to unity, and noise figures about 3 db better than the best crystal mixers. When operated in this manner, the tunnel diode is competitive with the conventional crystal mixer, which provides an insertion loss close to ten db and a noise figure one or two higher. Performance of the tunnel diode with respect to crossmodulation and other interference effects has yet to be fully evaluated.

Fig. 12 shows typical curves of amplifier power gain and noise figure for tunnel diodes. These results were obtained in various laboratories throughout the country, and should be considered only as an indication of the results that can be obtained in field equipment.

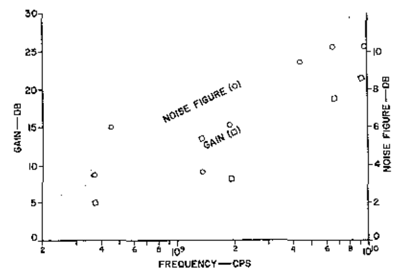


Fig. 12—Typical power-gain and noise-figure curves for tunnel-diode amplifiers.

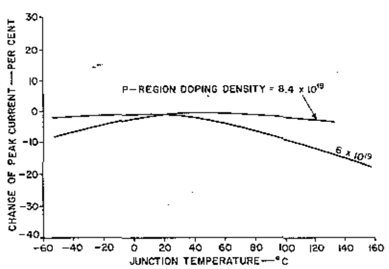


Fig. 13—Peak-current stability with temperature in specially-designed germanium tunnel diodes.

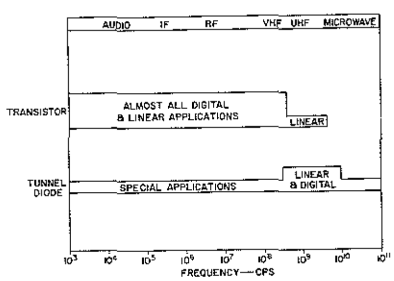


Fig. 14—Summary of application domains for tunnel diodes and transistors.

SPECIAL APPLICATIONS

The tunnel diode is almost ideal for circuits which require threshold action with high stability and speed, such as pulse discriminators, coincidence detectors, scalers, and counters. Tunnel-diode stages have been observed to switch in less than 0.1 psec, a performance not likely to be matched by transistors. The excellent temperature stability of the peak current in specially designed diodes is shown in Fig. 13. The peak-current stability of diodes with respect to radiation damage was shown previously in Fig. 7.

DEVICE IMPROVEMENTS

Although the main aspects of tunnel-diode design are well understood, a few problems still remain. One is to understand and control the diode's "excess" current—the current in the valley region of the characteristic which is in excess of that expected from simple p-n junction theory. Another problem is to increase operating-life expectancy of high-performance GaAs tunnel diodes.

Device design in the future will emphasize smaller, lower-inductance packages. For some microwave applications, the device will have a distributed junction which is built as an integral part of the passive circuit. Emphasis in the future will also be on the low-cost manufacture of diodes with very closely specified characteristics.

SUMMARY

The comparative application domains of the tunnel diode and the transistor are broadly summarized in Fig. 14. The tunnel diode has very special properties, but also a basic problem: lack of input-output isolation. Thus, it will be overshadowed by the transistor at frequencies economically attainable by the transistor. At higher frequencies, the tunnel diode has a clear-cut advantage over the transistor, but will be in competition with such high-frequency devices as the parametric diode, tubes, and the maser.

Regardless of the relative status of the tunnel diode in the future, however, it will prove to be an extremely valuable addition to the active-device arsenal of electronic engineers.

Table II—Equations for Important Parameters of Two-Terminal Devices. (Equivalent Circuit of Fig. 11)

Power Gain:

$$\beta = \frac{4G_L G_g}{[G_g + G_c - |G| + G_L]^2}$$

Bandwidth:

$$\Delta W = \frac{G_g + G_c - G + G_L}{C}$$

Gain-Bandwidth:

$$\beta \Delta W = \frac{2\sqrt{G_L G_g}}{C} < \frac{|G| - G_c}{C}$$

Noise Figure:

$$F = 1 + \frac{T}{T_o}\left[\frac{G_c + G_L + G_n}{G_g}\right]$$

Where:

$$G_n \sim \frac{W_s}{W_i}|G| \text{ for masers}$$

$$G_n \sim \frac{W_s}{W_i}|G| \text{ for parametric diodes}$$

$$G_n \sim \frac{eI_o}{2KT} \text{ for tunnel diodes}$$

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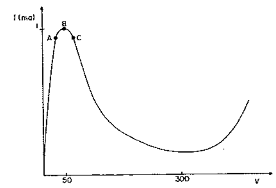

Fig. 1—Typical germanium tunnel-diode characteristic.

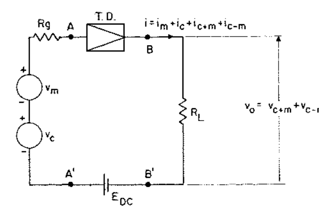

Fig. 2—Tunnel-diode modulator simplified schematic.

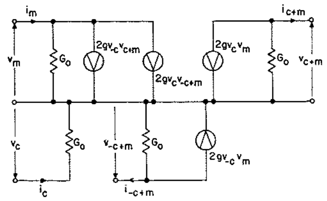

Fig. 3—Tunnel-diode modulator, linear equivalent circuit.

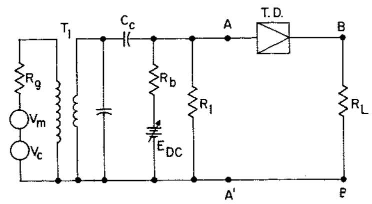

Fig. 4—Tunnel-diode suppressed-carrier modulator, simplified schematic.

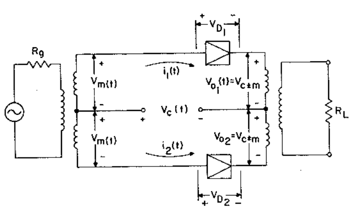

Fig. 5—Tunnel-diode balanced modulator, simplified schematic.

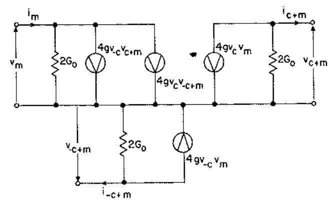

Fig. 6—Tunnel-diode balanced modulator, linear equivalent circuit.

MODULATION WITH TUNNEL DIODES

Inherent tunnel-diode characteristics are advantageously used herein to design a single-tunnel-diode suppressed-carrier modulator, and a two-tunnel-diode balanced modulator that acts as a ring modulator with proper biasing. Both require low carrier and modulating power, making them suitable for low signal levels.

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The nonlinear current-voltage characteristic and negative dynamic-conductance region of tunnel diodes offer the possibility of modulation with gain, normally achieved by use of transistors and vacuum tubes. Further, the unique characteristic of the tunnel diode, nearly parabolic at the current peak, permits the design of very simple suppressed-carrier modulators.

Previously, carrier suppression was obtained by the use of carefully balanced circuits with two conventional diodes; a single-tunnel-diode modulator, properly biased, gives an equivalent carrier suppression. Similarly, ring-type modulators with conventional diodes use a double-balanced circuit with four diodes; two tunnel diodes, properly biased and in a balanced arrangement can give equal performance.

A linear equivalent circuit for the nonlinear modulation process can be used to calculate the performance of the modulators.

LINEAR EQUIVALENT CIRCUIT

Fig. 1 shows a typical tunnel diode *I-V* characteristic.[1] The tunnel-diode modulators described herein operate in the region *A-B-C* of the characteristic. This region may be approximated by the first two terms of a power series:

$$i = G_O v - g v^2 \qquad (1)$$

Where: i and v = current and voltage variations, respectively, about the bias point; and G_o = dynamic conductance at the bias point.

Fig. 2 is a simplified schematic diagram of a tunnel-diode modulator. If sinusoidal voltages and small-signal conditions are assumed, the current-voltage relationships of the tunnel diode are given in matrix form as: (2)

$$\begin{bmatrix} i_m \\ -i_{c+m} \\ -i_{-(c-m)} \\ i_c \end{bmatrix} = \begin{bmatrix} G_o & 2gV_{-c} & 2gV_c & 0 \\ 2gV_c & G_o & 0 & 0 \\ 2gV_{-c} & 0 & G_o & 0 \\ 0 & 0 & 0 & G_o \end{bmatrix} \times \begin{bmatrix} V_m \\ V_{c+m} \\ V_{-(c-m)} \\ V_c \end{bmatrix}$$

Matrix 2 represents the current-voltage relationship of the tunnel-diode modulator, containing one equation for each frequency component of interest. The matrix shows a linear relationship between the currents and voltages of the tunnel diode at the frequencies ω_m, ω_c, and $\omega_{c\pm m}$. Therefore, a linear equivalent circuit can be constructed which represents the tunnel-diode modulator. This linear equivalent circuit (Fig. 3) makes it possible to apply the well-developed linear-circuit techniques to a modulation process that is inherently nonlinear. Note that in agreement with the physical picture, the input and output voltages are mutually coupled by the carrier voltage.

Through linear-circuit analysis techniques, the performance criteria of the tunnel-diode modulator are as follows.

Input Admittance:

$$Y_{in} = G_o - \frac{2\,(\Delta G)^2}{G_o + G_L} \qquad (3)$$

Output Admittance:

$$Y_{out} = G_o - \frac{2\,(\Delta G)^2}{G_o + G_g} \qquad (4)$$

Voltage Gain:

$$A_v = \frac{V_{c\pm m}}{V_m} = -\frac{\Delta G}{G_o + G_L} \qquad (5)$$

Power Gain: (6)

$$A_p = \frac{8 G_g G_L\,(\Delta G)^2}{[(G_o + G_g)(G_o + G_L) - (\Delta G)^2]^2}$$

Where: ΔG = change in the tunnel-diode conductance introduced by the carrier swing, and G_g, G_L = generator and load conductances, respectively.

SUPPRESSED-CARRIER MODULATION

The single-tunnel-diode circuit can give suppressed-carrier modulation. In Fig. 1, the region *A-B-C* is very nearly parabolic. The even symmetry can be further enhanced by choosing the proper value of the load resistor. For the 1-ma tunnel diode used, a 27-ohm load resistor was found to yield the optimum curve.

Suppressed-carrier modulation is achieved by biasing the tunnel diode at the peak of the *I-V* curve. Note that at the peak there is 1) *zero conductance* (i.e. zero slope), and 2) *even symmetry about the peak.* When the tunnel diode is biased at the peak of its *I-V* characteristic, its dynamic conductance, G_o, is zero. It can be seen from matrix 2 that when G_o = 0, no current flows at the carrier frequency. The even symmetry is important in order to avoid a carrier-frequency current component due to odd higher-order curvatures.

Fig. 4 is a schematic of a single-tunnel-diode suppressed-carrier modulator which was built. The measured side-band-to-carrier ratio at the output was 40 db with a gain of about 2 db. The carrier level at the output is about 70 db below that at the input.

BALANCED MODULATION

Fig. 5 is a simplified schematic diagram of a tunnel-diode balanced modulator. Proceeding in the same manner as for the single-tunnel-diode modulator, but taking the output current as the difference between the currents of the individual tunnel diodes, the current-voltage relationships are in the form: (7)

$$\begin{bmatrix} i_m \\ -i_{c+m} \\ -i_{-(c-m)} \end{bmatrix} = \begin{bmatrix} 2G_o & 4gV_{-c} & 4gV_c \\ 4gV_c & 2G_o & 0 \\ 4gV_{-c} & 0 & 2G_o \end{bmatrix} \times \begin{bmatrix} V_m \\ V_{c+m} \\ V_{-(c-m)} \end{bmatrix}$$

This matrix is identical to matrix 2 except that G_o is replaced by $2G_o$, and g by $2g$. Note that the carrier component of current is zero even though the tunnel diodes are not necessarily biased at the peak. This is because the two tunnel diodes were assumed to be identical and biased at the same point, the usual manner of achieving suppressed-carrier modulation with other devices.

Fig. 6 is the linear equivalent circuit representing matrix 7. The performance equations for this modulator are:

Input Admittance:

$$Y_{in} = 2G_o - \frac{2\,(2\Delta G)^2}{G_L + 2G_o} \qquad (8)$$

Output Admittance:

$$Y_{out} = 2G_o - \frac{2\,(2\Delta G)^2}{G_g + 2G_o} \qquad (9)$$

Voltage Gain:

$$A_v = - \frac{(2\Delta G)}{G_L + 2G_o} \qquad (10)$$

Power Gain: (11)

$$A_p = \frac{8G_gG_L\,(2\Delta G)^2}{[(G_g + 2G_o)\,(G_L + 2G_o) - (2\Delta G)^2]^2}$$

RING MODULATION

The tunnel-diode balanced modulator described above acts as a ring modulator, if the tunnel diodes are biased at the peak of the *I-V* characteristic.

The current is an even function of voltage when the tunnel diode is biased at the peak of the *I-V* curve and the load resistor is properly chosen. Therefore, the *I-V* curve can be expressed as a power series:

$$i = \sum_{n=o}^{\infty} a_n V^n \qquad (12)$$

Where a_n is related to the nth derivative (n even) at the operating point and V is the voltage across the tunnel diode. The output current is the difference between the currents of each tunnel diode and may be expressed in the form of a series with the nth term given by: (13)

$$i_n = 2a_n \left[nV_c^{n-1} V_m + \frac{n(n-1)(n-2)}{3!} V_c^{n-3} V_m^3 + \cdots + \cdots + \frac{n!}{(n-r)!r!} V_c^{n-r} V_m^r + \cdots \right]$$

Where: r is always an odd integer as a result of the balanced circuit arrangement. Since n is an even integer as described above, $(n\text{-}r)$ is always odd. If this term is expanded (recalling that V_c and V_m are sinusoidal), then the only terms appearing at the output are odd-order sidebands spaced around odd multiples of the carrier frequency. This is tantamount to ring modulation, which is normally accomplished with four nonlinear elements in a bridge-type arrangement.[2]

The physical picture of this ring-modulation process may be conceived in the following manner: When a tunnel diode is biased at the peak of its *I-V* characteristic, it has some properties of a balanced circuit, as seen in reference to its carrier-suppression capabilities. Two such circuits in a balanced arrangement are, therefore, equivalent to a double balanced arrangement—another expression for ring modulation.

In the tunnel-diode ring modulator that was constructed, the sideband-to-carrier ratio measured was 50 db. The second-order sidebands were 62 db below the primary sideband level, and the second harmonic of the carrier was 40 db lower than for the single-tunnel-diode modulator.

CONCLUSIONS

A single tunnel diode, biased at the peak of its *I-V* characteristic, offers a 40-db sideband-to-carrier ratio — normally achieved by a pair of matched nonlinear active elements.

Ring modulation is accomplished with two tunnel diodes in a balanced circuit, both diodes being biased at the peak of their *I-V* characteristics—normally achieved by four nonlinear elements in a bridge arrangement. If the tunnel diodes are equally biased, but not at the peak, only balanced operation is obtained.

Both modulators require low carrier and modulating power when biased at the peak of their *I-V* characteristics, where $G_o = 0$. This makes them suitable for low-signal-level applications. The power-handling capability of the modulators is rather low for the 1-ma tunnel diode (IN2939) used; however, it could be increased by using tunnel diodes with higher peak-current characteristics.

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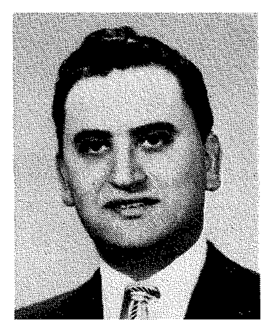

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NEURONS AND NEURAL NETWORKS

M. B. HERSCHER, T. B. MARTIN, E. P. McGROGAN, and F. L. PUTZRATH

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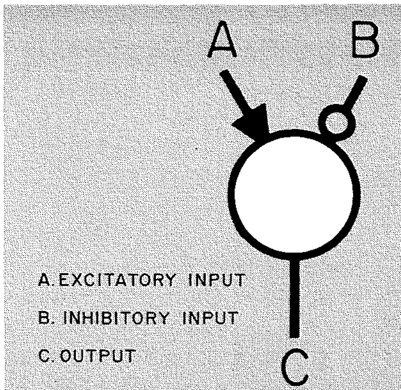

Fig. 1—The neuron symbol.

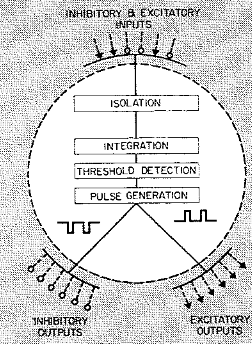

Fig. 2—Functional diagram of the neuron model.

In the new field of bionics—the application of knowledge of biological systems to engineering problems—an important effort is the simulation of nerve cells and their processes through electronic neurons and neural networks. Current progress suggests that this approach will lead to an array of discerning and adaptive devices with "intelligence" far beyond anything familiar today. Summarized herein (with a selected bibliography included) are some of the findings of DEP Applied Research regarding the logical capabilities of artificial neurons and the design and function of these cells in speech and visual pattern-recognition networks.

UNTIL THE last decade or so, man's technological progress has paralleled his inventiveness in assembling purely mechanical devices to perform his work. Then, with the computer came the transition to devices that could respond to instructions and render decisions on complex problems. Labeled "brains" in the vernacular, these machines imitate in crude fashion some of the thought functions of man and so display "intelligence." Now, to meet ever more complex and difficult problems on the earth and in space, man is driving toward the perfection of electromechanical servants *with a much higher order of intelligence.*

One of the most fascinating, promising approaches to the design of this new family of servants is through bionics (from Greek *bion,* meaning unit of life). Basically, bionics is the application of our knowledge of biological systems to the solution of engineering problems. This, for the first time, makes physiologists, neurologists, psychologists, chemists, physicists, mathematicians, and specialist engineers partners in a common effort.

Varied attacks on the problems of duplicating human capabilities in electromechanical systems are underway. One, the study of elemental pattern recognition by animal sensory systems, is being pursued by DEP Applied Research. Electronic *neurons* (simulated nerve cells with *all* their processes) and neural networks have been designed and in tests have demonstrated simulation of the simplest neurological patterns.

THE NEURON

One of the significant discoveries regarding the functioning of biological systems is that spatial and temporal modifications of the stimuli impinging upon the primary transducers in the recepter organ are performed *almost immediately and entirely apart from* the higher functional centers of the brain. These modifications are not distortions, but rather are accentuations of significant features of the stimulus pattern. That is, feature abstraction forms an integral part of the recognition processes of biological systems.

To reproduce the type of progressive selection demonstrated by its natural counterpart, the artificial neuron is a signal-processing device that is digital, analog, and temporal in nature. The neuron is digital in the sense that the integrated sum of the inputs is either above or below threshold, and consequently, the neuron is either firing or not firing. The analog properties result from the fact that both the inputs and the threshold setting are analog quantities. The output, although consisting of standard pulses, when integrated, is an analog quantity that depends on either the repetition rate or the number of pulses in a pulse train. The temporal properties result from the fact that the output is not only a function of the present input, but also a function of the previous inputs—the more recent ones being more significant than the remote ones. In this respect, the neuron is a sequential as well as a combinational logic element.

The basic element of nerve networks is the neuron denoted by the symbol shown in Fig. 1. Fig. 2 is a functional representation of the neuron; two types of inputs are indicated, *excitatory* and *inhibitory.* The neuron either fires or doesn't fire according to whether the summation of the two types of inputs exceeds a threshold value. After firing, the threshold value rises instantaneously to a very high value and exponentially decays to the original value. This is referred to as *refractoriness.* The output is a train of pulses of fixed amplitudes and duration. The frequency at which these pulses occur is a measure of how much the net excitation exceeds the threshold. The summation process at the input corresponds to an integration of the pulses present.

APPLIED RESEARCH NEURON MODEL

The model (Fig. 3) developed by DEP Applied Research simulates the functional properties of the biological neuron as closely as possible.

The inputs are summed into the low input impedance of a common base transistor Q_1, thereby achieving effective isolation between inputs. The integration network is in the collector of the common base stage, and the integration time constant is, therefore, independent of the input summing resistors. When the integrator signal exceeds the threshold of the following transistor Q_2, the threshold transistor fires and triggers the complementary monostable multivibrator, Q_3 and Q_4. Both outputs of the multivibrator are quiescent at zero volts. When the multivibrator fires, a positive pulse is generated at the excitatory output and a negative pulse is generated at the inhibitory output. The output pulses are clamped in the high-voltage stage to provide a low-impedance output and, thus, an output amplitude that is independent of loading. The firing rate will increase as the input signal is increased until the output duty cycle approaches 100 percent. A resistor feedback connection between the positive output and the collector of Q_2 makes the circuit absolutely refractory during the period of the output pulse. A relative refractory period is forced by the capacitor and parallel resistance in the collector circuit of Q_2.

The input-output characteristics of the neuron model are summarized in Fig. 4. The normal characteristics (Fig. 4a) show that the input-output relationship is a nonlinear function. It can be thought of as a combination of both digital and analog functions. The digital property is intrinsic to the two possible states,

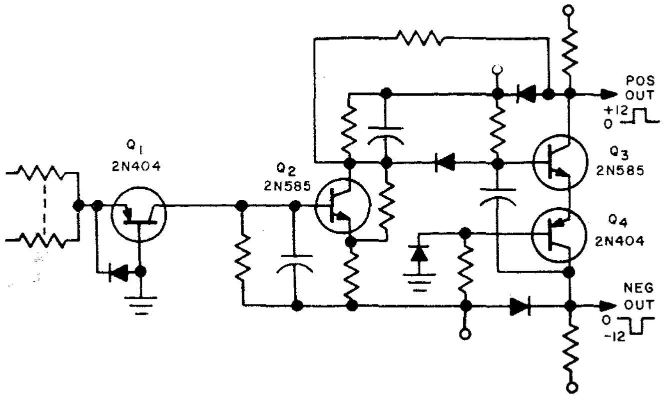

Fig. 3a—A circuit diagram of the neuron model.

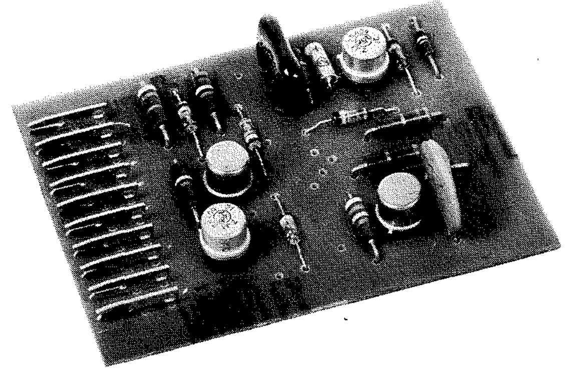

Fig. 3b—Experimental neuron model.

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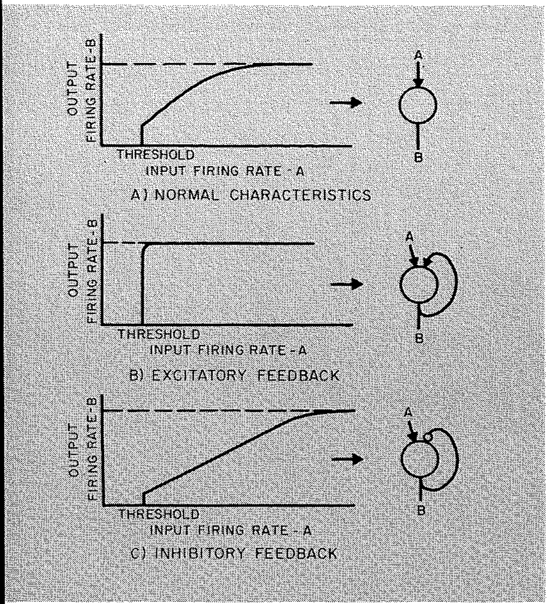

Fig. 4—Input-output characteristics of the neuron model.

either firing or nonfiring. The analog property is the rate of firing together with the threshold setting. Variations in the standard response can be achieved as shown in Fig. 4b and 4c. The maximum firing rate can be achieved very rapidly by providing an appropriate amount of excitatory feedback. As a matter of fact, the feedback can be increased to the point where a sustained firing rate is maintained once an external excitation is delivered. An inhibitory input can then be used to return the neuron to the quiescent state. The firing rate can be made a nearly linear function of the input signal by inhibitory feedback.

BASIC NEURAL NETWORK PROPERTIES

The basic properties that can be incorporated into more complex networks will demonstrate the capabilities of neural networks. The properties to be described have all been used in experimental studies performed by Applied Research in the past three years. (Although not shown, weighted input connections will be assumed in the network descriptions.)

Mutual Inhibition

Enhancement of small differences between two quantities *A* and *B* can be achieved by the mutual-inhibition connection shown in Fig. 5a. Assume that both *A* and *B* are either DC quantities or are output pulses from two other neurons. The mutual, partial-inhibition connection widens the difference between *A* and *B*. If *A* is only slightly larger than *B*, the output *A′* is much larger than *B′*. The result is such that small differences in *A* and *B* can be magnified, thereby providing the very useful function of contrast enhancement.

AND Function

It is difficult to achieve the neural-network analogy of the digital *and* function (multiplication) with a simple threshold device because the input signals have a range of values. An output is desired when both input signals are present, even though their amplitudes are very small; conversely, no output must occur when only one large-amplitude input signal is present. The combination of a threshold device plus the inhibition property can be used to achieve the *and* function (Fig. 5b). The inhibition connections to *3* from *1* and *2* are made lower-resistance connections than the excitatory inputs from *A* and *B* to *3*. As a result, a single excitatory input cannot cause *3* to fire. However, the cross-inhibition inputs to *1* and *2* from *A* and *B* are sufficient to cause *3* to fire if *A* and *B* are both present. The symbol for this network function is the normal neuron symbol with a dot inside the circle (Fig. 5b).

On-Off Response

Fig. 6 shows the *on-off* response that has been found to exist in biological nerve networks. Certain neurons are known to respond only to changes within a receptor field. The *on* response is typified by an initial burst of pulses that occurs at the onset of the input signal, followed by a diminishing firing rate which eventually ceases altogether. A similar *off* response occurs upon the cessation of an input signal. The firing rate tells how long ago a particular event occurred. This type of response has been achieved experimentally and can be useful in the time-pattern recognition, since it indicates changes in the environment and provides a measure of how long ago the change occurred. Many variations of the two basic responses are possible and can be used to achieve novel network functions.

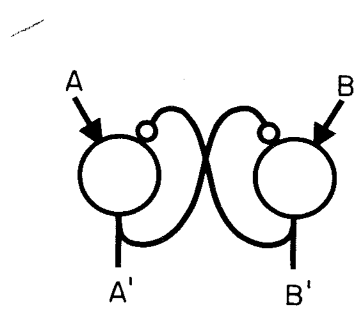

Fig. 5a—A mutual inhibition connection for a basic neural network.

APPLICATION TO SPEECH PATTERN RECOGNITION

Human speech is a series of complex acoustic waves modulated by tonal qualities of the speaker and is made intelligible by the unique way the human ear converts acoustic energy into neural signals. The initial transformation of auditory patterns to neural signals in the biological hearing system is performed by the *cochlea,* a snail-shaped organ in the inner ear, and the first level of neurons. This transformation has many nonlinear characteristics that result in neurophysiological and psychoacoustic effects such as masking, equal loudness sensation, etc.

The initial transformation of the auditory pattern into neural signals can be modeled through the use of a simulated cochlea and artificial neural networks. The mechanical movement of the cochlea and the corresponding microphonics closely resemble the characteristics of a distributed low-pass structure. These effects can be approximated by the RLC transmission line shown in Fig. 7. Several levels of artificial neurons are connected to the transmission line to accomplish the desired preprocessing. The primary neurons are excited or inhibited by the signal voltages impressed upon the distributed line; the secondary neurons are stimulated by the primary row. The neurons near the input end of the distributed line are excited by the total energy of the acoustic spectrum while those neurons close to the end of the line are excited only by the lowest frequency components of the incoming speech pattern.

Space-Energy Pattern Abstraction

Having transformed one part of the input, namely frequency, into linear space, the system must be able to abstract various features from acoustic patterns. The experimental networks that have been developed for this purpose have been limited to operations in the two domains *linear space* and *energy.* The time domain has been given only preliminary consideration. The net-

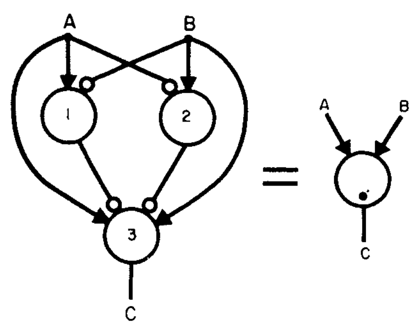

Fig. 5b—AND function for basic neural network showing combination of a threshold device and the inhibition property.

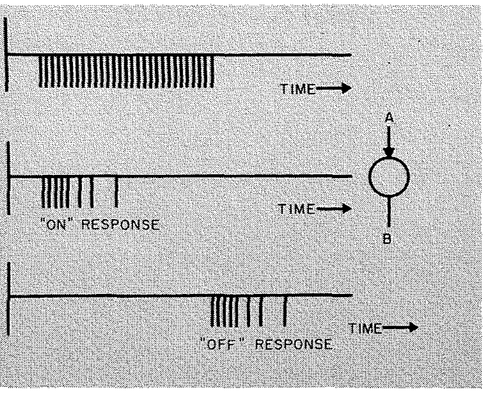

Fig. 6—ON-OFF response existing in biological nerve networks.

work for the first stages of combined-energy pattern abstraction is shown in Fig. 8.

Five of the inputs to the primary neurons from the cochlea model are shown in Fig. 8, although a larger number is necessary to cover the entire speech spectrum. The primary row of neurons is mutually inhibited, in order to enhance small differences in adjacent channels. The second level of neural processing selects the larger output of two neighboring neurons. The notation inside the individual neurons states the conditions for firing. From the information contained at this level of processing, it is possible to abstract from the input pattern the location along the linear input space of the local maxima, minima, positive, and negative slopes. An example of each of these properties is shown in the final levels of Fig. 8. The local maximum shown occurs if $1 < 2 > 3$, the local minimum if $1 > 2 > 3$, the positive slope if $3 < 4 < 5$, and the negative slope if $1 > 2 > 3$.

Also shown in Fig. 8 is a network using the *on-off* responses to indicate when the location of a local maximum shifts from the position of neuron *2* to neuron *3*. This type of connection can be used to indicate the local transmissions of the maxima, minima, and slopes, and actually involves operations in the three domains of time, space and energy. Recognition of simple vowels and some consonants has been achieved with networks similar to that shown in Fig. 8. The further development of these speech recognition techniques is now being carried out under a Government contract.

APPLICATION TO VISUAL PATTERN RECOGNITION

In the near future, a large amount of visual data will be available from satellite reconnaissance and surveillance vehicles, weather satellites, etc. This influx of data will require the development of automatic equipment that can process such data in a preliminary manner. By screening the input material, only the most important data will have to be transmitted and/or analyzed in greater detail.

The problem of recognizing visual patterns is extremely complex and is quite different from the recognition of alphanumeric characters in document or card readers where type font, size, and orientation are normally known. In the general pattern-recognition problem, the pattern may be positioned anywhere in the field of view and may be in any orientation; therefore, it is quite important that automatic recognition equipment be capable of recognizing objects irrespective of orientation. The use of simulated neurons and parallel processing techniques would allow for automatic visual recognition *regardless* of position and orientation of the object.

One of the difficulties investigators encounter in pattern recognition is the necessity of describing the characteristics or features of patterns. In many schemes of pattern recognition, patterns are classified or reduced to such features or characteristics as the number of corners, intersections, line lengths, and radii of curvature. Many difficulties arise when the patterns are not simple geometric shapes and cannot be classified simply. Since there can be many variations of basic patterns, a different name for each pattern or a different list of features requires a very large language and memory. Thus, a semantic problem is encountered in describing abstract patterns.

To avoid this problem, Applied Research has conceived a technique which does not require the listing of features or patterns. Instead, information can be abstracted from the original pattern based on the manner in which the pattern itself is interconnected. By a spatial arrangement of logic elements, the original pattern is rearranged in a manner dependent on its over-all properties. This rearranged information can then be compared with similar information obtained from a standard, or reference, pattern.

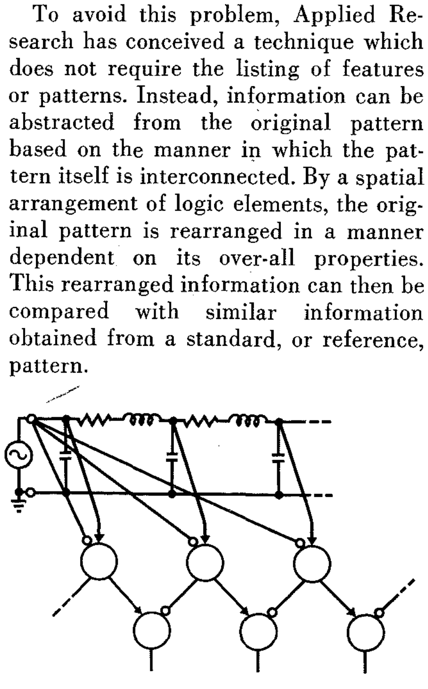

Fig. 7—RLC approximation of cochlea frequency discrimination and loudness sensation.

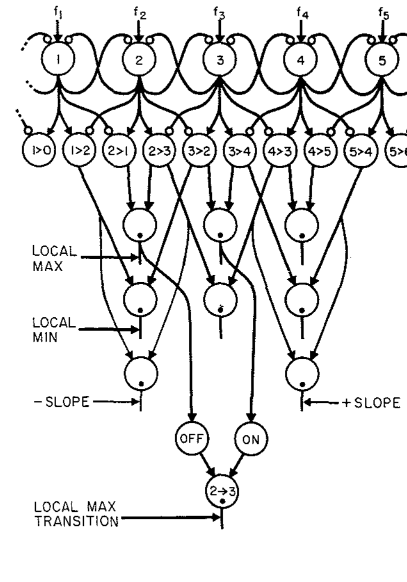

Fig. 8—Network for first stages of the combined-energy pattern abstraction.

In many cases, in spite of the variations in the basic pattern, it is extremely desirable to be able to recognize the basic pattern in the face of all the various distortions and other operations performed. Although an ideal system could handle all of these variations, this would require extremely complex equipment. Many of these problems, however, can be handled by Applied Research's approach to pattern recognition.

The Animal Visual System

How can a pattern recognition system be developed that will be independent of translation and rotation? This can be answered by borrowing some of the principles of the human visual system.

Fig. 9 is a sketch of the retina and some of the functioning neurons near the retina. The receptor plane contains rods and cones which act to change the light energy impinging on them into electrical energy. As Fig. 9 illustrates, each neuron is *not* simply connected to each rod and cone. Instead, the neurons are interconnected in some form of neighborhood logic which is repeated throughout the structure, not only laterally but also in depth. As the transformation progresses through the various neural levels, the original input pattern is transformed. This process generates characteristic features by which the pattern can be recognized.

It is known that in many lower forms of animals a great deal of preprocessing takes place at or near the retina of the eye. In this manner, the original information is processed to extract the important characteristics of the pattern. For example, the frog extracts only four types of information from its field of view: edges, changing contrast, moving corners, and large-area dimming. From these characteristics, sufficient information is obtained to permit the frog to live and survive in its environment.

There is also fairly strong evidence that similar preprocessing occurs in the human visual system. A significant thing to note in Fig. 9 is that there are *less* output connections going to the visual cortex and higher nerve centers than there are input receptor (rods and cones) elements. This is further evidence that some form of preprocessing does occur in this region. One other interesting observation is that although the neurons appear to be randomly interconnected, there is a specific ordering.

Simulated Visual System

It is possible then to synthesize this parallel processing through the use of simulated neurons performing neighborhood logic. Fig. 10 is a simplified conception of a simulated neural system to accomplish these transformations. In this case the receptor plane might consist of photocells, photoconductors, or some other transducer which will transform light into electrical energy. Each of these receptor elements is connected to simulated neurons. Each neuron in turn has weighted connections from its surrounding neurons. The surrounding neurons might consist of the first (i.e., nearest) ring, the second ring, etc., depending upon the extent of interaction desired. Thus, the firing rate of each neuron is also affected by the firing rate of its surrounding neighbors. The weighted connections can be made to be either excitatory, inhibitory, or zero. In this manner, an effect can be obtained from the neighborhood neurons which may increase or decrease the firing rate of the central neuron or leave it unaltered. In addition, these weights may be fixed or may consist of adaptive elements which will permit a dynamic change of weighting, as desired.

Applied Research has carried out computer programs which simulated neural logic for visual pattern recognition and, under a Government contract, is now building an experimental model of the frog's eye that will have the feature abstraction capabilities of the living organism. (This work is based upon concepts originally advanced by E. E. Loebner of the RCA Laboratories.)

CONCLUSIONS

Progress in the study of biological neurons and successes in the laboratory simulation of the behavior of biological neurons suggest that in time man will have at hand an array of discerning and adaptive devices far beyond anything available today. But beyond the purely utilitarian aspect of this movement into bionics is the remote promise that the replacement of defective organs such as ears and eyes by electronic organs will become commonplace.

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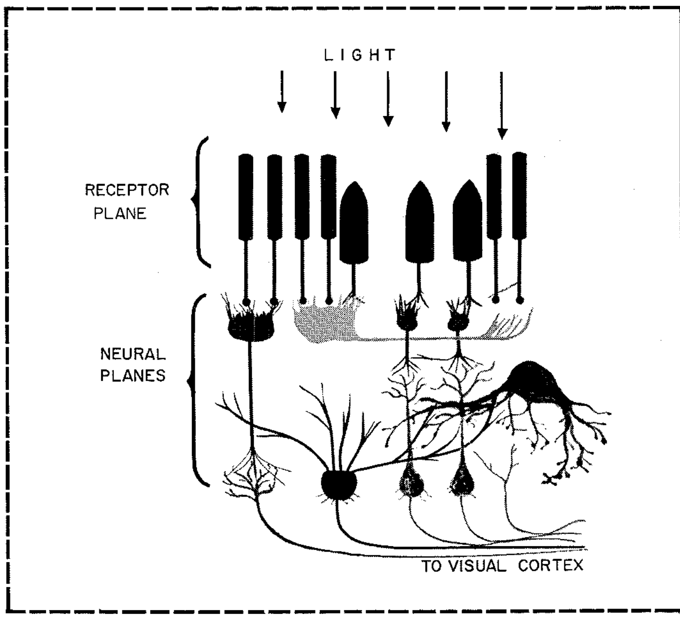

Fig. 9—Diagrammatic presentation of an animal retina.

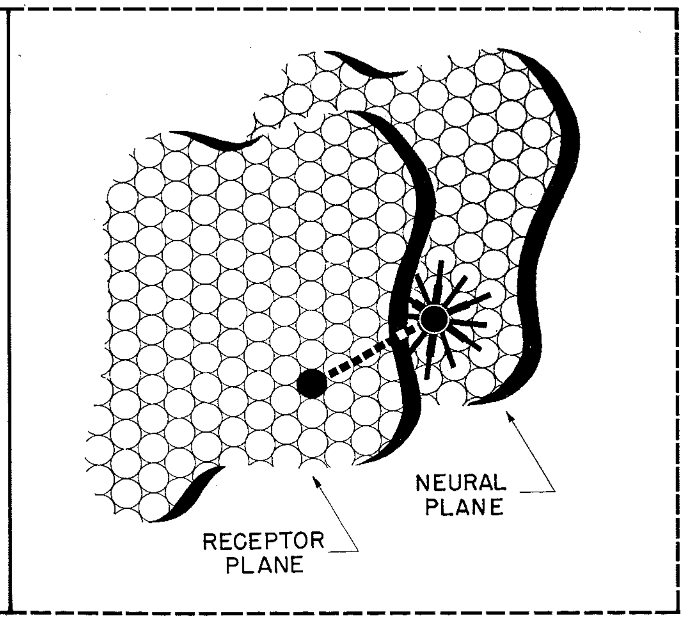

Fig. 10—Simplified version of a simulated neural system.

THE DARK HEATER ... Major Advance in Tube Technology

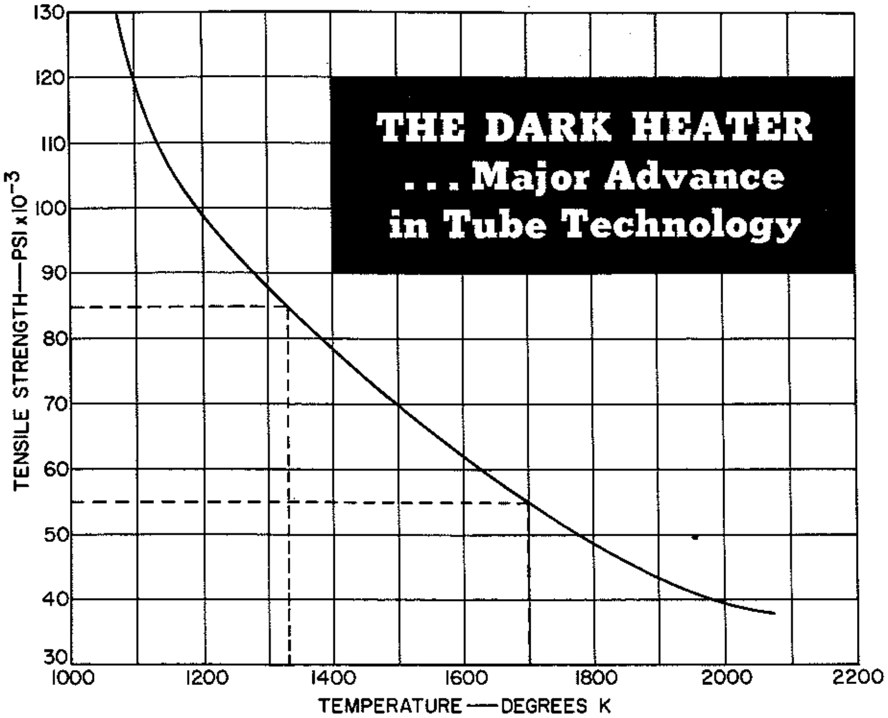

Fig. 1—Strength vs. temperature of tungsten heater wire. Dashed lines show effect of lower operating temperature of dark heater (1350°K) and conventional heater (1700°K).

Development of the dark heater has reduced operating and processing temperatures of the electron-tube heater so significantly that important improvements in life and reliability have been achieved. Change-over to the dark heater is well under way, with a goal of 100-percent utilization.

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Tube Materials and Techniques

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Current-Product Receiving-Tube Design

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For proper operation of electron tubes, it is necessary to maintain the emissive surface of the cathode at a temperature of approximately 1050°K to provide sufficient electron emission. This temperature is usually achieved by resistance-heating of a tungsten wire placed inside the cathode sleeve and electrically insulated from it with a layer of aluminum oxide. The insulation between the heater wire and the cathode sleeve prevents the heater from interfering with the relatively small signals at which the tube operates.

Because good electrical insulators such as aluminum oxide are generally also good thermal insulators, the heater wire is often operated at temperatures as high as 1900°K to provide sufficient thermal gradient to drive the required power into the cathode. During tube processing, heater temperatures may even approach the melting point of the aluminum oxide coating (about 2300°K).

Such high temperatures are a major cause of heater failure in tubes. Because the thermal expansion of the insulating coating is greater than that of the tungsten wire, strains are produced in the heater. At these high temperatures, the physical properties of tungsten are seriously degraded (Fig. 1), and sustained operation may embrittle the wire and cause further loss of strength.

These considerations led to development work on heater materials and design, with the objective of lowering operating and processing temperatures. The resultant *dark heater*, described herein, has achieved this important breakthrough in electron-tube technology, with significant improvement in tube life and reliability.

TRANSFER OF HEAT BY RADIATION

Because electron-tube heaters are usually a series of folds of straight wire or some coiled configuration, there are very few points of contact with the cathode, and heat transfer by conduction is a minor part of the total heat-transfer mechanism. Most of the heater power is transferred to the cathode by radiation from the coated surface of the heater.

The amount of heat radiated from the surface of a body at a given temperature is (Stefan-Boltzmann fourth-power law):

$$P_r = 5.67\, \varepsilon A T^4 \times 10^{-12} \qquad (1)$$

Where: P_r = heat power radiated, watts; ε = total emissivity of the radiating surface; A = area of radiating surface, cm²; and T = temperature of the radiating surface, °K.

In the transfer of heat between heater and cathode, however, the total radiated power P_r is not completely absorbed by the shiny inside wall of the cathode. If it is assumed, for simplicity, that the transfer is similar to the case of one long cylinder enclosed by another, then the heat transfer is:

$$P_t = \frac{5.67\, A_H\, (T_H^4 - T_K^4)}{\frac{1}{\varepsilon_H} + \frac{A_H}{A_K}\left(\frac{1}{\varepsilon_K} - 1\right)} \times 10^{-12} \qquad (2)$$

Where: P_t = power transferred, watts; A_H = effective radiating area of the heater; T_H and T_K = temperatures of the heater and the cathode, °K; ε_H = total emissivity (effective) of the heater; A_K = inner surface area of the cathode; and ε_K = total emissivity of the inner cathode surface. Although Eq. 2 does not represent the actual geometry of the heater-cathode configuration, it serves to illustrate the general nature of the heat-transfer process—that if the emissivity of the heater ε_H is low, the heater temperature T_H must be high to provide a given power P_t.

The amount of power required for tube operation is determined by the temperature and dimensions of the cathode. The heater temperature required to provide this power is determined by the efficiency of heat transfer,

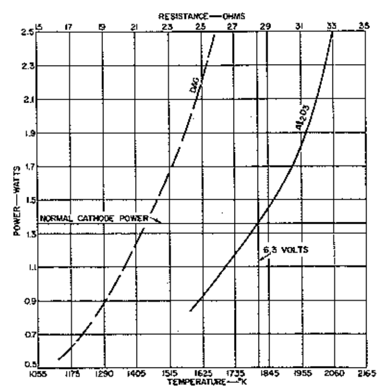


Fig. 2—Heater operating temperatures of the 6EA8, with conventional (solid curve) and dark (dashed curve) heaters.

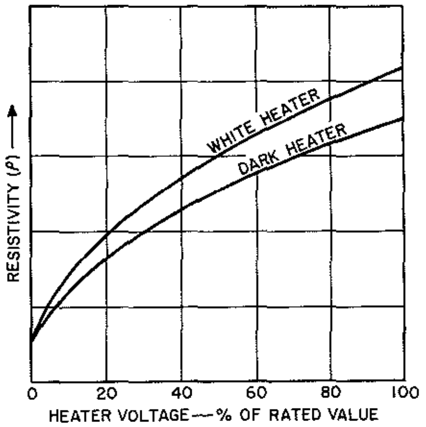


Fig. 3—Heater voltage vs. resistivity.

i.e., by the thermal-emission capabilities or the heater emissivity ε_H. The emissivity ratio of an aluminum oxide insulating coating is generally less than 0.2; i.e., the coating radiates less than 20 percent of the heat that would be radiated by a hypothetical perfect black body of the same shape and size at the same temperature. If this emissivity ratio can be increased, the required amount of power can be transferred to the cathode at a lower heater temperature.

DARK-HEATER COATING

Initial tests established that sizable reductions of heater temperature could be obtained by blackening the heater with graphite. At a given heater voltage, tubes having such dark heaters drew considerably more heater current than tubes using conventional heaters. Thus, the dark heater tubes had a greater input power (voltage × current) or heat transfer from heater to cathode, as well as a lower heater resistance (voltage ÷ current). Because the resistance of tungsten varies almost linearly with temperature, the dark-heater tubes provided the greater power at a lower heater operating temperature.

Although graphite was used in the initial tests to demonstrate the principles involved, it is a poor darkening material for heaters because of its tendency to oxidize and produce gas. A search was made for more suitable dark materials, but no thermally dark materials were found which were also good electrical insulators at the high operating temperatures of electron-tube heaters. Attempts were then made to darken the heater with materials that were electrically conducting but chemically stable at high temperatures. The dashed curve (dag) in Fig. 2 shows the lower operating temperature achieved when the 6EA8 heater was coated with a lampblack mixture.

The use of these conductive materials was not completely satisfactory, however, because of leakage problems. Therefore, nonconductive darkening materials were developed and tested. The nonconductive material was deposited by spraying, dipping, or cataphoretic coating. Although somewhat lighter in color, these coatings achieved most of the temperature reduction of conductive coatings, but without the electrical leakage problems.

DARK-HEATER DESIGN

Because dark heaters operate at a lower temperature than conventional heaters to provide a given amount of power, the dark heaters have a lower resistivity (Fig. 3). Heater dimensions must be changed, therefore, to provide the specified heater current at the normal tube voltage. When a tube type is converted from conventional to dark heaters, the tungsten heater wire must be made longer or thinner, or both, until the resistance of the dark heater at rated heater input is comparable to that of the conventional heater. Fig. 4 shows voltage-current curves for dark heaters and their conventional counterparts; the curves are essentially congruent.

Although the heater-operating temperature is greatly reduced in dark-heater tubes, the cathode temperature remains essentially constant. In some cases, cathode temperature may even rise slightly because of reduced end-loss effects resulting from the smaller heater-wire size and the reduced operating temperature. Fig. 5 shows the relationship between heater and cathode temperatures in dark-heater and conventional-heater tubes.

INCREASED HEATER STRENGTH AND RELIABILITY

The relative tensile strength of tungsten heater wire increases by more than 50 percent when the operating temperature is reduced from 1700 to 1350°K (Fig. 1). However, this increased strength is only part of the story of increased heater reliability.

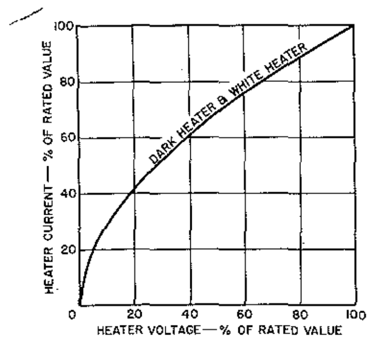


Fig. 4—Heater voltage-current characteristics, showing congruency of conventional and dark heaters.

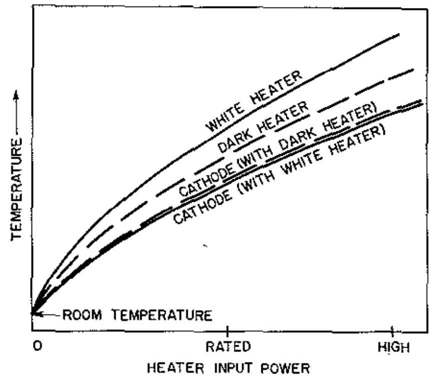


Fig. 5—Effect of heater input power on heater and cathode temperatures.

Heater failure in electron tubes may be caused by "invisible opens", actually fractures of the tungsten wire inside the insulating coating without a consequent fracture in the coating itself. These fractures are caused by the dissimilar thermal-expansion properties of the wire and the coating. Differential expansion and resulting heater growth can also cause bare heater apexes to short to each other or to the cathode. Because this expansion is temperature-dependent, the differential between the tungsten wire and the insulating coating is minimized at the lower operating temperature of the dark heater. Furthermore, the tensile strength of the wire increases more than that of the coating at the lower operating temperature. Consequently, the two are better able to withstand any differential expansion that occurs as the heater is brought up to operating temperature.

The increased reliability of the dark heater has been demonstrated by life tests on thousands of dark-heater tubes of many different types. Data have been accumulated for over a million hours of life test under a wide variety of operating conditions. Fig. 6 shows the results of accelerated life tests run at 143 percent of rated heater voltage E_f (9 volts for a 6.3-volt type), a high value of heater-cathode voltage E_{hk}, and an operating cycle of 1 minute on and 2 minutes off. After 500 hours, the dark-heater tubes showed an improvement of almost 20 to 1 over conventional tubes as regards heater-associated defects. Percent-survival figures for the dark-heater tubes were 99 percent at 500 hours and 94 percent at 1000 hours—as compared to 80 percent at 500 hours and 63 percent at 1000 hours for the conventional control tubes.

Earlier studies of life-test acceleration factors indicate that 500 hours (16,000 on-off cycles) under the conditions described above correspond to approximately 14,500 hours of operation at rated heater voltage as far as heater-associated defects are concerned. The data shown in Fig. 6 were obtained on more than 25 different tube types. In other tests which compared dark-heater tubes with conventional tubes from various manufacturers, similar results were obtained.

OTHER PERFORMANCE ADVANTAGES

Dark heaters have many other advantages which contribute to a new standard of reliability in electron tubes. The lower temperature of the dark heater provides an added safety factor in the heater-cathode voltage ratings. In addition, the dark heater reduces leakage and hum, particularly *spike leakage* —a very sharp peak of leakage current, or spike, superimposed on the normal AC leakage waveform (Fig. 7a). Spike leakage is *completely eliminated* in dark-heater tubes (Fig. 7b).

Dark heaters also minimize a second form of hum and leakage caused by emission from the exposed portions of the heater to the grid structure. The amount of emission from the heater is reduced at the lower operating temperature, and the elimination of heater growth minimizes the portion of the heater exposed to the grid.

As an additional advantage, dark heaters withstand surge currents about 40 percent higher than conventional heaters can allow. Although both types of heaters have the same resistance at their operating temperatures, dark heaters have a higher resistance at room temperature because of their smaller-diameter base wire. Consequently, their ratio of hot to cold resistance is smaller and their current-surge capability greater. This advantage is especially significant in series-string applications, where high snap-on surges are applied to the heaters of the tubes in the string.

Another benefit is heater-current stability during life. In conventional tubes, increasing cathode emissivity during operation increases the heat transfer, which cools the heater, reduces its resistance, and increases heater current. An increase of 3 to 5 percent in heater input power after 1000 hours of operation at rated conditions is not unusual for conventional tubes. Dark heaters, on the other hand, are remarkably stable because of the lower operating temperature and chemical activity of the coating, which prevents the discoloration on the inside of the cathode that raises its emissivity. Dark-heater tubes evidence virtually no change in heater input after 1000 hours of operation (Fig. 8). The constant heater input-power of dark-heater tubes also tends to improve over-all electrical stability during life.

The dark heater also provides added flexibility in tube design and manufacture. All tubes are processed during and after the exhaust and sealing operations with high heater voltages, or *hot-shots*, for short periods of time to break down the emission carbonates on the cathode. In conventional tubes, it is sometimes difficult to process the carbonates properly because of the possibility of damaging the heaters during the high-temperature operation. Because dark heaters operate at much lower temperatures, they are able to withstand relatively high voltages with less chance of damage.

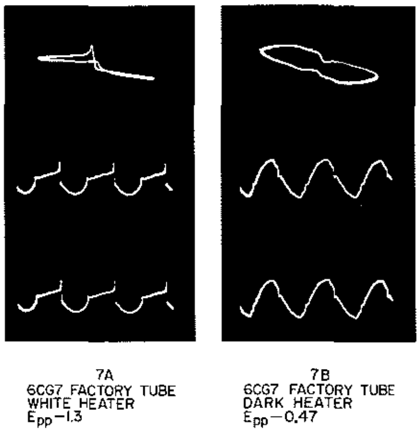


Fig. 7—AC leakage waveforms; a) spike leakage with conventional heater; and b) elimination of spike with dark heater.

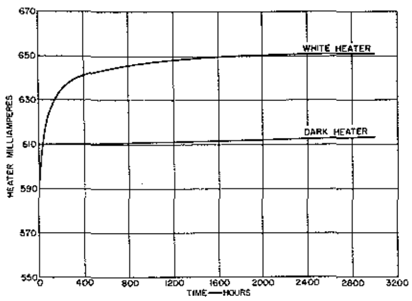


Fig. 8—Stability of dark-heater input.

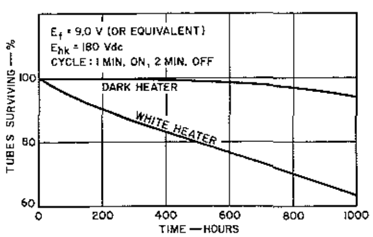


Fig. 6—Life test at higher-than-rated voltages, reflecting data on over 25 different tube types. Results were similar in comparison tests of RCA dark-heater tubes and conventional tubes from other manufacturers.

SUMMARY

The dark heater represents a significant technological breakthrough in electron-tube science. Its superiority over conventional heaters has been established through exhaustive laboratory tests which demonstrate a significant improvement in tube reliability. The already-impressive performance record of conventional electron tubes should be enhanced by the virtual elimination of heater failures as the dark heater achieves wide usage.

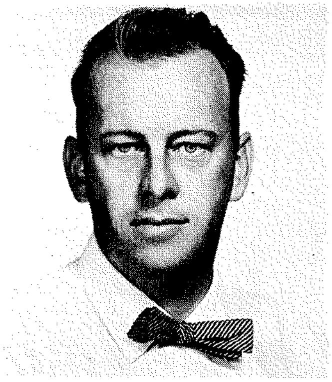
At present, more than 150 tube types are being manufactured with dark heaters, including all new types introduced by the ETD Receiving-Tube activity since 1961. Additional types are being added week by week, as progress is made toward the goal of 100-percent utilization of the dark heater.

JOHN CARRONA received his BSME from the Newark College of Engineering in 1950, and his MS in Metallurgy from Stevens Polytechnic Institute in 1958. Prior to joining RCA, he was Plant Manager for the North American Research Laboratory. He joined RCA in 1954 and since then has worked on the metallurgical problems relating to tube structures and materials, such as grid wires, plate and cathode materials, and glass sealing alloys. In 1959 Mr. Carrona was appointed an Engineering Leader of Tube Materials and Techniques. In his current work, he is concerned with product problems, particularly those related to cathodes and to sealing, exhaust, and aging cycles. Mr. Carrona is a Member of the IRE, Electrochemical Society, American Electroplaters Society, and Sigma Xi.

E. M. TROY received the BSEE from Rutgers University in 1948. He entered the RCA Specialized Training Program after graduation, and joined the Electron Tube Division as a Test Engineer in 1949. Starting in 1951, he served successively as Tube Rating Laboratory Supervisor, and Engineering Leader and later Manager of Test Engineering. Since 1959 he has been Manager of Receiving Tube Design—Current Product. In this capacity his responsibilities include the direction of engineering effort toward the solution of electron-tube performance and manufacturing problems and the introduction of improved design and processing techniques to tube manufacture. Mr. Troy is a Member of Tau Beta Pi, Phi Beta Kappa, and the IRE.

J. J. Carrona

E. M. Troy



DR. J. P. KEUPER received the BS in Physics from MIT in 1948, the MS in Physics from Stanford in 1949, and the Ph.D in Physics from the University of Virginia in 1952. Engaged as an Associate in Physics at the Carnegie Institution from 1949 to 1950, he was a Senior Research Physicist at the Remington Arms Co., Bridgeport, Conn., from 1952 until 1958. While at Bridgeport he served as Chairman of the Mathematics Department at Bridgeport Engineering Institute. He joined the RCA Service Company at the Missile Test Project as a physicist in 1958, receiving his present post as Manager, Systems Analysis, in 1960. He founded and became the first president of Brevard Engineering College in 1958.

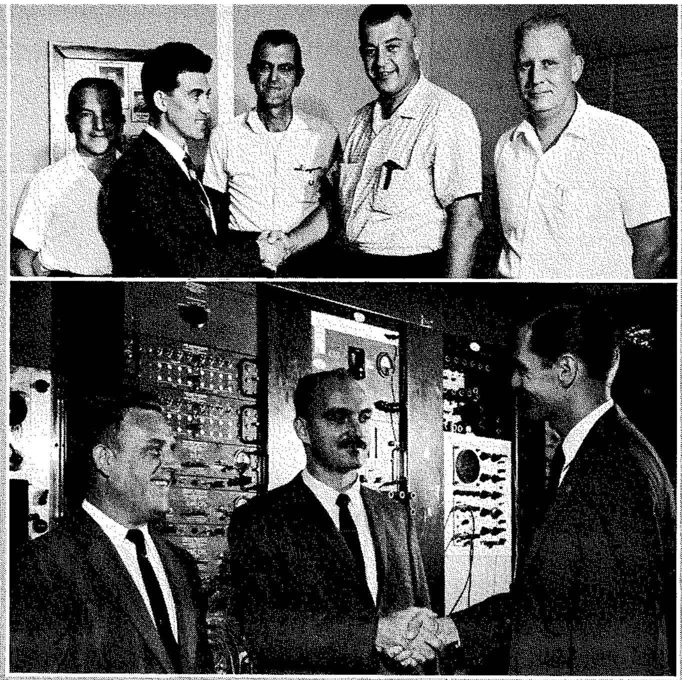


Fig. 2—RCA's first graduates of Brevard Engineering College are congratulated by members of RCA's MTP management. In the top photo, Blaine Sweatt, Jr. (second from right) Mgr. Engineering Support, is shown with G. D. Grosich, J. A. Vallee, E. D. Johnson and R. A. Work, Jr. In the lower photo, T. M. Farr, Jr. (center) is congratulated by C. R. Scott, Mgr., Data Processing. At left is Mr. Farr's supervisor, R. J. Fitzsimmons, Mgr., Data Reduction Maintenance.

BREVARD ENGINEERING COLLEGE

The unique Brevard Engineering College was started in early 1958 by a group of RCA Service Co. scientists to fill the need for high-level engineering education at the Cape Canaveral missile test site—where such opportunities were not available from conventional educational institutions. Now, with an enrollment of 450 and a faculty of 40, this privately supported college is an eminent success at its own 37-acre campus in Melbourne, Fla., offering undergraduate and graduate courses and degrees in many fields, and taking advantage of the high level of instruction available from the many eminent engineers and scientists working at Cape Canaveral.

Fig. 1—Artist's conception of permanent classroom facilities for the Brevard Engineering College at Melbourne, Fla., situated on 37-acre campus grounds.

Dr. JEROME P. KEUPER, Mgr.

Systems Analysis

Missile Test Project

RCA Service Company

Patrick Air Force Base, Fla.

A COMPLETELY new concept in engineering colleges is rising on Florida's east coast to meet the challenge of the space age. The new concept is the *Brevard Engineering College*, and the challenge is to provide high-level engineering education at a time and place that will not wait for conventional measures.

This new kind of college is forced to be unconventional in one sense but conforming in the other. History of the college dates back to early 1958 when VANGUARD I was orbited from Cape Canaveral. Almost unnoticed in the excitement, a small group of RCA Service Company scientists filed an application for a charter to start a college at their Missile Test Project site only a few miles south of VANGUARD's launch pad. Working and teaching evenings, they were soon joined by other missile scientists and engineers in the area. In the fall of 1958, the Brevard Engineering College was officially launched with 150 part-time students from the Air Force Missile Test Center.

NEW FACILITIES UNDERWAY

After frequent moves — from rented high-school classrooms to an old church, then to a World War II Navy Barracks — the college began construction of permanent classroom facilities on its own 37-acre campus in Melbourne, Florida (Fig. 1).

Already completed and fully utilized is a combination administration and classroom unit. Another building houses a modern library with over 3500 technical volumes which, in addition, boasts one of the most extensive collections of technical journals in the southeastern U.S.

A GROWING ORGANIZATION

In spite of skyrocketing educational expenses, Brevard Engineering College demonstrates that a private school—voluntarily supported by the community and by industry—can become a successful, growing organization. At present, nearly 450 students are enrolled, a third of them in the graduate school. Most of the students are employed at the Missile Test Center during the day. The faculty now numbers 40, and the faculty-student ratio of 1:10 is outstanding among the nation's colleges, especially considering Brevard's relatively low tuition rates.

RCA was the first contractor to approve the College for employee participation under the tuition loan and refund plan. Presently, all of the missile contractors at the Test Center approve the college for employee educational benefits, despite the fact that many of the companies have had to waive formal, rigid accreditation requirements. Full accreditation for Brevard Engineering College is expected in late 1963. *Brevard* is the name of the Florida County in which both the college and Cape Canaveral are located. (Florida's *Brevard Engineering College*, the subject of this article, is not connected with the Brevard College located in North Carolina.)

THE STAFF AND THE CURRICULUM

The students demand and get the best instruction in their particular fields. The college requires that each faculty member teach only that subject in which he has had extensive training and up-to-date experience. The majority of the faculty members are also employed by day at the Test Center.

Noteworthy also is the growing curriculum. Among the undergraduate courses offered are Chemistry, Physics, English, Labor Relations, Management Principles, Algebra, Calculus, Astronomy, AC Circuit Theory, Digital Computers, Circuit Theory of Electronic Devices, and Logic. Graduate courses include Advanced Calculus, Matrix Theory, Numerical Analysis, Network Synthesis, Logical Design of Digital Computers, Solid-State Electronics, Introduction to Space Technology, Rocket Propulsion, Guidance, Mathematical Physics, and Celestial Mechanics.

Although it was established primarily as an evening school of engineering, the college also offers day classes to fit the needs of regular students and those employed evenings. Day classes parallel the evening classes so that students may attend either throughout the year without conflict in regular employment schedules.

Two baccalaureate degrees are conferred—a Bachelor of Science in either Electrical Engineering or Mathematics. Graduate studies lead to Master of Science degrees in Space Technology, Applied Mathematics, Physics, and Electrical Engineering.

RCA EDUCATION COMMITTEE SUPPORT

This successful experiment in higher level education would not have been possible without the enthusiastic support of RCA and other companies represented at the Air Force Missile Test Center. Each year, RCA, through its Education Committee, has supported the college with generous grants and participating employees under the Tuition Loan and Refund plan. Other companies and organizations in the missile area have also made donations of funds and equipment. Some of the largest grants have been made by private individuals in the community.

SPECIAL ADVANTAGES OF BREVARD

Certainly, no one today questions the value of engineering education; nevertheless, it may be well to review the particular benefits of this college. From the standpoint of the students, Brevard Engineering College offers an invaluable opportunity to complete their education or reinforce it with the very newest knowledge in the technical field. It thus aids their professional advancement.

Industry and the community also benefit. The completion of college courses increases the efficiency and effectiveness of employees; many technical personnel choose to remain in areas where opportunity for professional academic advancement is provided. The college also provides an important aid to missile contractors recruiting technical employees for the area. Advanced education is also available to members of a community where no institution of higher learning previously existed.

High-caliber scientific personnel sometimes demand opportunities for part-time teaching as a necessary adjunct to their full-time industrial careers. It is this anomaly that makes it possible for the college to list among its instructors and administrative staff some of the top-level scientists and engineers in the country.

Undoubtedly the most important achievement of the college is the contribution now being made to America's growth in space technology. Education in space technology for scientists and engineers can best be secured *where problems occur and where they are being solved* at the nation's major missile development center.

Brevard Engineering College was planned and organized with foresight to meet a present need and to match its growth with the challenge of the future.

THE MM&SR ANTENNA SKILL CENTER
. . . A First-Year Report

Editor's Note: In the June-July '61 RCA ENGINEER, the formation of an Antenna Skill Center at the DEP Moorestown Missile and Surface Radar Division was announced. It now stands as one of RCA's major concentrations of technical capability in antenna work. (Another, for example, is located in the Broadcast and Communications Products Division in Camden, well known for their antenna design work for broadcast equipment, as well as specialized systems.) The MM&SR Antenna Skill Center is an organizational concept that integrates all the technical skills necessary—from research through fabrication—to achieve a flexible product capability in a complex, competitive field. It is one of five such integrated Skill Centers at Moorestown, the others being Signal Processing (described in the Feb.-Mar. '62 RCA ENGINEER), Transmitter, Radar Data Takeoff, and Design Support and Integration.

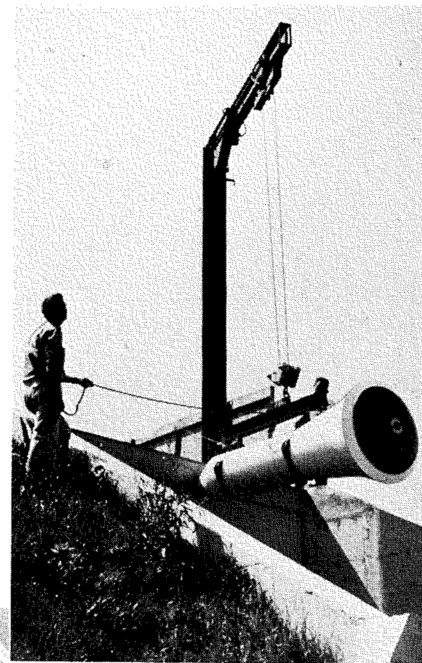


Fig. 4—Full-scale mockup of typical re-entry body being emplaced on the radar range at the Skill Center's Electromagnetic Research Laboratory.

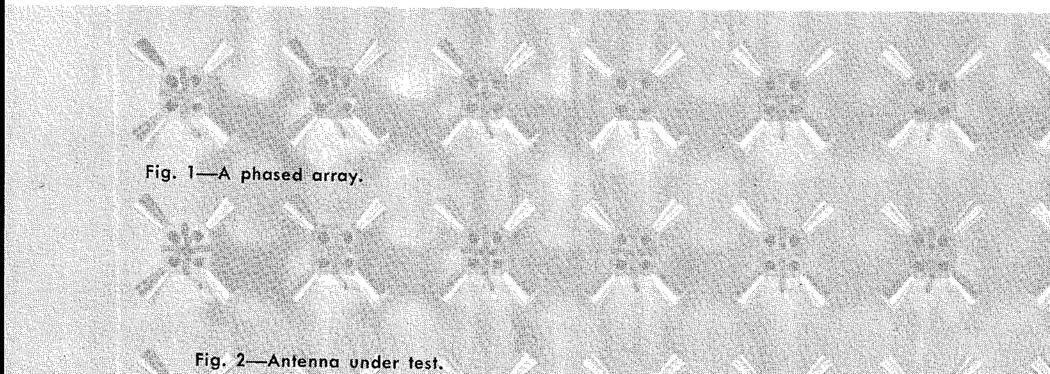


Fig. 1—A phased array.

Fig. 2—Antenna under test.

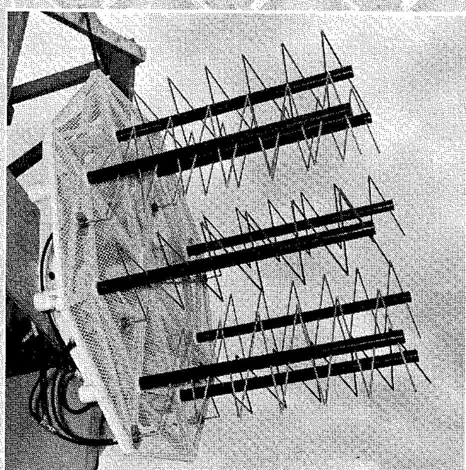
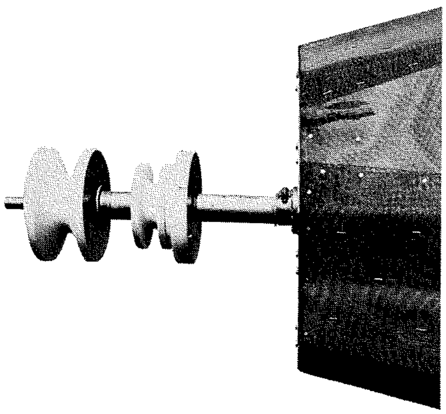


Fig. 3—Wideband antenna for RELAY satellite.



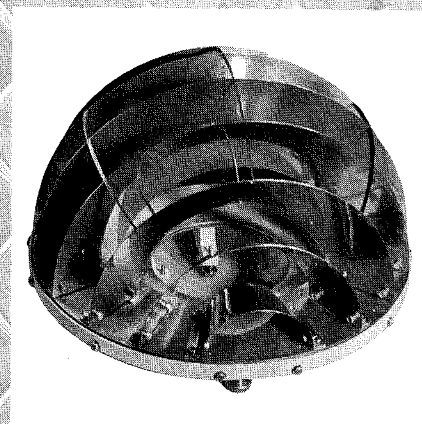
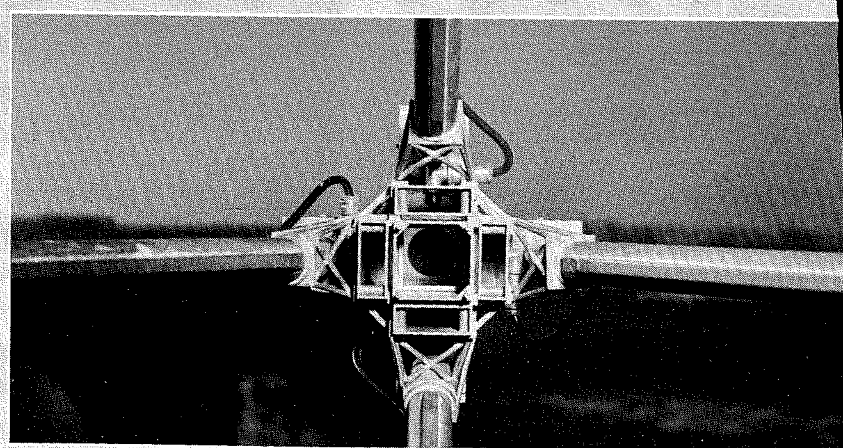


Fig. 5—Polarizing grating.

Fig. 6—Feedhorn assembly.



THE PHILOSOPHY BEHIND the organization and staffing of the Antenna Skill Center at the DEP Moorestown Missile and Surface Radar Division is to concentrate those engineering skills and facilities necessary to achieve a broad technological capability—in this case for the research, development, design, and fabrication of antennas. Staffed with specialists in fields ranging from structures to solid-state physics and equipped with extensive laboratory and test facilities, the Antenna Skill Center's mission is three-fold: 1) to carry antenna systems from conception to construction for both government and industry; 2) to make technical assistance available to other RCA Divisions; and 3) to advance the state-of-the-art of antenna technology through continuing research and development.

After a year of operation, the programs described herein illustrate the diversity of the antenna work being performed and the range of capabilities being applied.

ANTENNAS FOR SPACE

At the Skill Center's Medford Antenna Site near Moorestown, new families of space communications antennas are being developed (presently at 100 to 5500 Mc) for telemetry, command reception, beacons, and relays. These generally employ circularly-polarized radiation patterns with very broad angular coverage.

All antennas on NASA's Project RELAY satellite are being supplied for the DEP Astro-Electronics Division. The wideband antenna system operates at 2 and 4 Gc for spacecraft reception and transmission, respectively. This extremely lightweight structure has one receiver output and two transmitter inputs, all fully decoupled and radiating broad-pattern, circularly polarized signals for carrying out required spacecraft communications functions. The design must be in conformity to the needs of five ground stations in four countries.

Other space programs include furnishing communications antennas to the DEP Aerospace Communications and Controls Division (Burlington) for the USAF SATELLITE INSPECTOR program; and antenna designs for the ECHO communications satellite and for SERT, NASA's experimental ion propulsion rocket.

RADAR PROGRAMS

Infrared and LEAP (Launch Elevation Azimuth Programmer) modification kits for instrumentation radars permit acquisition and tracking of high-acceleration vehicles from launch. The infrared kit, using a sensor developed by DEP-ACC (Burlington) locks onto missile plume noise during ignition and provides angle error data to drive the pedestal. Radar lock-on is achieved at angles just great enough to eliminate ground clutter. Given predicted missile dynamics, LEAP provides a programmed angular velocity to minimize dynamic pedestal lags.

Low-noise, phase-stable parametric amplifiers have been designed and constructed for the UHF, L, C, and K_u bands —and are in use in BMEWS and TRADEX. Tunnel-diode L-band and transistor UHF amplifiers have been built and evaluated for phased arrays. The design of ferrite devices for radar has been studied, with emphasis on devices not commercially available.

Several large, sophisticated radars were completed in 1961. Among these is a 140-foot-high fixed antenna with stringent vibration-amplitude criteria. It is electromechanically steerable and has a total aperture of one acre. Another, a 70- by 90-foot corner reflector mounted on a 180-foot tower, rotates to any desired azimuth position.

The Skill Center's Electromagnetic Research Laboratory is instrumented to measure radar backscattering cross-section of both large and small targets. Facilities include two C-band radars, data recording equipment, a radar range, and a model shop. This Lab is important in meeting specific customer requirements, enhancing equipment performance, and improving radar range techniques.

Skill Center achievements in large, high-precision tracking radars include unit testing and delivery of the TRADEX antenna, shipment of the AN/FPS-16 Mod I pedestal, and design and fabrication of the MIPIR pedestal. The 84-foot TRADEX antenna incorporates an MM&SR-furnished servo system.

The MOD I and MIPIR pedestals were completed designed at MM&SR, going into production *without* prototypes. Both feature excellent high-load, low-friction hydrostatic azimuth bearings, and hydraulic drives designed and built by MM&SR. In one case, a variable-volume pump is employed as the controlled drive element, while in the other a constant pressure valve-controlled motor system is used. Both pedestal systems possess outstanding dynamic range and low-speed characteristics.

The microwave feed system for the TRADEX tracking radar transmits and receives a dual polarized pencil beam at UHF- and L-band frequencies. Dual polarized monopulse angle-tracking signals are received at UHF.

The Skill Center was technical consultant for dynamic soil tests at the TRADEX site, which provided physical parameters needed to design the pedestal, tower, and foundation. Partial test results were presented in a paper at the ASTM Symposium on Soil Dynamics in 1961.

SPECIAL STUDIES AND R&D

Among the many specialized studies conducted were: 1) measurement of the earth's conductivity at very low frequencies (for Project PANGLOSS, RCA Laboratories), 2) recommendation of antenna types, pattern coverage, and optimum working frequencies for a Nigerian Broadcast Facility for RCA International; 3) evaluation of conical antennas for the DEP Data Systems Division; 4) consultation on test planning and target data analysis at a Trinidad radar facility for the RCA Service Co.; and 5) a comparison of UHF and VHF television operation in New York City.

Electronic steering can ease many problems inherent in conventional high-resolution antenna designs. A steerable, phased-array model was constructed to study effects of impedance changes on scan angle and element position, wide-banding techniques, and sidelobe reduction. Also in development are high-gain, electronically steered satellite arrays that will direct their beams in a given direction *regardless* of vehicle attitude.

Another important effort is the analysis of parameters contributing to noise in space tracking antennas. Methods of controlling these parameters are being developed, and several low-noise antenna configurations are currently under study.

There has been broad research in structures. Problems of hardening antennas against the thermal shock and overpressures of a nuclear detonation has been intensively studied. Also, antenna structures and pile foundations have been analyzed for dynamic response and damping under various loading conditions. Preliminary structural investigations have been made of lightweight expansible space antennas.

SUMMARY

These diversified activities illustrate how the activities of the DEP-M&SR Antenna Skill Center are contributing to the state-of-the-art in antenna research, development, and design. Its resources are available to RCA as well as directly to government and industrial customers for proposal, planning, and production of the most advanced antenna systems.

Credit is due MM&SR Engineering for supplying this information.

NBC TELEVISION MULTI-STANDARDS CONVERSION FACILITIES

This new facility enables NBC to convert foreign TV programs that are made on one of the foreign scanning standards (different than in the U.S.) to the standards used in the U.S., and vice versa. The picture quality obtained is operationally suitable for network broadcasting and is now in use for news media.

E. P. BERTERO, Staff Engineer
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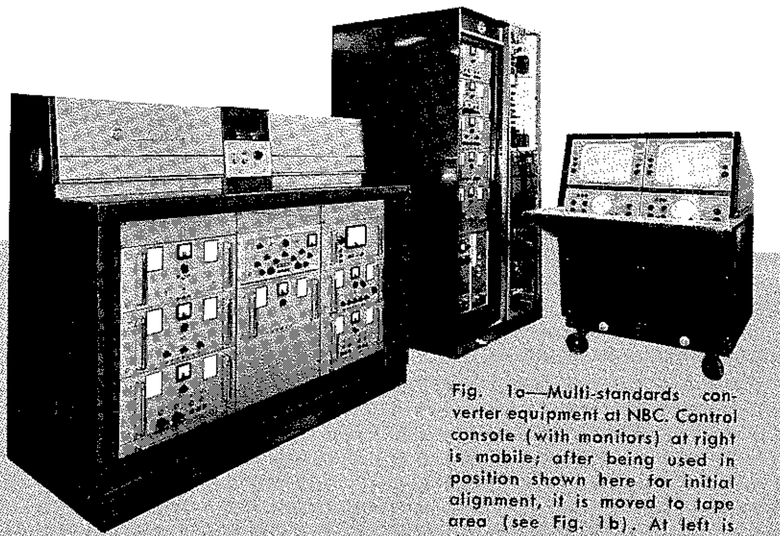

Fig. 1a—Multi-standards converter equipment at NBC. Control console (with monitors) at right is mobile; after being used in position shown here for initial alignment, it is moved to tape area (see Fig. 1b). At left is the camera-display cubicle. In center is the flicker cubicle and sync generator.

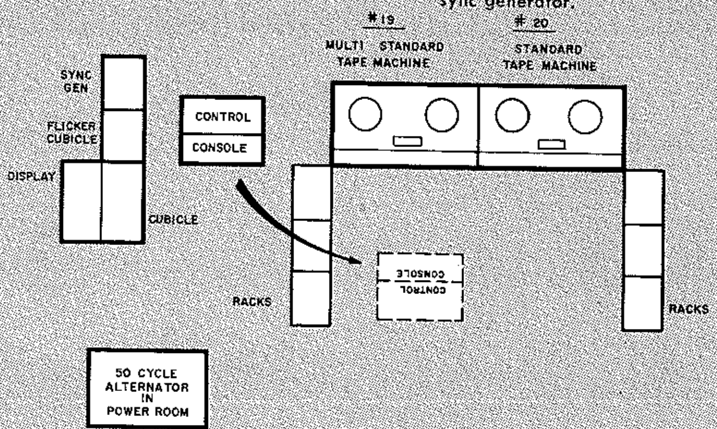

Fig. 1b—Floor plan of converter-equipment installation. (Fig. 1a is a view of equipment at top left.)

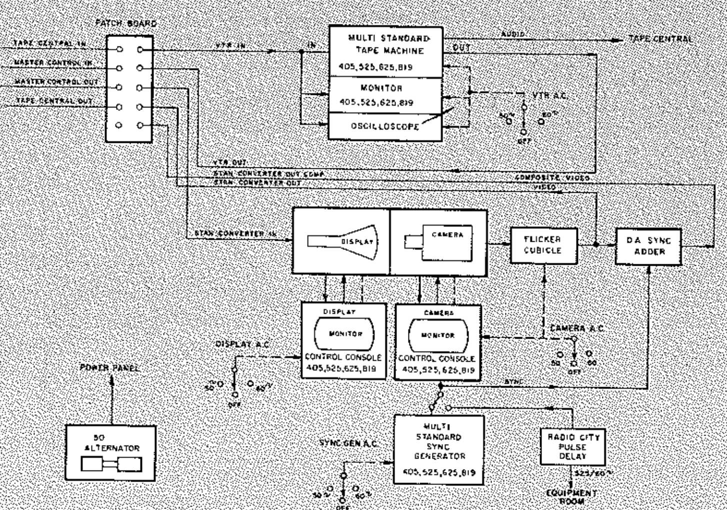

Fig. 2—Operation of the multi-standards converter installation.

THE EXCHANGE OF TV programs between European countries necessitated the development of a system of TV standards conversion. There are four principal TV scanning systems used: 405 lines/50 fields/sec in the United Kingdom; 525 lines/60 fields/sec in the Western Hemisphere and Japan; 625 lines/50 frames/sec in Western Europe (including Germany) and Russia; and 819 lines/50 fields/sec in France and Belgium.

The TV broadcast of the coronation of Queen Elizabeth in 1951 was one of the first successful attempts of standards conversion. The program, originating in London on 405/50 was relayed and converted to 819/50 for France and to 625/50 for the rest of Europe. This involved only line conversion, while today the more difficult conversion of combined line and field differences has been successfully accomplished. In the past ten years, improvements in circuit design, camera tube performance, and nearly complete elimination of flicker have transformed the "standards converter" from a laboratory device to an operational equipment.

TV EXCHANGE WITH EUROPE

The NBC News Department has long been interested in a fast exchange of TV news of international importance, particularly with England. For instance, for the coronation of Queen Elizabeth in 1951, NBC made a kinescope recording of the event in London, processed the film in an airplane enroute from England to New York, and immediately transmitted the kinescope recording to the network on arrival at Radio City.

Two years ago, NBC installed in Radio City a BBC-designed trans- Atlantic cable slow-scan TV terminal equipment. There is now weekly exchange of TV news items between NBC in New York and the BBC in London.

With the advent of video tape recording, the NBC News Department asked that we take a hard look at the standards converters used in England and on the Continent.

NBC REQUIREMENTS

The following requirements were considered to be essential in a standards converter installation at NBC:

1) Convert video tape recordings made on any of the European TV standards to U.S. 525/60 TV standard.
2) Convert and record any U.S. TV program, live or tape, to any European standard.

3) The standards converter installation must be conveniently located to NBC tape operations.

The following equipment is required to fulfill these specified services at NBC:

1) A standards converter capable of reading and writing at 405 line/50 cycle, 525 line/60 cycle, 625 line/50 cycle, and 819 line/50 cycle.
2) A TV synchronizing generator capable of operation on any of these scanning systems on a switchable basis.
3) A modification kit to permit four TV standards operation, both in playback and record modes, for either an RCA or Ampex video tape recorder.
4) A multi-standard monitor and oscilloscope for video tape operation.
5) A 6-kw, 50-cycle alternator.
6) Video distribution amplifier and power supply.

CONVERSION METHOD

An optical transfer method is used in which a high-quality picture is displayed on a kinescope on one TV standard and read with a camera operating on the TV standard to which conversion is to be made. If the field frequencies are different, the camera signal contains flicker components, which are then processed to remove the flicker. (The flicker correction cubicle is not required if the field frequencies are the same.) The standards converter was designed by the BBC Engineering Research Department[1,2] and was built for NBC in England.

The principal features of the standards converter include:

1) Conversion between all video standards.
2) All operational controls on control console.
3) Full equalization of input signal by time derivatives to allow best use of marginal input signals.
4) Elimination of spurious signals outside bandwidth in use by means of phase-equalized filters.
5) Light path available for kinescope recording.
6) Cathode-potential-stabilized storage pick-up tube has linear gray scale; no shading errors nor halo; negligible tendency to "stick."
7) Vertical resolution of pick-up tube superior to vidicon.
8) DC component can be removed from pick-up tube output signal by clamping.
9) Forced-air cooling of all circuitry.

INSTALLATION

The equipment was installed in the NBC video tape recording area, adjacent to Tape Central and TV Master Control. The installation is shown in Figs. 1a and 1b and a block diagram of its operation in Fig. 2. The control console is mounted on wheels. It is first used at the standards converter for initial alignment, and then is rolled into the tape operator's area for use during conversion.

A small video-patch field is located under the sync generator which permits video integration of the standards converter with any and all facilities. By means of a patch the multi-standard type machine on U.S. standards can be integrated with tape operation as a normal machine. For conversion of European tape to U.S. standards, the output of the tape machine is patched to the input of the converter. The output of the converter is patched to Tape Central or TV Master Control. For conversion of U.S. to European, video from Tape Central or TV Master Control is patched into the standards converter. The output of the standards converter is fed to the multi-standard tape machine and recorded on the European standard.

The camera of the standards converter is driven by pulses from the multi-standard sync generator or by properly timed pulses from Radio City.

A power panel is located adjacent to the standards converter. Remote control of the alternator is also incorporated in the power panel. The distribution of either 50-cycle or 60-cycle power to the various components of the installation is controlled by four switches: *VTR19*, *Display Unit*, *Camera Unit*, and *Sync Generator*. The power frequency selected for each component is the same as the field rate of the TV standard the component is to process in conversion.

STANDARDS CONVERSION OPERATION

Since its installation, three half-hour English tape recordings and many foreign news tape recordings have been successfully converted. Several conversion of U.S. to foreign standards have also been accomplished.

Table I—Typical Performance for Conversion from 405/50 to 525/60 Standards

Horizontal Resolution:	420 picture elements per line (with a "Modulation depth" greater than 80%).
Vertical Resolution:	Approximately 200 lines (due to the halving of the input vertical resolution by spot wobble. Subjectively resolution appears better than this).
Signal-to-Noise Ratio: (noise-free input)	35-db (peak-to-peak picture to RMS noise).
Amplitude Characteristic:	Linear over range greater than 10:1, corresponding to an original scene brightness range greater than 100:1.
Flicker:	Signal output variation at 10 cps less than 1%.
Movement Portrayal:	Just perceptible image smearing and some image jerking on fast movement (fundamental with difference in field frequencies).
Locking:	Not necessary to lock the input and output field frequencies in any fixed relationship (i.e., 5 to 6, 6 to 5, or 1 to 1).

EDWARD P. BERTERO received a BSEE in 1942 from New York University. He has been associated with NBC since 1932. In 1937 he became an apprentice engineer of the Operations Group of the Engineering Department. From 1939 to 1942 he was assigned to both the Field and Studio Groups. While on leave of absence from 1942 to 1945 he served as an officer in the US Naval Reserve as an Electronic Specialist. Upon his return to NBC he joined the Development Laboratory Group. From 1948 to 1951 his activities were concerned with the development of optical, mechanical, and electronic special effects for TV. Since 1951 he has been actively engaged in color TV operational development program concerning studio, field, and film equipment. Appointed to the position of Staff Engineer in 1956, he has published and presented several papers, and has been a guest lecturer on color TV New York University and Columbia University. Mr. Bertero is a member of Eta Kappa Nu, SMPTE and an associated member of the IRE, and Amateur Astronomers Association. He has also served on NTSC, EIA, and SMPTE panels and committees.

The standards converter will reach normal operating temperature and be stable in performance an hour after it is turned on. In the various combinations of conversions there is no apparent distortion in gray-scale reproduction. The horizontal resolution as good as the lowest video bandpass of the TV standard used in the conversion will permit. The vertical resolution is about 200 lines. Noise is determined by the camera tube and preamp. Flicker is nearly completely eliminated and is well within the limits of acceptability. When the equipment is in proper adjustment only an occasional slight optimization is required to keep it at peak performance for a day's operation. Typical performances for conversion from 405/50 to 525/60 is shown in Table I.

The equipment has operated satisfactorily since it was installed in September 1961. The quality of pictures obtained by the various combinations of conversion is considered acceptable and operationally satisfactory for TV broadcasting.

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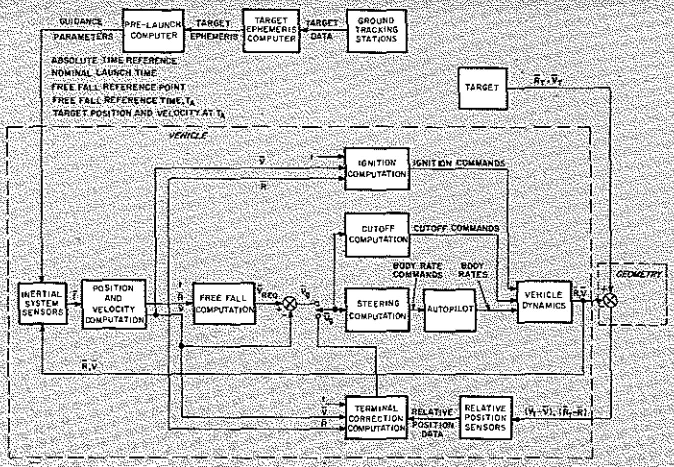

Fig. 1—Guidance and control system.

NAVIGATION FOR RENDEZVOUS IN SPACE

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Important to many future space systems is the successful rendezvous of a vehicle launched from the earth with an orbiting satellite, by maneuvering the vehicle into close proximity or actual soft contact. The problem has been analyzed extensively and computer-simulated. The approach described here leads to a flexible, well-behaved system with realistic demands on the capacity and speed of a control-system computer.

To NAVIGATE a maneuverable space vehicle, launched from the earth, into close proximity or soft contact with an orbiting satellite, the vehicle position and velocity vectors must be made to match the corresponding vectors of the satellite, or *target.*

As pointed out by Peterson, Pode, and Hoover in their discussion of broad navigational requirements,[1] this can be accomplished by a succession of finer and finer thrust maneuvers interspersed by coast periods of various lengths. The first, or *gross,* maneuver launches the vehicle and boosts it to a sufficiently high velocity for it to follow a ballistic coast to a point in space close to the target. In the second, or *intermediate* maneuver (which may actually consist of a sequence of spaced maneuvers), the vehicle acquires essentially orbital velocity. Before this maneuver begins, the vehicle is near the target, but does not have the target's velocity. At that time, in general, it does not have sufficient velocity to remain in orbit. Assuming impulsive burning, an earth-launched vehicle requires a minimum of two bursts to become orbital.

While the gross and intermediate maneuvers can be controlled by inertial means, with no direct knowledge aboard the vehicle of the relative target position, the third, or *terminal correction,* maneuver depends on precise knowledge of relative position and velocity conditions. Therefore, additional data must be introduced from sensors which measure relative data directly. With this new information, the velocity and position errors resulting from the inertially-guided launch and adaptation maneuvers can be nulled out in a succession of finer maneuvers until the velocity and position of the vehicle match those of the target, as required.

Although not necessary, it is convenient when considering the use of inertial techniques in the solution of the navigation problem, to separate guidance from control, both in the analysis and in the system mechanization. The guidance function in the solution of the navigation problem consists of determining a proper course of action. The control function involves generation and execution of commands to carry out this action. In the present problem, the control function includes steering or thrust vector directional control during engine burning periods, vehicle attitude control during nonthrust periods, and execution of engine ignition and cutoff commands. The guidance function can be satisfied in this mission by 1) the determination of when to start maneuvers, 2) the determination before each thrust period, after the first, of an initial value of a velocity-to-be-gained vector for the maneuver, and 3) the continuous determination during each thrust period of the current value of the velocity to be gained.

The velocity-to-be-gained vector is defined as the difference of present velocity and that velocity which would solve the navigation problem at the present time and position. This vector can conveniently be used as the interface between guidance and control in all phases of the mission.

The essential point of view presented in this paper can be summarized as follows:

The function of the guidance loop is to derive a velocity-to-be-gained vector. The function of the control loop is to drive this vector to zero.

Therefore, the guidance during each phase of the mission will be discussed from the standpoint of generating a velocity-to-be-gained vector. Later, the use of this vector for control of the vehicle will be discussed. Fig. 1 illustrates the functions of a guidance and control system. [*Editors Note:* The authors' complete mathematical analyses may be found in the expanded version[2] of this paper.]

GUIDANCE

Gross Maneuver

The intent of guidance during the gross manuever is to put the vehicle in a situation from which the intermediate maneuver can be performed efficiently. This can be done by placing the vehicle on a path which approaches close to the target at a predetermined nominal position and time, called the free-fall reference position and reference time. This method is particularly suited to a constraint on the location of rendezvous and the final direction of approach to the target. If this constraint is not imposed, the additional degree of freedom gained by allowing the reference point to move along the target orbit may be used to minimize fuel expended or to satisfy other conditions.

During the powered portion of the gross maneuver, the guidance computation periodically computes the velocity vector required to reach the reference point at the reference time. The computation is based upon a knowledge of present position and present time. Both these quantities are available in the inertial system, which here includes the guidance computer. A knowledge of the required velocity, combined vectorially with the vehicle's indicated velocity, provides the velocity-to-be-gained vector used for steering and thrust cutoff control. If the computations are repeated rapidly enough and the information obtained is properly processed, precise control for the entire powered phase may be obtained. The computation of the required velocity is based upon the free-fall equations which relate a present point O and a reference point A located in the region of a gravitational central force field. (The characteristics of the total velocity increment required for circular target orbits are developed in Fig. 2.)

Inputs to the free-fall guidance computation system are:

1) present position and velocity vectors,
2) reference position vector,
3) required time from launch to reference position, and
4) clock time from launch time to present time.

On the basis of the above information, a required velocity vector is computed; and from this and the vehicle's present velocity, a velocity-to-be-gained vector is deduced.[2]

Components of the velocity-to-be-gained vector are desired for steering and cutoff control. Therefore, components along and perpendicular to the desired path are the desired output signals from the free-fall guidance computation system. (Various methods for applying these guidance signals will be given later under *Control.*)

As a result of the guidance signals, the following takes place during the power phase of the mission: Until the vehicle reaches the required velocity, it is steered such that velocities perpendicular to a desired course are zeroed out. When the magnitude of the actual velocity is equal to the magnitude of required velocity the engine is cut off. The vehicle then coasts in free fall; and if no errors existed in cutoff conditions, the vehicle will pass through the reference point at the specified time.

Intermediate Maneuver

The intent of the intermediate maneuver is to put the vehicle in a situation which will ensure a high probability of detection of the target by the vehicle's sensors and which will allow the terminal correction to be performed efficiently. This can be done by putting the vehicle on a collision course with the target at a range consistent with the detection range of the vehicle's sensors, with a closing velocity determined by consideration of 1) cumulative probability of detection and fuel expended in terminal guidance, and 2) time and range angle allowed during the terminal correction.

In general, the desired closing velocity for the start of the terminal correction

Fig. 2—Characteristics of total velocity increment for circular target orbits.

The material presented here is to consider the required nominal velocity for rendezvous with a target in a circular orbit. Included are the velocity required for the gross phase, and the intermediate maneuver, and terminal correction combined, with plane changes taking place during the intermediate maneuver. The nominal case for all runs is assumed to be one in which the apogee of the coast phase equals the desired altitude and that the intermediate maneuver takes place at apogee. Variation in time from nominal will usually require more capability depending upon the requirements of the mission. The variables in the problem are:

1) altitude ratio, or ratio of target altitude (for circular orbit) to boost burnout radius from center of earth force field.
2) downrange angle of rendezvous from burnout point; for purposes of this discussion, rendezvous is assumed accomplished after the impulsive intermediate correction;
3) required plane change of intercept in intermediate maneuver.

Impulsive burning is assumed in intermediate correction. Losses in gross phase are bypassed since burnout velocity of the gross phase is considered as the start point in the problem.

Fig. 2a shows a plot of burnout velocity ratio required to reach a desired relative altitude at apogee for various downrange angles. Also shown is the total velocity ratio required to obtain a circular orbit from such an initial burnout condition. Figs. 2b and 2c give intermediate maneuver velocity ratio required for in-plane and out-of-plane cases, respectively. In all of these plots, velocities are non-dimensionalized with respect to the circular orbital velocity at burnout radius. A plot of time to apogee relative to period at burnout is given in Fig. 2d. The curves themselves give the relationship of the various orbits while actual quantities involved may be determined by application of the known dimensional factor.

From Fig. 2a, it can be seen that with no plane change, a total velocity ratio requirement greater than escape velocity ratio at burnout is, by an amount depending upon downrange angle to apogee, necessary to obtain a circular orbit above some altitude. In particular, the worst case is vertical rise to an altitude ratio of 2, then impulsive thrusting to circular velocity, giving a velocity ratio of $\sqrt{3}$. When considering a plane change, a greater total velocity ratio is required. Also, for any particular altitude of apogee, the required total velocity decreases as the down-range angle increases. The velocity curves also show that for angles as short as 75° downrange, the velocity requirements are not increased much over those required for Hohmann-type transfer, which is 180° downrange. The vicinity of 90° downrange in angle or $(2n+1)\times 90°$ would be desirable to minimize velocity requirements for out-of-plane adaptation maneuvers.

Fig. 2d shows that for low altitudes, the time is dependent on down-range angle, while for altitudes above ten radii, the time to apogee varies almost linearly with the altitude of apogee.

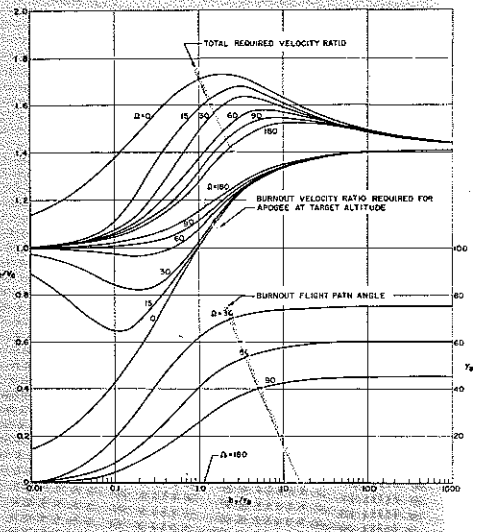

Fig. 2a—Burnout velocity ratio, total velocity ratio, and burnout flight path angle as functions of altitude ratio for various downrange angles. NOTE: Target in circular orbit and no plane change.

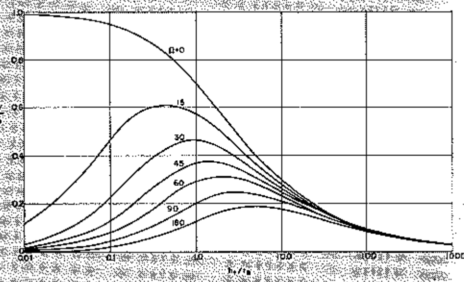

Fig. 2b—Intermediate impulsive velocity ratio as a function of altitude ratio for various downrange angles. NOTE: Target in circular orbit and no plane change.

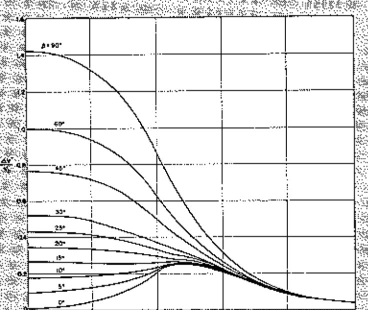

Fig. 2c—Intermediate impulsive velocity ratio as a function of altitude ratio for various plane change angles. NOTE: Target in circular orbit and downrange angle to apogee is 90°.

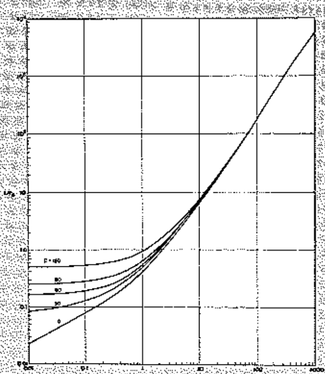

Fig. 2d—Normalized time to apogee as a function of altitude ratio for various downrange angles. NOTE: Target in circular orbit and no plane change.

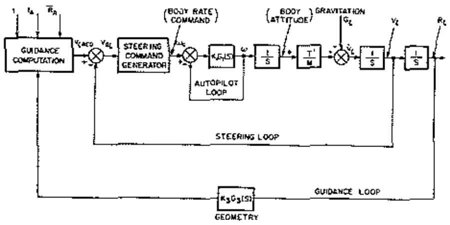

Fig. 3—Guidance, steering, and autopilot loops.

will be a small fraction of the target's orbital velocity, of the order of hundreds of feet per second. The result of the intermediate maneuver will be, therefore, to place the vehicle in an orbit nearly matching that of the target. If the plane of the vehicle's ascent trajectory differs from that of the target's orbit, the intermediate maneuver must reduce the out-of-plane component of vehicle velocity, while increasing the in-plane component to approximately that of the target, accomplishing the so-called *plane change* and *orbit injection.*

The nominal position and time at which the intermediate maneuver is made are chosen so that at the end of the maneuver the range to the target satisfies the above requirements. The velocity requirement is then satisfied by the maneuver itself.

If, during the gross phase, steering errors exist at cutoff or the thrust tail-off of the engine differs from the value assumed in the cutoff computation, then the actual path will deviate from the desired. Earth oblateness effects also cause a deviation if the free-fall computation is made on the basis of an inverse-square central field. These deviations will be measured or computed by the inertial navigation system, however, so that the actual position and velocity which the vehicle would attain at the nominal time to reach the free-fall reference point, if no corrective thrust were applied, can be predicted accurately at any time during the coast phase. The position and velocity of the target at the same instant can be computed during the prelaunch phase and stored in the vehicle's guidance computer. The position and velocity vectors of the vehicle relative to the target at the nominal instant are thus known or computable by the vehicle's guidance system in advance of the time that the thrust for the intermediate maneuver must begin.

Therefore, the problem the guidance system must solve is *when* to start and stop the thrust for the intermediate maneuver, and *what* direction to orient the thrust vector. If the desired velocity change could be made impulsively at the free fall reference point, the problem would readily be solved, for the velocity before and after this instant are known or computable, as indicated above. It can be shown that the same final position and velocity conditions can be obtained with a constant-thrust, constant-mass-flow-rate rocket, if it is started at the proper instant and gains the same velocity increment as in the impulsive case.

The proper instant to start thrust in this case is:

$$t_1 = T_A - \frac{v_e}{a_1}\left[1 - \frac{v_e}{v}\left(1 - \exp\left[-\frac{v}{v_e}\right]\right)\right]$$

Where: T_A = nominal value of time at the free-fall reference point, a_1 = initial acceleration, v_e = effective exhaust velocity, t_1 = time of thrust initiation, and v is the velocity-to-be-gained during the intermediate maneuver.

Terminal Correction

The mission profile must be planned in advance so that the intermediate maneuver will result in a favorable set of conditions for search and acquisition. Once the target has been acquired, the terminal correction may begin. At least two thrust periods are required in the general case. The first sets up a condition of closing velocity of the vehicle relative to the target, assuming that a noncollision course is discovered upon lock-on of the relative position sensors. The last thrust zeroes the relative velocity when the relative range reaches zero. There may be extra maneuvers between these two that refine the collision course, reduce the closing velocity, and/or bring the vehicle in to the target from some preferred direction.

Several methods of guidance to accomplish the purpose of the terminal correction have been suggested by previous authors. If those methods can be instrumented in such a way that a velocity-to-be-gained vector can be defined for each thrust period, then the inertial system can be used to control the vehicle during terminal corrections in the same manner as during all other thrust maneuvers. To do so capitalizes on the excellent dynamic performance characteristics of inertial systems.

CONTROL

As has been shown in the preceding discussion, the mission can be designed so that a velocity-to-be-gained vector is defined for every thrust maneuver. The object of the control system during thrust periods is to drive the velocity-to-be-gained vector to a null, and to cut off the engine when this condition is obtained. The control system accomplishes this by steering, which reduces two components of the velocity-to-be-gained vector to null, and by issuance of a cutoff command when the vehicle thrust vector drives the third component of the velocity-to-be-gained to zero.

The steering commands, which can be expressed as a set of vehicle angular velocity commands resolved to body axes, are derived from this vector. These commands are delivered to the autopilot, which monitors their execution. The autopilot causes torques to come into play to achieve the angular velocity of the vehicle as required. Fig. 3 shows the guidance, steering, and autopilot loops.

Several steering laws have been formulated to control the velocity-to-be-gained vector, including *cross-product steering,* in which a body angular rate is made proportional to the angular difference between the velocity-to-be-gained vector and some other vector or defined direction. This method, with no compensating modifications, suffers from the nonconstancy of the effective steering loop gain, which drives the loop toward instability as the velocity-to-be-gained vector passes through its null value, because of high angular rates of the vector at this time.

Another method of steering, characterized by essentially constant steering loop gains throughout the thrust period, may be designated as *second-order steering* because of the nature of the response to initial condition errors or induced transients. (This form of steering was suggested to the authors by Prof. W. VanderVelde of M.I.T.)

In this method, an angular velocity command to the vehicle is made up of a weighted sum of velocity and acceleration terms:

$$\overline{W}_c = K_{h+1}\overline{l}_\xi \times \overline{V}_g + K_h\overline{l}_\xi \times \overline{f}$$

Where: $\overline{W}_c$ = vehicle angular velocity command, K_h, K_{h+1} = constants, $\overline{l}_\xi$ = a unit vector along ξ, ξ = an inertially fixed reference direction, $\overline{f}$ = specific force, the nongravitational acceleration of the vehicle (i.e. the output of the inerital system accelerometers).

In a typical implementation of this law, an inertially non-rotating right-handed orthogonal triad (ξ,η,ζ) is established with ξ parallel to the velocity-to-be-gained vector at the start of the maneuver. The η axis is taken perpendicular to the ξ axis and in the guidance plane, which passes through the vehicle position at the start of the maneuver, the center of the earth force field, and the free-fall reference position. The ζ axis is normal to the other two, thereby completing the set.

In the actual implementation, the velocity components are computed directly, the f's may be obtained from a resolved accelerometer measurement or, in case a digital computer is used, by differencing successive values of velocity, scaling for the time between the values, and including a gravitation correction.

Fig. 4 shows the response of the steering loop for one channel, assuming a perfect autopilot for which the yaw rate response equals the yaw-rate command. It is seen that the response of the steering loop to initial conditions is that of a damped harmonic oscillator, where the frequency and damping ratio of the oscillation are subject to the control of the designer through the gains K_h and K_{h+1}. In practice, the natural frequency ω_n is taken an order of magnitude lower than the natural frequency of the autopilot loop. Under these conditions, the approximation of the autopilot loop by the transfer function of unity usually is not too unrealistic for first-cut design. Except for the gain change due to mass variation, which may in fact be compensated by programming gain changes to K_h and K_{h+1}, the response characteristics of the loop are unchanged as the vehicle approaches the cutoff point. There are no instabilities in the region of cutoff.

Guidance in the adaptation and terminal phase, as described here, may be made truly independent of the steering loop. That is, the loop can be made to control velocity only with no position feedback. In the gross maneuver, this is not possible for the form of guidance discussed here. However, when the time to the aim point is long compared to the natural period of the steering loop, then the coupling between the steering and guidance loops is very loose. In fact, it can be shown that the feedback in the guidance loop of Fig. 3 is of the order of $1/t_{ff}$, where t_{ff} is the remaining time to the free fall reference point. Analysis of this loop shows that one criterion for stability is:

$$f\, K_h > \frac{1}{t_{ff}}$$

This inequality can be satisfied by numbers of the order of 300 to 1 in practical situations.

Control in the coast portions of the mission is quite flexible up to the point of readying the vehicle for the next thrust maneuver. The initial value of the velocity-to-be-gained vector can be computed, for all thrust periods after the first, before the maneuver begins. The vehicle can be rotated so that the nominal thrust vector or rocket motor axis will lie in the correct direction when it is time to ignite the engine. The inertial reference provides the attitude information needed for this control.

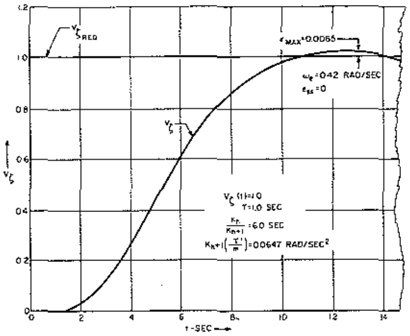

Fig. 4—Transient response to a unit step command in required velocity.

CONCLUSION

The guidance and control problems associated with rendezvous in space have been analyzed extensively by continuous and sampled data techniques, and simulated in detail on a large scale digital computer. The results have shown that the approach described above leads to a flexible well-behaved system with realistic demands on computer capacity and computing speed.

ACKNOWLEDGMENT

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E. P. WALLNER, JR. received his BEE from the University of Louisville in 1957, and in 1950, received an MEE from Rensselaer Polytechnic Institute where he taught Electrical Engineering for three years. In 1950, he joined the Sperry Gyroscope Company where he participated in the development of a missile guidance system, followed by design and flight testing of airborne inertial navigational systems. In 1955, Mr. Wallner joined RCA where he has been involved with the analysis of interceptor fire-control and guidance systems, navigation problems in global glide vehicles, and perturbations of ICBM and satellite trajectories. Recently, he has directed the analysis and simulation of missile control systems. He is a member of Sigma Xi, and an associate member of AIEE.

COMMUNICATIONS AND TRACKING FOR DYNA SOAR

Maintaining contact with a re-entering manned space vehicle poses special problems for the designer of the communications and tracking system. Described herein is the approach to such a system for the DYNA SOAR—the USAF's manned orbital vehicle designed for controlled re-entry and landing. For DYNA SOAR, extensive analysis has pointed to the SHF band. Since no SHF equipment exists that will fulfill DYNA SOAR requirements, a major engineering challenge has been posed.

L. B. GARRETT, JR., Ldr.
Engineering System Projects
DYNA SOAR *Program Office*
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THE Aerospace Communications and Controls Division, DEP, Camden, is now actively developing a communications and tracking subsystem for the Air Force DYNA SOAR program. The subsystem will be utilized both in the initial air-launch tests (from a "mother" aircraft) at Edwards Air Force Base and in the eventual ground launches (by a TITAN booster) at the Atlantic Missile Range. The ultimate purpose of DYNA SOAR is to achieve a manned earth-orbit flight, with a controlled re-entry and landing.

The DYNA SOAR (Fig. 1) consists of a TITAN booster, associated transition hardware, and the manned "glider." During initial tests to verify terminal-phase flight characteristics, the glider will be air-launched from a mother plane in a manner similar to that currently used with the X-15 supersonic rocket aircraft. Such air launches will permit a first-order operational check of glider electronics in conjunction with the surface instrumentation equipment that will be used later in the TITAN-launched flights. During these future ground-launch tests, the TITAN will boost the glider to hypersonic velocities (Fig. 2). Several unpiloted flights are planned in order to check out equipment and staging; piloted flights involving reusable gliders will follow the unpiloted flights. The trajectories will be planned to permit exploration of the re-entry corridor (the speed-altitude regimes associated with re-entry).

The major functions of the communications and tracking subsystem are to provide:

1) vehicle-to-surface transmission of pilot voice, flight safety data, and scientific test data;
2) surface-to-vehicle transmission of range-safety and test-conductor voice commands;
3) vehicle position data in spherical coordinates; and
4) rescue communication between pilot and search craft.

The principal emphasis in the current development and fabrication program is on the radio equipment required for vehicle-to-surface-to-vehicle transmissions during re-entry. (The transponder and associated surface instrumentation radar, as well as the UHF radio and associated surface and airborne equipment, are standard devices and will not be given attention in this article.)

DESIGN FACTORS

Communication problems with re-entry vehicles have been given considerable attention by both industry and government in recent years. Standard VHF

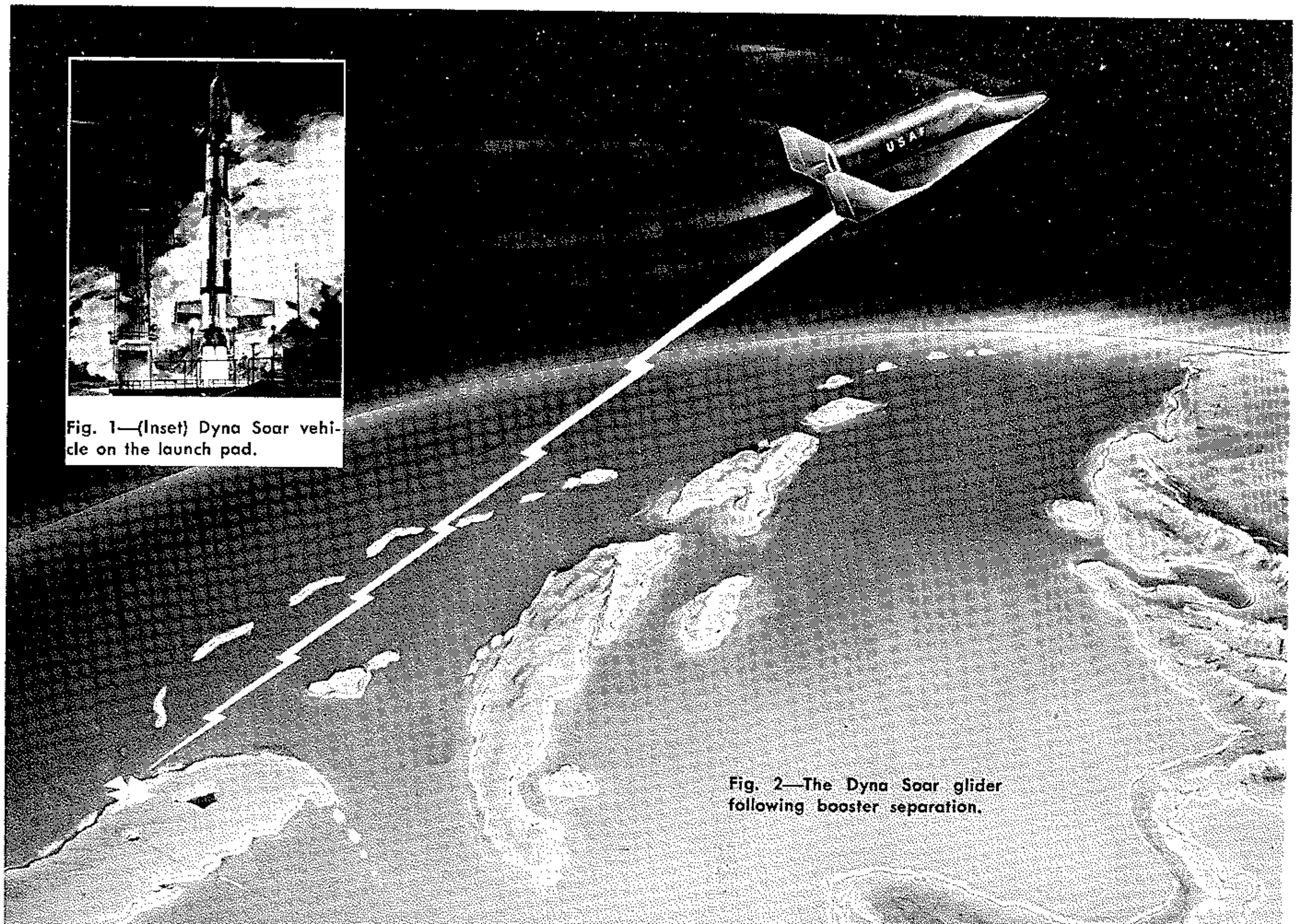
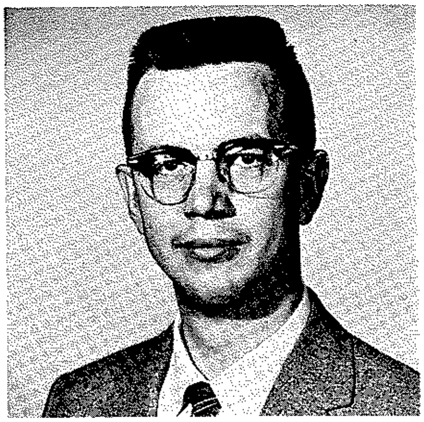


Fig. 1—(Inset) Dyna Soar vehicle on the launch pad.

Fig. 2—The Dyna Soar glider following booster separation.



L. B. GARRETT, JR. joined RCA after receiving a BSEE from Drexel Institute of Technology in 1953, where he also received his MSEE in 1958. He has worked on the design, development, and production of the AN/ARC-34, specializing in frequency-synthesizing systems and receiver tuners, and on the AN/ARC-62 design and development program, specializing in receiver development. He has participated in coordination of the USAF time-division-data-link program, served as project engineer on command and long-range data links developed under USAF contract, and has been responsible for technical direction of communication studies for orbital military systems.

telemetry frequencies (215 to 260 Mc) suffer such severe attenuation during re-entry that they can be said to be blacked out. Re-entry is generally considered to begin when the velocity becomes sub-orbital and terminates when aerodynamic drag reduces the body's velocity to the sonic region. Whether undergoing a ballistic trajectory initiated from the earth's surface or from an earth orbit through de-boost, velocities at re-entry can be from 15,000 to 35,000 ft./sec.

These hypersonic velocities, along with other factors, form the principle DYNA SOAR communication design parameters. The compression and attendant heating of the low-density air causes ionization. This ionized shock wave, like flame and nuclear-burst ionization, surrounds the vehicle and causes refraction of electromagnetic energy. Just as in the ionosphere, the influence on radio propagation is frequency-selective, and the effect is dependent on the density and thickness of the ionized media as well as the incident angle of the electromagnetic energy. The net effect on a typical re-entry body is that the vehicle appears to be surrounded by a copper bubble of electromagnetic energy at frequencies from VLF through much of the super-high-frequency band (SHF, 3 to 30 Gc), and occasionally extending through the extremely-high-frequency band (EHF, 30 to 300 Gc). The exact frequency span of the blacked-out band depends on the velocity, altitude, geometry, and configuration of the re-entry body.

Extensive analysis and experiments performed by government agencies and industry—particularly The Boeing Company—showed that communication outages for the first DYNA SOAR flights could be held to less than 1 percent by use of the SHF communication band. Since no SHF equipment existed capable of performing the DYNA SOAR communication functions, its design constitutes a major engineering challenge for RCA.

The compression heating of the rarified gases leads to a second item—elevated skin temperatures, on the order of 2000°F. in the neighborhood of the SHF antennas. The selection of dielectrics and metals for the antennas and waveguides has required some compromises between optimum RF performance and the need for good thermal isolation between the waveguides and equipment; such compromise selections often lead to higher RF losses. In addition to conduction losses on the order of 3 db, the noise emission from the heated conductors results in a 5-db increase in the vehicle receiver noise figure.

The total air-vehicle weight restrictions dictate that the surface portion of the communication link must provide a significant part of the total radio-link gain required. Sufficient gain is needed to overcome the additional free-space and atmospheric losses evoked by SHF operation—plus the losses induced by temperature effects. This has led to surface-antenna gains in excess of 40 db, state-of-the-art receiver preamplifiers, state-of-the-art ground-transmitter power levels, received-signal polarization diversity, and predetection bandwidth-reduction techniques. The penalties of high-gain antennas are resultant beam-widths on the order of 1° and the attendant affects on acquisition and tracking.

The signal acquisition problem is considerably aggravated by vehicle maneuverability. The signal acquisition is fairly routine when communication between surface sites is adequate to permit transmission of real-time vehicle-position data, and when facilities are available for translating position data into antenna pointing angles having requisite accuracy. Under less fortunate circumstances, the communication and tracking equipment must establish the communication links to a vehicle positioned in a fairly large volume of space. Toward this end, a significant capability for unaided acquisition has been designed into the surface communication equipment.

AIRBORNE EQUIPMENT

In the glider-mounted equipment (Fig. 3) two transmitters (*test data voice* No. 1 and No. 2) are connected to a transmitter antenna multicoupler. These transmitters, together with the microphone amplifier in the control panel, form the airborne portion of the SHF vehicle-to-surface link. The two receivers and pilot's headset amplifier in the control panel form the airborne portion of the surface-to-vehicle SHF communication link. The pilot's voice is fed to the test instrumentation subsystem where it is modulated on a sub-carrier and fed back to the transmitters.

The test instrumentation equipment includes several-hundred sensors for checking temperatures, pressures, and accelerations which indicate unsafe glider conditions, as well as structure, design verification data, and biomedical monitoring. Signal conditioning and conversion equipment for both PCM and continuous analog data on FM carriers are also part of this subsystem. The necessary multiplexing of the PCM with the FM subcarriers, including the voice-modulated one, is performed by the conditioning and conversion equipment and then fed in a single 400-kc baseband to the transmitters where subcarriers are frequency-modulated on the carrier.

The two transmitters are fixed-tuned to different frequencies, but within 40 Mc of each other. When both transmitters are operating under normal conditions, the antenna coupler connects transmitter No. 1 to the top antenna and No. 2 to the bottom antenna. Thus, the frequency diversity prevents serious interference patterns between the two antennas. In the event of failure of one transmitter, a sensing signal causes the multicoupler to switch the surviving transmitter onto both antennas, permitting full coverage at reduced performance. Transmitter sidetone circuits return the pilot's voice to the headset amplifier so that he can listen to his voice. Sidetone is supplied only when failure circuits judge the transmitter to be working; hence, the pilot is provided with a confidence check.

Two SHF receivers (*command data/voice* No. 1 and No. 2 in Fig. 3) are employed in the glider. Simultaneous reception and transmission is a feature provided by the following isolation methods: Receiver and transmitter operating frequencies are sufficiently removed from one another, preselection filtering is used, and adequate physical separation is provided between the receiving and transmitting antennas.

The two receivers are each connected to different antennas, one to the top SHF

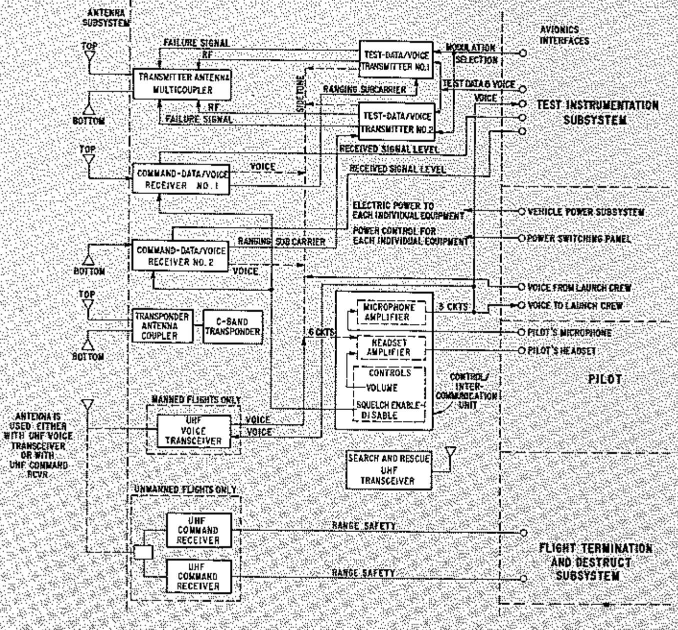


Fig. 3—Glider communication and tracking equipment.

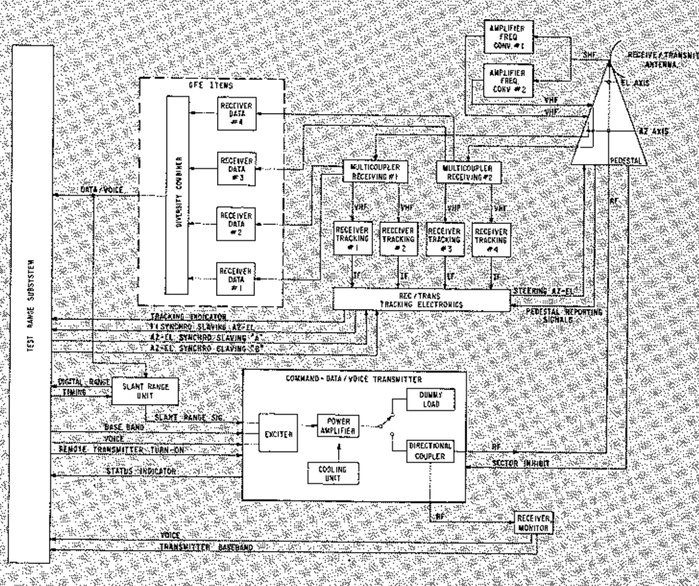


Fig. 4—SHF composite transmit/receiver site equipment.

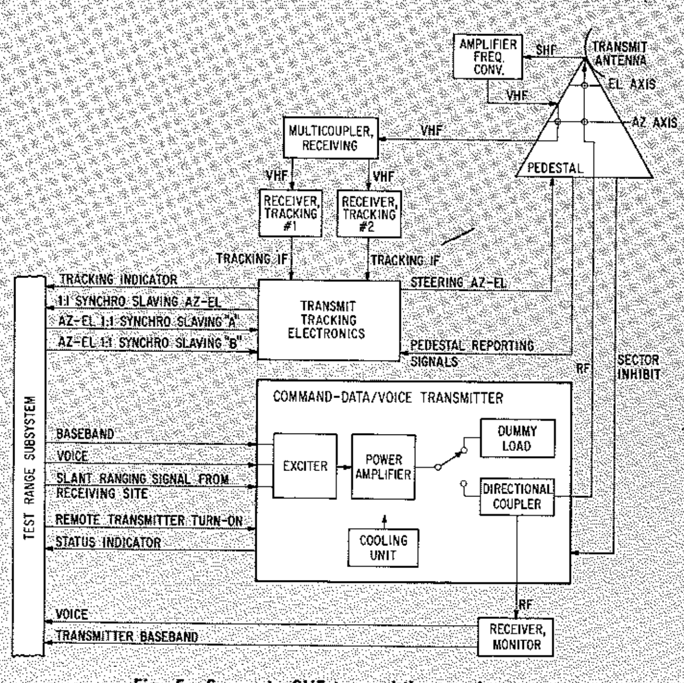


Fig. 5—Separate SHF transmitting equipment.

receiving antenna and the other to the bottom, as in the case of the normal SHF transmitter antenna connection. Differing from the transmitter connection, however, is the fact that no switching multicoupler is needed because of the higher reliability of the receivers. The connection of the two receivers to independent antennas does permit a form of space diversity to combat destructive antenna pattern interference, although both receivers are tuned to a single ground-to-air frequency. Hence, a form of diversity-combining must be employed.

To accomplish voice-diversity reception, a voice squelch is used to prevent receiver noise from entering the pilot's headset. In the ranging channels, diversity is accomplished through an independent connection to each of the two transmitters. If required, a decoder may be added to handle a standard keyed tone or digital data. At present, the only data conveyed on the SHF surface glider link is via a *slant-ranging* subcarrier which is fed to the SHF transmitters for retransmission.

The control panel shown in Fig. 3 contains the pilot's microphone and headset amplifier as well as simplified controls. A single control provides a *received-voice-volume* adjustment with independent trimmer adjustments being located on the transmitters and receivers. A switch *enables* or *disables* the voice squelch circuits and a *push-to-listen* switch controls the transmitter sidetone; this switch allows the pilot to disconnect the sidetone signal from his headset when he is not talking and gets tired of hearing himself breathe. Connections are also provided so that the pilot can converse with the ground crew prior to glider-cord separation.

The UHF command receiver decoders will be employed for range safety during unmanned flights, and the VHF voice transceiver will be employed during orbital and landing phases of the manned flights.

SURFACE EQUIPMENT

The basic surface equipment design is for the single site location of transmitting and receiving facilities. The composite receive-transmit site is shown diagramatically in Fig. 4. Three major functions are represented in this design: signal tracking, RF conversion/demodulation, and RF transmission.

Dealing first with the conversion/demodulation equipment, the received signal can be traced from the surface of the parabolic reflector into the nutating feed system and to the low-noise amplifier/frequency converter employed in a polarization diversity configuration. The functional portions of the amplifier/frequency converters are mounted at the rear of the reflector on the two-axis pedestal, above the pedestal's elevation axis. Power supplies for generating DC voltages are housed as is done in the other equipment; power is fed through slip-ring assemblies in the azimuth axis of the pedestal. The amplifier/frequency converter heterodynes the two received SHF signals down to frequencies lying in the 216-to-260 Mc telemetry band.

To maintain a single conversion process and a reasonable RF bandwidth through the low-noise preamplifier, received frequencies must be within the 40-Mc limit mentioned previously. Sufficient linearity is maintained through the amplifier/frequency converter to handle three received signals in the event SHF telemetry is added to the TITAN booster. The wideband, VHF output from the converter is fed through a coaxial rotary joint in the azimuth axis to an active VHF multicoupler having eight coaxial output ports. Four of the ports are utilized for the polarization, diversity-connection receivers of Fig. 4. Receivers No. 1 and 2, for example, are tuned to the two VHF frequencies corresponding to one polarization while receivers No. 3 and No. 4 can be tuned to the two VHF frequencies corresponding to the other polarization. These VHF receivers feature self-acquiring AFC circuits for the real-time frequency demodulation loop, and predetection intermediate-frequency recording for post-flight analysis. The recording of IF frequencies permits the use of post-flight, slowed-down signal-recovery techniques; such methods are particularly useful for recovering signals that would otherwise be below the FM-demodulator threshold.

The baseband derived from the real-time demodulation process is fed to the baseband diversity combiners where the combined output is routed to the slant-range unit and to the test instrumentation subsystem. The slant-range unit separates the ranging subcarrier from the remainder of the baseband and utilizes the subcarrier for slant-range computation. The slant-ranging technique utilizes low- and high-frequency audio tone frequencies modulated on a subcarrier. This ranging subcarrier is generated in the slant-range unit and provided to the command transmitter for transmission to the glider. The returned subcarrier is demodulated and the phase of the received tones are compared with the phase of the transmitted tones. Fixed delays are subtracted and the remaining delay (the loop propagation time) is converted to digital range information. The low-frequency tone is used to resolve the range to a few miles and the high-frequency tone is used to resolve the range to a few hundred yards.

The tracking portion of the surface receiving equipment makes use of the conical nutation performed by the antenna feed. Signal energy from the electrical boresight is subjected to an amplitude modulation which is proportional to the tracking error. Amplitude variations are retained through the multicoupler and the two tracking receivers, and are amplitude-demodulated by a special IF-demodulator in the antenna-tracking circuits. The tracking circuitry divides the error into azimuth and elevation components which are amplified and used to power the elevation and azimuth drive motors in a direction that minimizes the errors; tracking error will rarely exceed 0.1°. Antenna position is available to the test-range subsystem either in the form of 1:1 synchro information or as a shaft position for sine-cosine potentiometers, or digital encoders. Angular data together with the slant-range information provide position data accurately enough to aid other on-site or down-range trackers in acquisition.

The self-acquisition features of the antenna include the ability to receive azimuth and elevation data from either of two sources; a circular scan can be superimposed on such designation data to compensate for information errors. The antenna operator can select sector scans from 0° to 32° for acquisition at the horizon. Once the signal energy is detected by the tracking IF demodulator, the tracking circuits remember the position and automatically initiate tracking. In the event of a tracking loss, the tracking circuits revert automatically to *slave*, *rate memory*, and *manual* modes in a priority sequence. Facilities are provided for aided and unaided manual tracking.

The antenna pedestal and feed system employ high-power rotary joints in the azimuth and elevation axes. The requisite diplexing is included in the feed to permit simultaneous non-interfering transmission and reception. The transmitter receives the slant-range subcarrier along with voice from the Test Director, augmented where necessary by the surface-communication facilities of the test-range subsystem. The transmitter contains the requisite voice subcarrier modulators, video multiplexer, and carrier modulators to frequency-modulate the composite baseband onto the SHF carrier. The monitor receiver employs an airborne receiver assembly and provides an output suitable for recording and monitoring transmitter operation. In addition, a directional coupler provides both the RF signal for the monitor receiver and a DC-voltage-indicating carrier level. Protective circuits in the transmitter are arranged to automatically shut down the high-voltage circuits in the event of excessive VSWR or primary power failure.

Provision is made for accepting either standard keyed tone-data or a digital-modulated subcarrier on the transmitter baseband input. Where such information is used for range safety, two transmitters will be employed in a master-slave arrangement with provision for an automatic switchover when the master fails. A control ladder is added to the monitor-receiver assembly to actuate waveguide switching and for the changeover of transmitters.

USE OF SEPARATE SITES

On certain range instrumentation sites, there is traditionally a physical separation of receiving and transmitting functions, which is brought about primarily by RF-interference considerations. Since it is economical to make use of the existing separate facilities such as housing, wiring, and personnel, the SHF surface equipment is adapted to this type of installation. Here, two additional configurations of the SHF surface equipment arise: the *receiving site* and the *transmitting site*.

The receiving site has the same functions as the receive/transmit site described above, except that the transmitter and its associated monitor-receiver are removed. The transmitting site has a number of differences with respect to the composite site; its configuration is illustrated in Fig. 5.

As Fig. 5 shows, the transmitting site also employs signal tracking equipment and hence is capable of operating independently of the receiving site. Because of the less-severe tracking-reception capability, polarization diversity is not required, and a single amplifier/frequency-converter is employed. In other respects, the signal tracking operation is the same as that described above for the composite site. In fact, the same antenna and tracking electronics can be employed.

SUMMARY

Through the use of these communication equipments, the DYNA SOAR program will have the ability to maintain voice communication with the pilot and to collect, on the ground, the data necessary for in-flight evaluation.

THE HIGH-POWER RF GENERATOR FOR THE CAMBRIDGE ELECTRON ACCELERATOR

RCA has contributed importantly to the new Cambridge Electron Accelerator, located at Harvard University, by designing and building the unique 400-kw power generator that supplies RF energy for accelerating electron particles to velocities approaching the speed of light. The Accelerator, one of the largest of its kind in the world, will be used for sophisticated high-energy-physics studies of electron particles and represents a significant increased capability for basic research on the nature of matter. The RF equipment, placed in successful operation late in 1961, is the first of its kind to be built by RCA.

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A UNIQUE 400-kw power generator designed, built, and installed by RCA supplies the RF energy to the Cambridge Electron Accelerator (Figs. 1-3). The RCA high-power equipment operates at a frequency of 475.8± 2 Mc and provides the energy for accelerating electron particles to velocities approaching the speed of light.

THE CAMBRIDGE ELECTRON ACCELERATOR

To fully appreciate the challenge facing RCA's high-power transmitter engineers, the enormity of the Accelerator project deserves brief description here. Under contract with the Atomic Energy Commission, the Massachusetts Institute of Technology and Harvard University have built and are activating the Cambridge Electron Accelerator. The Accelerator is a basic-research laboratory apparatus utilizing an electron synchrotron of alternating gradient type, designed to produce electrons of 6-Bev. energy with an average beam intensity of 6×10^{12} electrons/sec.

The Accelerator facility is an unclassified project located on the grounds of Harvard University. The entire system includes a 240-foot-diameter underground orbital tunnel having a 750-foot-long path. The tunnel houses 48 massive focusing magnets, 16 RF-powered accelerating cavities, various vacuum pumps, and other accessories. A 20-to-30 Mev linear accelerator (LINAC) injects particles into the 750-foot circular track at the required initial velocity.

Fig. 1—The RCA 400-kw Generator operating area at the Cambridge Electron Accelerator installation.

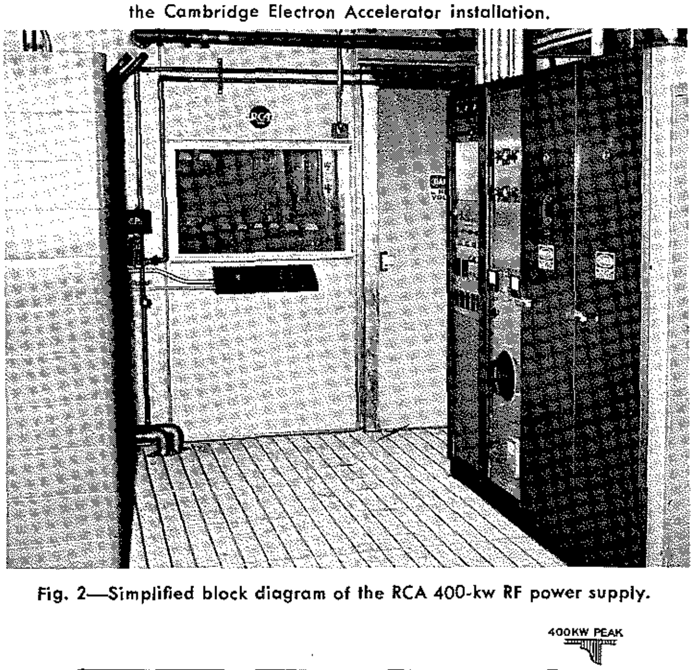
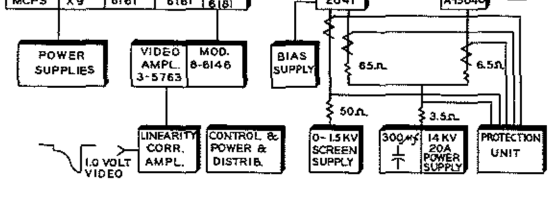


Fig. 2—Simplified block diagram of the RCA 400-kw RF power supply.



CARLETON H. MUSSON received a BSEE degree from Michigan State University, graduating with high honors. He joined the University staff as an engineer of radio stations *WKAR* and *WKAR-FM*. In 1951-1952 he returned to active duty in Japan and Korea as a fixed-base radio officer and as special communication aid to the Commanding General, United Nations Command, Far East. In 1953 he returned to Michigan State University as Engineering Supervisor of TV station *WKAR-TV*. In 1956 he became Chief Engineer of Gross Telecasting, Inc., and stations *WJIM* and *WJIM-TV*, Lansing, Michigan. In 1958 he left this position to join RCA as a senior design engineer in the Broadcast Transmitter section of Industrial Electronic Products. In 1959 he became Leader, Design and Development Engineering, High Power and Nucleonics Division, IEP. In 1961, he transferred to Moorestown as a Leader, Design & Development Engineering, High Power Transmitter Systems, Moorestown Missile and Surface Radar Division of Defense Electronic Products. Mr. Musson is a Registered Professional Engineer in the State of New Jersey, a Member of the National Society of Professional Engineers and a Member of Phi Kappa Phi.

Fig. 3—The author, C. H. Musson, standing between the high-power RF stages during engineering tests at Camden. The RF driver amplifier is shown at right and the final, or high-power, RF amplifier at far left.

BASIC FUNCTION OF RCA'S TRANSMITTER

RCA's 400-kw transmitter feeds RF energy through a waveguide ring that is coupled to each of the 16 cavities located in the orbital tunnel. The orbiting electrons are steered around the circular path by the 48 focusing magnets. Each time an electron passes through one of the 16 cavities, its energy is increased by 0.3 Mev by the RF energy; thus, electron particles attain higher and higher energies as they travel around the 750-foot orbit. During experimentation, electron particles are extracted from the stream and fired into an intermediate target which emits photons used to bombard experimental specimens. Extracted electron particles may also be fired directly into target specimens under observation.

DESIGN GOALS FOR THE RF POWER

The 16 accelerating RF cavities are very tightly coupled electrically and are

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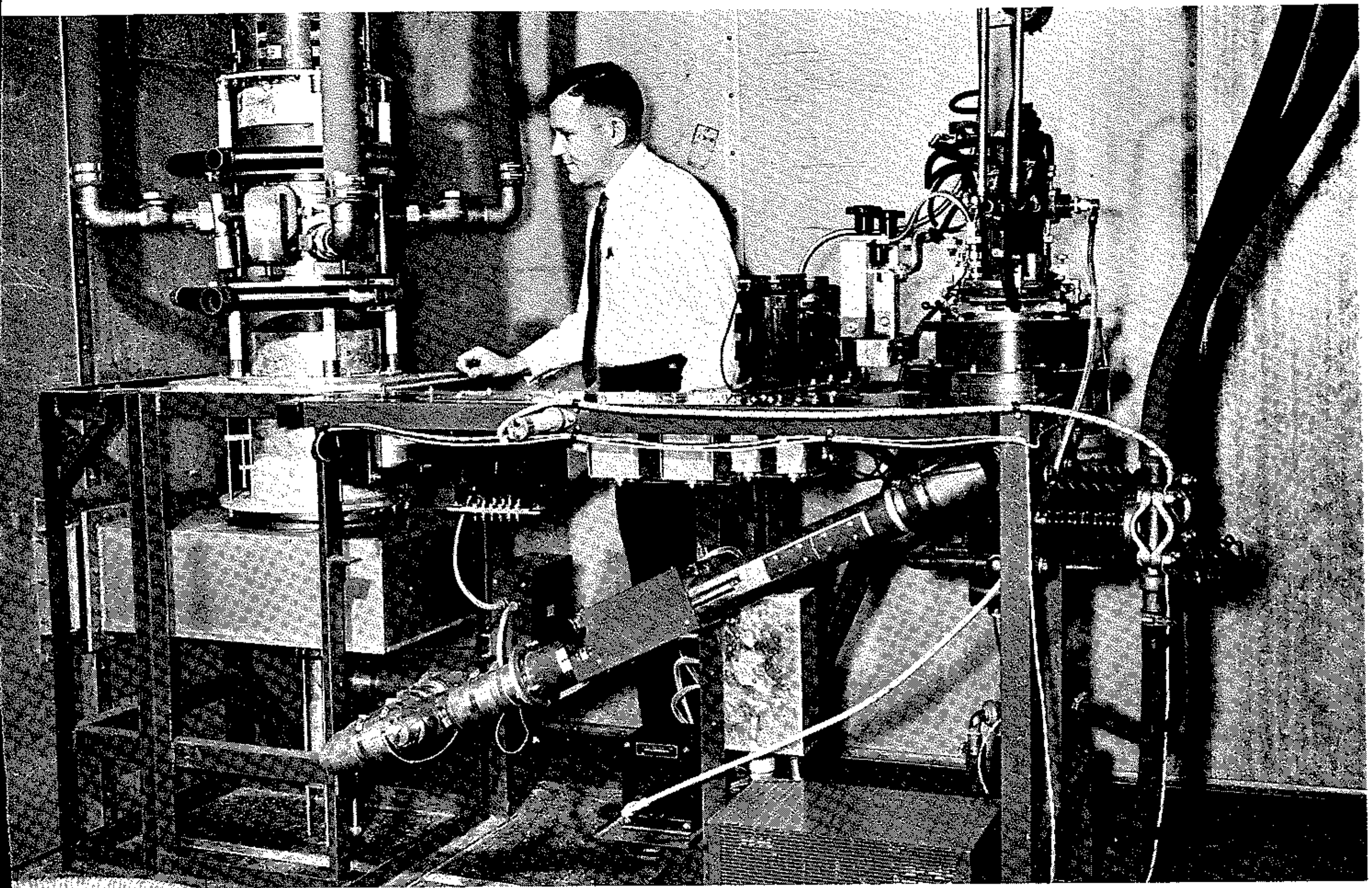

interconnected through 18-inch waveguides, forming a closed ring; this ring is fed from a single *T*-waveguide driving point. To achieve the desired energy level, a programmed pulse signal with up to 400-kw peak RF power is required to feed this *T*-waveguide driving point.

Specifications called for a programmed-pulse RF signal with an adjustable repetition rate near 60 cps and an adjustable pulse-duration of 8.33 msec. The basic pulse voltage waveform is a square wave with the following function added to each pulse:

$$\left[A \sin^4 \chi\right]_0^{\pi/2}$$

Where $A = 0.8$ peak voltage, $x = 2\pi f$ and $f =$ repetition rate. The shape of this pulse results in an output voltage duty of approximately 25 percent with a power duty of approximately 16.7 percent (Fig. 4). This input video pulse causes the transmitter to be amplitude-modulated to provide increasing amounts of power as the acceleration cycle progresses. Early in the accelerating cycle, the RF power requirements depend mainly on the relatively low power needed for optimum accelerator beam acceptance. Near the end of the cycle, however, the power requirement is a function of radiation loss as the beam reaches 4.5 Mev/turn at the start of the pulse and 6 Mev/turn at the pulse peak. The RF signal is generated and modulated at low power for ease of control of the desired output voltages during the cycle. Variations of the modulating video waveform may be adjusted by a video-signal analog computer circuit which provides the input video. Automatic adjustment of the waveform may eventually be incorporated through a feedback system to compensate for the accelerator-beam loading.

RF EQUIPMENT

The RF line-up was established considering the output-power requirements, the pulse waveform, pulse-reversal response, pulse video bandwidth response, pulse envelope delay, and variation of pulse repetition rate down to 30 cps.

The final-amplifier tube selected was an RCA developmental super-power triode, A-15040, now commercially identified as the RCA 4612. (This tube is closely related to the super-power UHF triode, RCA 2054).[2] The A-15040 (4612) is designed to be operated with constant DC plate voltage applied, with zero or minimum bias, and with RF grid-pulse drive. The tube achieves the required 400-kw peak power output with a nominal 14 kv applied to the plate, and with an RF peak driving power of approximately 30 kw.

To supply this 30-kw driving power, the RCA 2041 was selected. This tube comes from a family of tetrodes used in UHF television. The 2041 is particularly suited for this application, since

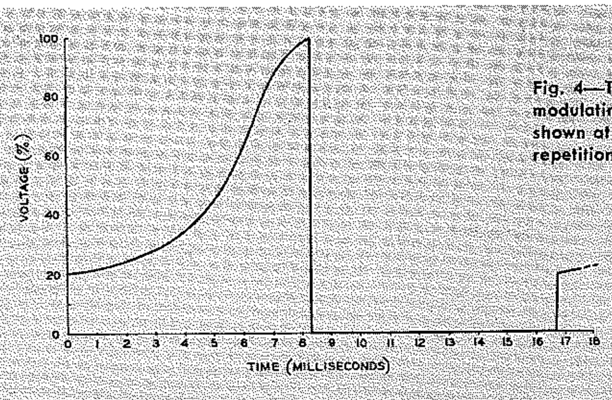

Fig. 4—Typical video modulating waveform shown at the 60-cycle repetition rate.

its plate voltage is supplied directly from the same 14-kv power source used for the high-power amplifier; the 2041 requires less than 1000-watt peak driving power to provide the 30-kw peak output.

The operating parameters for the driver amplifier (2041 stage) made it possible to use a standard off-the-shelf UHF exciter modified to accept the programmed-pulse modulating video signal. The exciter used was the visual-transmitter portion of the RCA UHF 1000-watt television broadcast transmitter (Type TTU1B)[3], tuned to television channel 14. The necessary modifications of the TTU1B included:

1) alterations of the video amplifiers and modulator circuits to improve low-frequency response and video linearity;
2) substitution of a highly stable variable-frequency oscillator for the crystal oscillator; and
3) the provision of additional filter capacitors in the power supplies to reduce pulse droop.

THE FINAL-AMPLIFIER RF CAVITY

The RCA A-15040 "compression seal" super-power tube used in the final amplifier was designed and built by the RCA Electron Tube Division, Lancaster, Pa. This double-ended coaxial triode acquired the "compression seal" name from the ceramic compression-insulating vacuum seals. The tube is actually a three-element coaxial structure with seals at each end. The cathode forms the inner element, the grid cylinder surrounding the cathode forms the intermediate element, and the anode forms the outer element. The tube, together with an attached set of RF cavity circuits (a grid inner-cavity and a plate outer-cavity on each end), forms the amplifier RF circuitry.

The total grid cavity-tube and plate cavity-tube structures form two independent 3/2-wavelength RF cavity circuits; each is made up of an upper ½-wavelength cavity, a center ½-wavelength formed by the tube, and a lower ½-wavelength cavity. The lower grid-cavity is RF-excited with coupling loops, and the upper grid-cavity is a slave resonator. In the same manner, the upper plate-cavity is a pretuned slave resonator, and the lower plate-cavity is tunable. The lower plate-cavity also includes a coaxial ¼-wavelength low-impedance loading section which is connected to an output coax-to-waveguide RF transition. The RF transition then connects to the accelerator waveguide transmission line.

POWER AMPLIFIER AND DRIVER ENCLOSURE

The A-15040 final amplifier and the 2041 driver amplifier are both housed in a walk-in enclosure. The enclosure is a shielded room, providing operating personnel protection from RF radiation and high voltage. It also houses: 1) the final amplifier and driver amplifier service rack; 2) the final-amplifier 1.5-volt, 2000-ampere filament supply; 3) the filament and bias supplies for the driver tube; 4) air blowers for tube seal and RF cavity cooling; and 5) the tube-cooling and high-voltage-isolating water connections. The front of this room is provided with an interlocked access door and a viewing window through which all equipment and high-level circuit meters may be viewed.

The room is serviced by the necessary water headers, power lines, high-voltage lines, interlock circuit, RF input coax, and output waveguide; all connections enter through RF-tight connection seals. The cavity-circuit tuning and other operating adjustments are accomplished remotely from a control console and control equipment racks (Fig. 1).

HIGH-VOLTAGE POWER SUPPLIES

The 14-kv plate voltage for the final and driver tubes is supplied from a unitized high-voltage, three-phase, full-wave rectifier utilizing six RCA 857-B mercury vapor tubes. This power supply will provide an output of 20 amperes through an LC filter comprised of a 0.3-henry reactor and a 300-μf fused capacitor bank. It was necessary to provide this relatively large amount of capacitance in the filter to insure an adequate availability of stored energy; this eliminates objectionable voltage droop on the video-pulse envelope and avoids objectional power-line pumping.

The 1.5-kv driver screen-voltage supply was also provided with a fairly large energy-storage capacitance to avoid excessive video-pulse envelope droop at the transmitter output.

HIGH-POWER TUBE PROTECTION

As the high-voltage power supply and driver amplifier screen supply contain a great deal of stored energy, the high-power amplifier and driver tubes must be protected from the possibility of having the power supplies dump large amounts of this stored energy into internal tube gas arcs or other tube faults. To avoid the passing of such damaging high energy into possible fault paths, fast-acting sensing and tube fault-protection circuits are used.

Fault-sensing (current) transformers were placed on the high-voltage buses leading to the tube plate and screen elements; the rate of change of currents is monitored by these transformers. When any abnormal current surge is sensed, a small thyratron is fired, triggering a large thyratron and an ignitron; the latter electrically short-circuits the screen and plate power supplies, dumping the stored energies into dissipating resistors. The protection-circuit tubes continue to conduct until the power supply circuit breakers are automatically opened.

The total time from the sensing of a fault to the removal of harmful voltages from the tubes is less than 10 μsec, thereby preventing damaging energies from entering the fault.

THE EXCITER MODULATOR

The exciter RF train begins with a highly stable VFO which covers a frequency range of 26.32 to 26.54 Mc. The output of this VFO is multiplied nine times and amplified to provide approximately 10 watts to drive an RCA Type 6161 tube used as a doubler. The doubler drives another RCA 6161 as an intermediate power amplifier that, in turn, drives an RCA type 6181 tube operated as a grounded-grid cathode-modulated amplifier. The 6181 provides output power up to 1200 watts at 475 Mc. The modulation is supplied by eight type 6146 video modulator tubes in parallel; the combination provides excellent video linearity and video frequency response.

CONCLUSION

The RCA custom 400-kw transmitter was installed during the fall of 1961; acceptance tests were completed before the end of the year. The Cambridge Accelerator is operating and will soon be conducting nuclear experimentation.

The high-power RF equipment used at the Cambridge installation is the first of its kind to be built by RCA. A considerable future demand is anticipated for this type of equipment for accelerator applications requiring pulsed RF power sources. More diversified applications and higher output-power requirements are to be expected.

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3. T. M. Gluyas & E. H. Potter, "The TTU-1B, 1-KW UHF-TV Transmitter," *Broadcast News,* pp 22-31, May-June 1953.

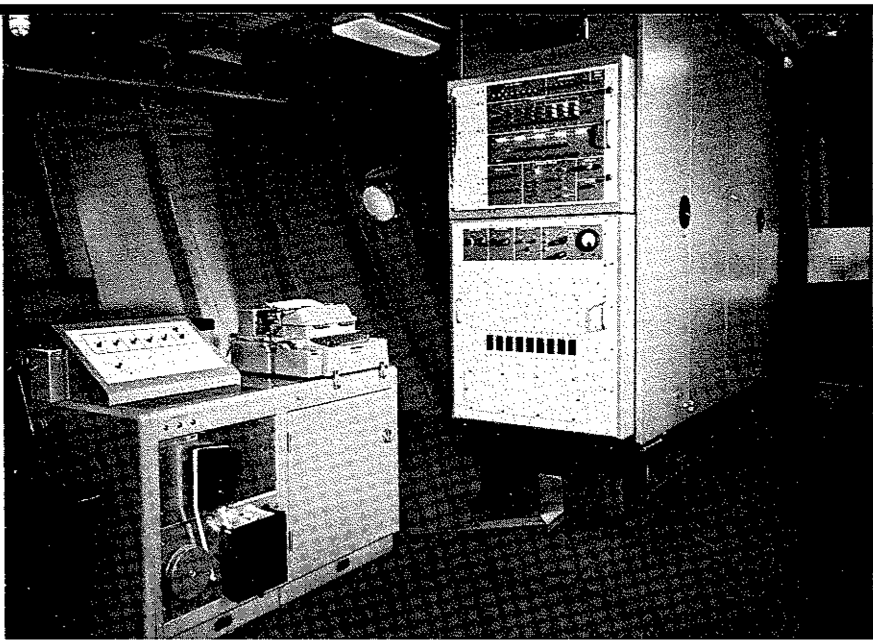

Fig. 1—The RADAP computer cabinet showing the control panel, power distribution panel and circuit breakers. Also shown is the auxiliary console housing the flexowriter, paper-tape punch, teletype read head and special AGENA-RANGER controls.

RADAP
. . . A SHIPBOARD DIGITAL COMPUTER

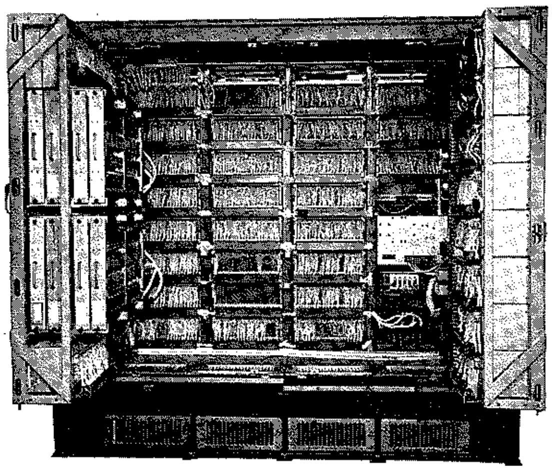

Fig. 2—Full view of the internal logic wiring of the computer. The random access memory is shown at the bottom right and the eight modularized instruction-program trays are shown in the swinging door frame on the left.

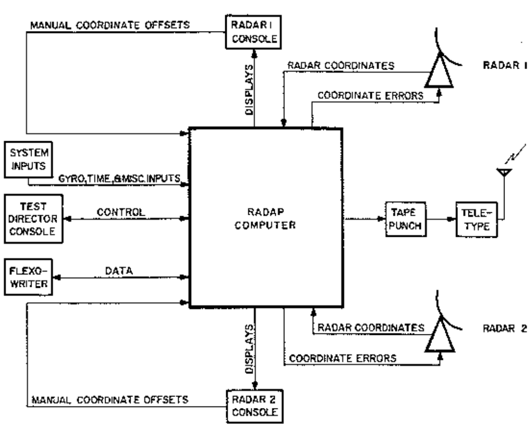

Fig. 3—Simplified block diagram of the computer-radar system.

The versatile RADAP computer is an important factor in making the DAMP ship (the USAS American Mariner a floating instrumentation center for the Atlantic Missile Range) one of the most sophisticated tracking stations in the world. RADAP's capabilities are at the forefront of systems combinations of radars and digital computers.

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The use of a digital computer as a mate for a radar is today an important element in advanced radar systems. Historically, analog computers and special-purpose digital systems have been combined with radar in, for example, fire-control and missile-command systems since World War II. The first major combination of a complete digital-computer system and a large radar at RCA was in the BMEWS tracking-radar data-takeoff subsystem; here, a medium-speed digital computer, known as RADCON, provided the real-time processing of radar data. This computer in its basic form proved suitable as a shipboard acquisition director, and has been used for this and other varied tasks in the operation of an improved version of the *USAS American Mariner*, as a part of the Down-Range Anti-Missile Measurement Program (DAMP).[1]

Some of the digital-computer work performed aboard-ship by the radar data processor (RADAP) includes:

1) radar designation from orbital parameters,
2) superimposition of various digital scan functions on the radar designation,
3) computation of orbital parameters from radar "on-track" data,[2]
4) determination of ship's position from TRANSIT satellite data,[3]
5) near-real-time data transmission of radar information during AGENA-RANGER moon probes,
6) check out and calibration of other radar subsystems.

The RADAP computer subsystem installed and checked out on the DAMP ship plays an important part in the ship's operation as a floating laboratory and tracking station in the Atlantic Missile Range (Figs. 1 and 2). RADAP employs a central solid-state digital computer having special input-output circuitry to assure a compatible integration into the existing shipboard system.

Fig. 3 illustrates how RADAP fits into the radar system in a closed-loop.

RADAP DESIGN

The central computer and input-output logic, designated by RCA as the FM 4402, utilizes approximately 5300 transistors on 670 modules. It consumes approximately 11 kw of power and has a delivered weight of 3800 pounds. The central computer utilizes a 27-bit, fixed-point arithmetic unit consisting of a sign bit and 26 bits of magnitude. The speed characteristics of the machine are: 16-μsec *add*, 146-μsec *short multiply*, 276-μsec *long multiply*, and 296-μsec *divide*. An additional 4μsec are required whenever address modification is required in the instruction. A 1024-word random-access, coincident-current magnetic memory (expandable to 4096 words) supplies temporary data storage and input-output buffering. An additional memory capacity of 4096 words is provided for instruction storage. A unique feature of this computer is the distinction between the instruction memory and the random-access data, memory—the instruction memory is nondestructible, which distinguishes this machine from the ordinary core-memory parallel computer. In effect, the random-access memory serves as a scratch pad for temporary data storage, while the instruction memory allows for wired programs. An extremely high degree of program integrity results, since transient errors or power failures cannot cause permanent loss of program information. This feature is particularly valuable in fixed-program solutions of data-system problems involving high real-time reliability. Flexibility in changing programs is provided by modularizing the instruction memory so that as many as 8 groupings of 512 instructions can be individually plugged into the machine.

The peripheral equipment provided with this computer consists of a flexowriter for special input-output data and a paper-tape punch for special data readouts. A *program-interrupt* feature is included to enable the program to be synchronized to the external timing system of the ship. Most real-time system data available every 10 msec is accepted at this rate; remaining data available under program control is treated as addressable locations. The output of computer data to the radars is at a 50-msec rate. This rate was selected as a compromise between the need to allow the computer enough real time to perform the required computations—and the need to maintain radar stability and reasonable radar servo bandwidths.

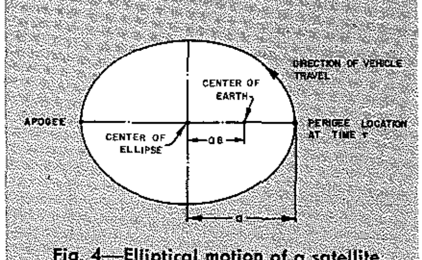

Fig. 4—Elliptical motion of a satellite.

MODES OF OPERATION

The DAMP ship now uses all of the modes of operation mentioned in the beginning of this paper. These are discussed in the following sections.

The Designation Program

The RADAP computer utilizes equations of elliptic motion to designate two radars to the flight path of a free-flight missile or satellite. These equations require the following six classical elements of an orbit:

- a, semimajor axis of the elliptical trajectory;
- e, eccentricity of the ellipse;
- i, angle of inclination of the ellipse to the celestial north pole;
- ω, angle which the perigee point of the ellipse makes with the equatorial plane;
- Ω, angle measured on the equatorial plane between the direction of the vernal equinox and the point where the satellite or missile crosses the equator in a south to north direction; and
- τ, time of perigee passage.

Figs. 4 and 5 illustrate the relation of these elements to the earth, using the earth as a focus of an orbital ellipse. Orbital elements are received by teletype from a Cape Canaveral site computer just prior to the ship's radar acquisition time and are read into RADAP via the flexowriter. Such data represents predicted elements or elements computed by Cape Canaveral based on inflight data received from uprange radar stations. The DAMP ship, normally being near or slightly uprange from the impact point, receives the elements minutes before the missile comes within range; in these few minutes, the data can be read into the RADAP. The radars are then designated to the dynamic space point in range, azimuth, and elevation coordinates in order to acquire the vehicle. As mentioned previously, the extreme precision of the RADAP computer is at a maximum when the computer is used within the radar loop. Therefore, designated coordinates are not directed "open loop" to the radars, but rather by error differences fed to the radar servos.

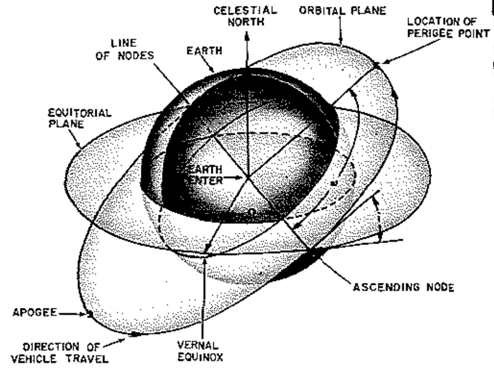

Fig. 5—Location of an orbital plane in space.

These error differences occur between the existing range and angle positions of the radar and the positions to which the computer is directing the radar. Included in the error loops are other influences such as operator offset controls, scans, and ship's motion. The RADAP computed designation data also includes these subtle corrections: index of refraction, the earth's nonspheroid shape, and the earth's solar rotation.

The Scan Program

This program is interrelated with the normal designation program in that it generates points offset from those based on information generated by the orbital elements. These "scan-generated" points form a pattern around the computed dynamic space-point supplied by the computer's designation program. Thus, a higher probability of acquiring the vehicle results, since more spatial area is covered by the radar beam around the theoretical position. Typical scans being used by the DAMP ship include spiral, circular, vertical, and horizontal ellipses. A high degree of flexibility has been built into the scan-generating capability of the computer because of the "technique-development" nature of the DAMP program. Such flexibility is attained by generating scans in the computer in accordance with general equations in which constants can be read into the computer via the flexowriter; based on the constants available for selection, a wide variety of scan patterns can be generated. The scan equations used in RADAP programs are:

$$T = (C_1 + C_2\, t) \sin (C_3\, t + C_4)$$
$$E = (C_5 + C_6\, t) \cos C_7\, t$$

By methodical selections of values for the constants C_1 through C_7 with the real time t, generalized scan patterns can be developed in relation to the traverse T and elevation E angle offsets. Therefore, RADAP easily generates bow ties, unsymmetrical spirals, tilted ellipses, lissajous patterns, lines, and any number of other geometric patterns with various shapes, sizes, rates, and periods. The RADAP computer memory receives six sets of scan constants via the flexowriter, and the computer is available to the radar control operator who may select instantaneously any one of six different scans. The other radar in the system has independent selection as to what scan it may use.

The On-Track Program

The execution of this program takes place once the radar acquires and locks onto the target. At this stage, the computer is not directing the radar; however, the computer accepts the radar input coordinate data and utilizes such information to compute a new set of orbital elements. The computer continually smoothes the data from the tracked vehicle until enough information is available to compute a new set of orbital elements; the time required by the computer to compute an optimum set of elements is approximately 25 seconds. Since there is a possibility that the radar may lose track in less time, the computer automatically allows for a minimum period of 13 seconds.

The test director is automatically notified as soon as these elements are computed, or when a radar track is lost. The director then has the option of choosing the newly computed elements for re-acquisition or using the elements previously utilized in acquiring the vehicle.

The AGENA RANGER Program

This is a special program designed for use in NASA AGENA RANGER moon-probe missions (Fig. 6). The DAMP Ship must acquire the vehicle, and track it before, through, and beyond its earth-moon–orbit propulsion stage. The radar trajectory data must also be transmitted by DAMP to Cape Canaveral in near real time (within 20 to 30 seconds) so that South African and Australian deep-space-probe tracking devices can be given up-to-date and accurate designation data.

The RADAP computer is specially programmed to punch out onto paper-tape such data as real time of day, range, and stabilized azimuth and elevation data. All information is automatically fed into a teletype transmitter for transmission to Cape Canaveral. RADAP can also be requested to punch out the radar coordinate data that existed at the instant the propulsion stage burned out, the time of burnout, and the latitude and longitude of the ship. As AGENA RANGER missions progress, it is contemplated that the RADAP program will be modified to yield not only coordinate data but also orbital element data of the moon-bound space trajectory.

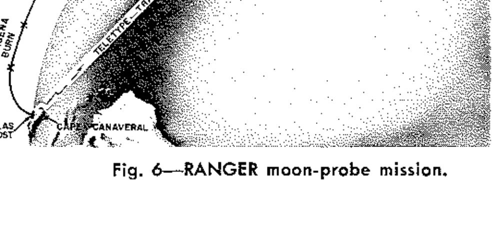

Fig. 6—RANGER moon-probe mission.

TRANSIT Navigation Program

Since the ship is quite often located in remote oceanic locations, the uncertainty of the ship's position has always been a problem. The location of the ship from the vessel's sextant is generally adequate for target acquisition, but is very critical for obtaining precise trajectory information. A satellite-navigation system was installed on the ship to detect the TRANSIT satellite's doppler on two frequencies and record the data with accurate time. Such data is then flexowriter-fed to RADAP.

The computer has information previously stored in it concerning the orbital parameters of TRANSIT, as well as the approximate position of the ship. The computer then begins an iterative process of calculating doppler curves to fit the incoming data and to place corrections on the assumed ship's position. This is iterated with continuous printouts of the ship longitude and latitude calculations. In due course of time position calculations converge to stable values and the computer operator terminates the program; this system determines the ship's position to within 1 mile.

Checkout and Calibration Program

Although RADAP is primarily an operational real-time computer, and used for navigation problem solutions, it is also used aboard ship as a tool in checkout and calibration of other subsystems of the ships radar complex. The checkout program is normally executed before and after mission, as follows:

1) check out the precision analog-digital converters used in the shipboard recording system;
2) check out and calibrate the radar wide-dynamic-range instrumentation receivers;
3) calibrate signal-to-noise ratio vs. wide-dynamic-range voltages during preshoot balloon tracks;
4) calibrate the radar performance factor during a postshoot balloon track; and
5) checkout the radar angle servos for operation integrity.

SUMMARY

All of the programs mentioned have been functioning in the ship's operational system. The advanced AGENA RANGER program has already been operated with complete success, as were the *designation* and *scan* programs now being used as the ship's prime means of acquisition.

The TRANSIT navigation, on-track and checkout and calibration programs are also contributing greatly to the shipboard operation system. This portrays only the beginning of concerted effort to develop even more sophisticated radar-computer systems.

To the writer's knowledge, RCA has the distinction of developing the *first operational digital-computer radar designation system* programmed with *orbital-element* and *digital-scan* capabilities. This, coupled with the other real-time, scientific, and checkout capabilities, has aided the DAMP ship in becoming one of the most advanced and versatile tracking stations in the world.

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THOMAS J. BURKE received his BSEE degree from Villanova University in 1951 and his MS from Drexel Institute of Technology in 1958. From 1951 to 1953 he worked on microwave repeater and terminal equipments at Philco Corporation and on development of frequency crystal test devices and frequency control equipment at Lehigh Valley Electronics. He joined RCA at Camden in 1953, as a design engineer, and worked on the development of a submarine direction bearing receiver. He transferred to the Moorestown Missile and Surface Radar Division in 1955 where he worked on the design and development of TALOS data-handling equipment and the BMEWS digital computer for tracking-radar data take-off. In 1960, Mr. Burke became Project Leader of DAMP data handling equipment, assuming development responsibility of the following shipboard equipment: a digital computer, digital and video analog recording devices, and the complementary reduction-center playback and analysis equipment.

THE DaSpan HI-SPEED T-R UNIT

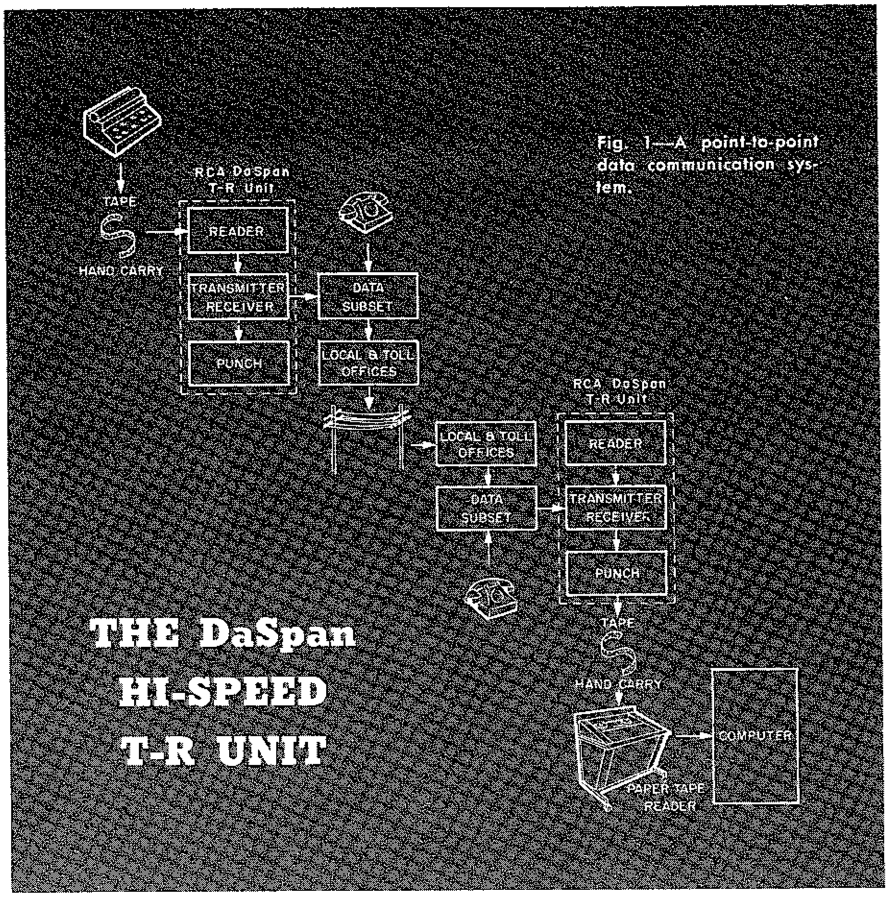

Fig. 1—A point-to-point data communication system.

The RCA DaSpan program is concerned with the development of equipment for point-to-point data communications, in order to provide computer users with an extension of data-processing capability. The Hi-Speed T-R Unit is a 100 character/sec data transmitter-receiver. With T-R Units installed at locations remote from the computer center, large volumes of data can be collected and transmitted to the computer—with speed, accuracy, and a minimum of operating attention.

JAMES J. O'DONNELL, Ldr.
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Electronic Data Processing, Camden, New Jersey

In the past decade, the growing use of electronic data-processing equipment in the day-to-day operations of government, commerce, and industry has created a demand for improved data-communication facilities to bring in the raw data from its source, rapidly and accurately.

Data communication, the art of sending and receiving information in the form of pulses arranged in code groups, traditionally has been offered in the form of teleprinter service. This service presently uses a 5-element code and gives an operating speed of 10 characters/sec or 100 words/min. To make this service economical, channels of minimum bandwidth are derived from voice-quality lines and assigned for teleprinter use. This, together with the widespread use of electromechanical keying (or modulating) techniques, limits transmission speed. In addition, the 5-element code precludes the use of redundant bits for accuracy checking. These limitations, imposed on the traditional subscriber of data communication facilities, caused computer users to look for a new data service offering higher speed and greater accuracy.

Working toward the same objective from another point of view were the nation's telephone and telegraph companies. To increase the revenue from their great plant investments, these companies were attracted to the use of their voice networks for data service during off-peak hours. It was perceived that the rapid expansion of direct-distance-dialing (DDD) over lines with a 3-kc bandwidth would permit a "dial-up" high-speed data service between any two network stations. Any office, plant, or warehouse that could be reached by voice telephone could be converted to data service by adding an auxiliary digital modulator-demodulator (data subset).

When the data subsets were proven feasible for coupling business machines into the DDD network, the telephone companies announced a new *Dataphone* service. The modulation rates offered on the DDD-network were 1200 bits/sec and higher on leased lines (no DDD network connection), which could be custom-tailored to the needs of the customer. Thus, rates in excess of 100 characters/sec with redundant coding were feasible. It still remained for business-machine manufacturers such as RCA to exploit this facility by offering their customers the terminal equipment required to extract data from cards, paper tape, or magnetic tape and to organize it for accurate transmission and reception via the data subset. An equipment called a data transmitter-receiver, or *T-R Unit*, performs all the functions described.

THE DaSpan PROGRAM

As RCA became a major factor in electronic data processing, the need for providing complete data service became

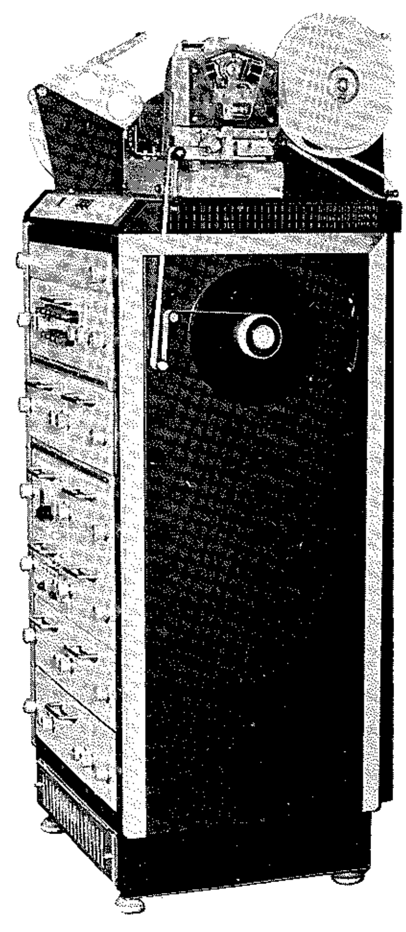


Fig. 2—The tape handling system for the punch is shown on the engineering model of the T-R Unit.

apparent. Thus, the DASPAN (data-span) program was launched to provide the terminal equipment and accessories required for point-to-point data communications. Punched paper tape was chosen as the input-output medium for the DASPAN family, since it is widely used and is easily prepared and handled. A low-speed transmitter-receiver was offered to customers to handle RCA's 7-level computer code over teleprinter or Dataphone lines at 7 characters/sec. At the same time, a development program was inaugurated to plan and design a high-speed data transmission equipment to utilize fully the speed capability of the DDD network and provide error checking. The Hi-Speed T-R Unit, a 100-character/sec paper-tape transmitter-receiver, was the result.

With the growing centralization of data processing, the need for greater accuracy and speed in sending large volumes of data between outlying offices and the data-processing center became paramount. Time consuming visual inspection was not possible when data entered the computer directly from remote points; accuracy was important to minimize computer stops on faulty data.

The T-R Unit satisfies this need for accuracy by using redundant transmission codes to ensure that data received at the computer site has a very low probability of error. Furthermore, the new T-R Unit offers an order-of-magnitude increase in speed over teleprinter service. Other significant features of the T-R Unit are ease of operation, low-power consumption, small size, styling compatible with modern office decor, and high reliability derived from use of transistor circuits field-tested in the RCA MUX/ARQ-2 Terminal.

Basically, the T-R Unit provides point-to-point, off-line data transmission and reception. Fig. 1 shows a typical application where data is prepared on a keyboard device and inserted in the tape reader for transmission to a remote point. The receiving DASPAN T-R Unit punches a paper tape which may then be inserted into the computer paper tape reader. Customers with teleprinter systems, only need to upgrade the primary trunks to high-speed service, since the T-R Unit accommodates teleprinter tapes. In an on-line application, one of the T-R Units is replaced by an RCA 301 computer with a subset access module.

T-R UNIT DESIGN

The logic and package design of the Hi-Speed T-R Unit were dictated by the need for flexibility to meet varying customer requirements. The equipment processes all of the existing tape codes (5-level to 8-level) and widths (5/8-inch to 1-inch). The teletype CX paper tape reader and BRPE punch provided this tape-handling capability. By simply rearranging the wiring on three program plug-ins, it is possible to process and check 5-level (teleprinter) through 8-level (FIELDATA) tapes whose data format may or may not have redundant bits. The rack and drawer design shown in Figs. 2 and 6 provide the space for expanding the equipment functionally. Three drawers of logic are required for the basic T-R Unit; and a fourth, containing optional logic, can be added when required. The drawers are easily removed for replacement, or for servicing by means of extender cables. Fig. 3 shows a drawer with a plug-in partially withdrawn.

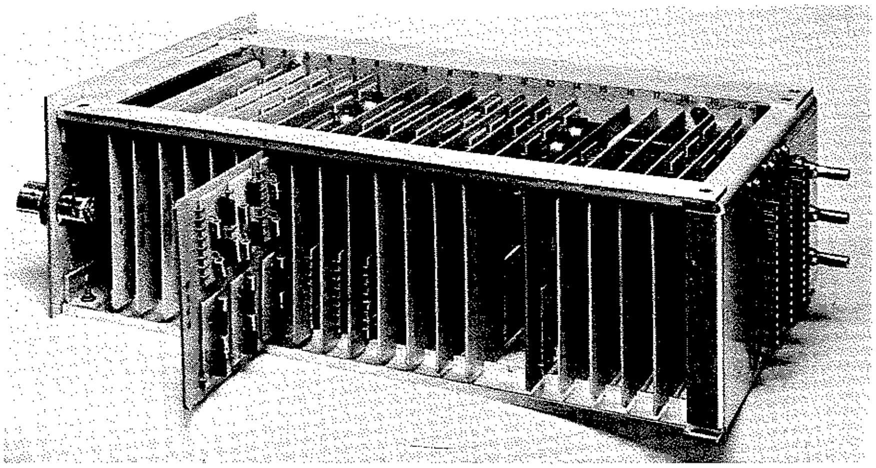


Fig. 3—The logic drawers hold up to twenty printed circuit plug-ins and permit easy plug-in replacement.

Signalling Codes

The signalling code used by the T-R Unit over the communication channel (data subset and voice-frequency line) consists of 8 bits/character (7 bits for data and 1 redundant bit to make the number of bits/character even). Studies of the noise and drop-out characteristics of telephone lines show that this character parity code cannot reduce the undetected error rate to an acceptable level. To further increase data reliability, a block check is performed at the end of transmission of each message or block of characters. The block length is not fixed and may be chosen by a customer to suit his needs. Internal multicharacter storage

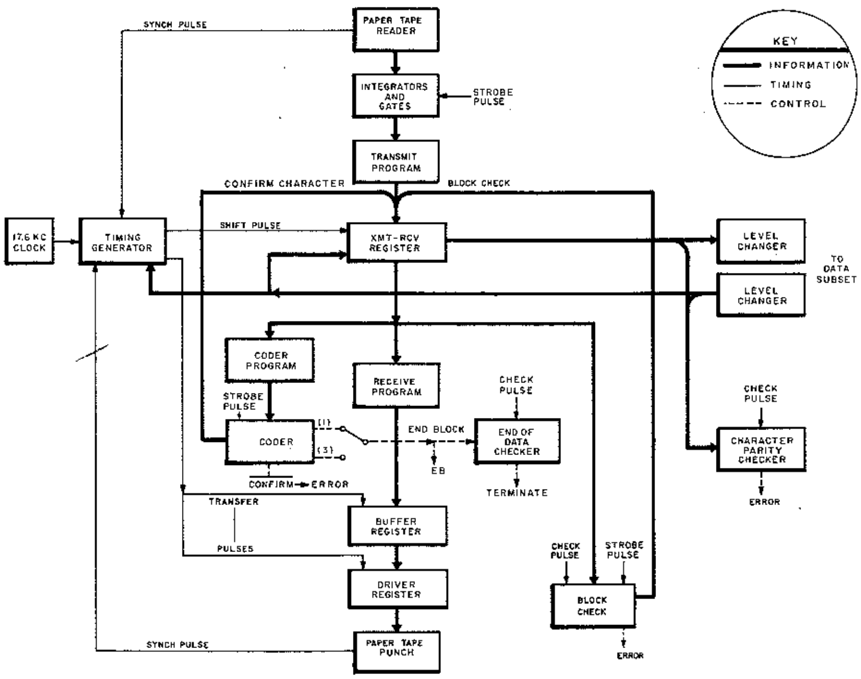


Fig. 4—Data flow diagram of the basic T-R Unit.

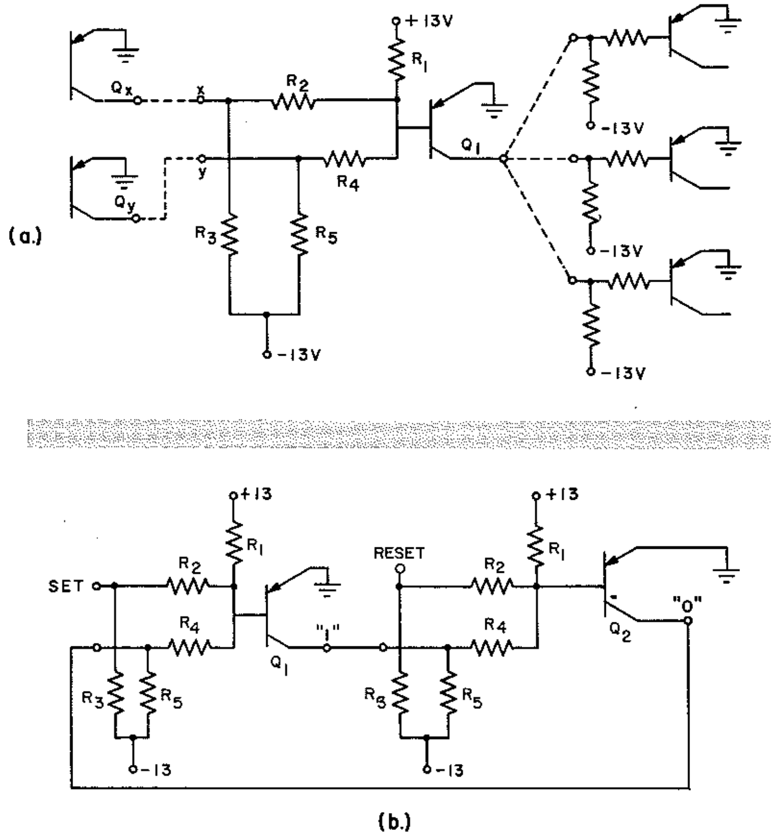


Fig. 5—a) Basic transistor circuit. b) Flip-flop made from the basic transistor circuit.

is not required for retransmission after an error is detected with this form of checking. Thus, it has an economic advantage over more-powerful schemes, since the input tape provides all the necessary storage.

Start-stop signalling is employed in the Hi-Speed T-R Unit to minimize the logic. Thus, an expensive, precision clock and associated components are not required. The T-R Unit logic adds start and stop elements to the data characters at the transmitter for framing. At the receiver, when incoming characters are framed, the start-stop elements are dropped. The characters on the communication channel are comprised of 11 bits: 1 *start* bit, 8 *data* bits, and 2 *stop* bits. (Characters of less than 8 bits are automatically filled out to that number for transmission). The stop element indicates the end of a character and is 2 bits long to account for all mechanical timing variations. Because the Teletype reader and punch handle tape at the rate of 100 characters/sec, a keying rate of 1100 bauds results.

Operating Procedures

The T-R Unit employs operating procedures which are compatible with the half-duplex DDD network. (Half-duplex means that transmission is limited to one direction at a time.) Echo suppressors are used by common carriers to attenuate impedance mismatch reflections in the telephone network. Accordingly, when going from *receive* to *transmit* to send an *acknowledgement,* turnaround delay sufficient to cover the reversal time of the echo suppressors is required. The T-R Unit uses a built-in delay of 460 msec to safely cover this turnaround, as well as the transcontinental propagation time.

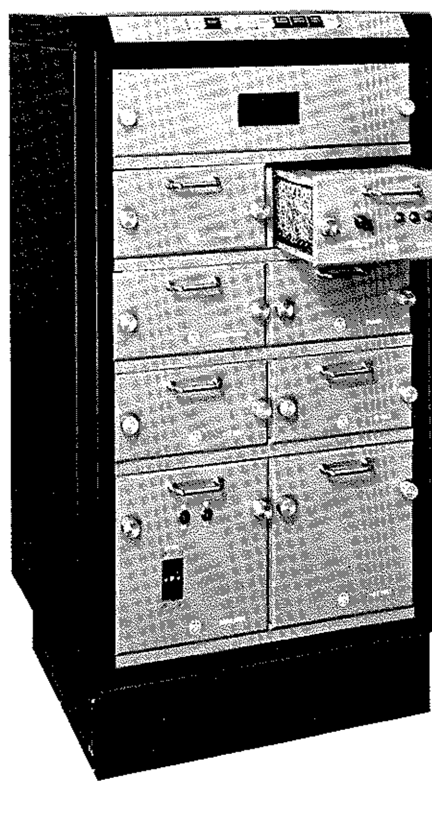
To transmit data, a normal call is placed using the handset to establish voice communication with the T-R Unit operator at the other end. If voice transmission is satisfactory, the channel may be used for data transmission by putting the subset in the data mode. By depressing the transmit control on the T-R Unit, data will be transmitted block-by-block and acknowledged by a *confirm* character sent by the receiving equipment in response to the *end block* character. An error detected at the receiving equipment will prevent return of the confirm character and cause both equipments to stop and display an error indication. This positive procedure assures that all errors are detected and that no information is lost in the loop. To handle the variety of special tapes and codes, the end block is programmable. It may be any single character, usually blank; or it may be a sequence of three identical characters.

Whenever an error occurs, each operator repositions his tape to the beginning of the block. The receiver operator then overpunches the erroneous block with *delete* characters. Release of the delete control signals the transmitter operator that he may start his T-R Unit. Indicators, controls and interlocks ensure that this rollback procedure is followed in the proper sequence.

For receiving, blank tape is mounted on the supply reel, threaded through the punch, and attached to the take-up reel. The supply reel holds up to 1000 feet of tape and uses a rim-brake mechanism that senses tape tension to supply tape on demand. The take-up reel is motor driven with a slip clutch to maintain tension.

For transmitting, up to 1000 feet of punched tape may be mounted on the supply reel, threaded through the reader, and attached to the take-up reel. Tape is controlled as is done for punching; tight tape or broken tape is sensed and fault indications given. Provision is made to read short lengths of tape, 6 inches or more in length, without using the reels, and without giving torn or tight tape indications. Fig. 2 shows the output punched-tape handling system used in the engineering model.

Fig. 6—The T-R Unit used with the Remote Terminal is shown with the Selector drawer partly removed for inspection of the wiring. The lower four chassis contain the power supply.



Logic

The data flow through the T-R Unit is shown in Fig. 4. In the *transmit* mode, bit-parallel data are read, integrated to guard against contact bounce, and strobed through the transmit-program plug-in into the *transmit-receive* register. The transmit-program plug-in permits parity bit insertion and some element rearrangement. A synchronizing pulse from the reader activates the character-timing generator. This generator is driven by a free-running oscillator (clock) and provides the input strobe pulse and the shift pulses for the transmit-receive register. Each of the 11 bits of a character in the transmit-receive register is shifted serially to the data subset through the interface level changer in 909 μsec—the reciprocal of the keying rate of 1100 bauds.

The clock rate was chosen to be a distortion-versus-cost compromise. Distortion is the time displacement of an element transition from the ideal. It is necessary to hold the equipment start-stop distortion under 10 percent, since the communication channel will significantly add to it. With the 17.6-kc clock chosen (56.8-μsec period), the output distortion is $(56.8 \div 909) \times 100 = 6.25\%$, thus within 10 percent. Correspondingly, the input margin or acceptable incoming distortion is $(50 - 6.25) = 43.75$ percent, where the ideal is 50 percent (since an element is sensed at its midpoint). The distortion, and consequently the margin, can be improved by increasing the clock rate and by adding stages to the timing chain, but this increases the cost.

As each outgoing character is staticized in the transmit-receive register, it is inspected for end block. By means of the coder program plug-in, any character or sequence of three identical characters can be recognized by the coder as end block. Decoding of an end block from the input tape causes the transmitting equipment to stop and wait for the confirm character. If this is not received after the 460 msec delay, an error is indicated. Each character is checked for parity serially at the output of the transmit-receive register by the character parity checker. Although character parity is checked, only failure to receive the confirm character (usually end block) from the receiving equipment will stop transmission. The character parity-error indication only serves to indicate that the error originated in the transmitter or the input tape.

In the receive mode, the same transmit-receive register is used to staticize the incoming serial data. Detection of the start element in the incoming data causes the timing generator to advance data into the transmit-receive register. The character is held in the transmit-receive register until the buffer register is freed. Since the punching cycle is independent of data arrival, the buffer register stores an incoming character until it is called for by the driver register. The punching magnets are operated by driver circuits gated by the output of the driver register and by a synchronizing pulse from the punch. Transfers from register to register are made under control of the same pulse.

The coder and parity-checking circuits used in the transmit mode also serve in the receive mode. Bit-serial characters entering the transmit-receive register are inspected by the character parity checker. After end block is detected in the coder, a block check is performed and the communication channel is seized for transmission of the confirm character. After the 460-msec delay, if there are no character parity errors, no block errors nor tape faults, the confirm character is transmitted and the loop closed.

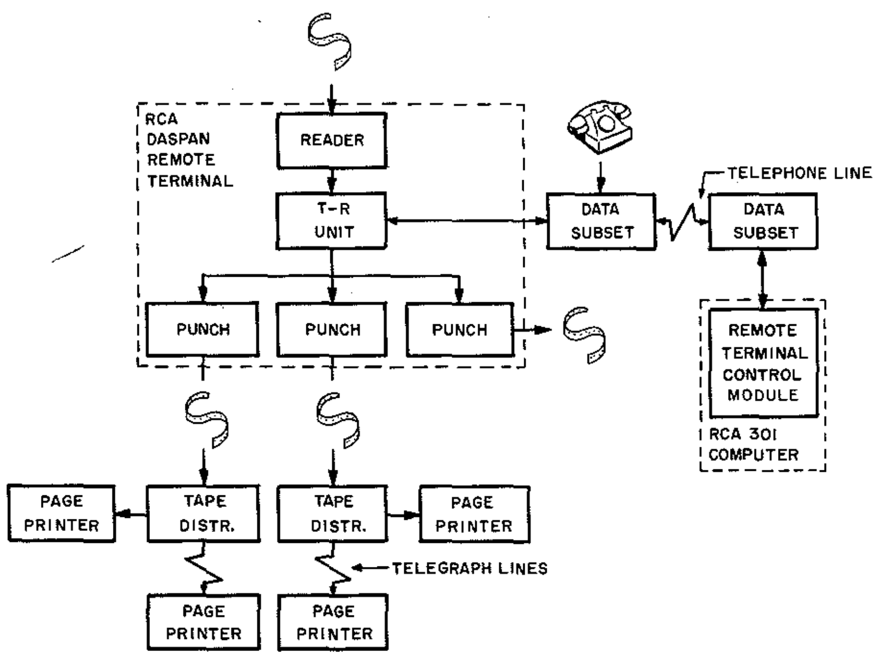
To indicate the end of data, a block consisting of any single character followed by end block is employed. When the receiving equipment senses this block, the confirm character is sent as usual and the unit goes to *standby* and indicates the end of transmission. The transmitting equipment, upon receipt of the confirm character, terminates transmission and goes to the quiescent (receive) mode. After resetting the receiving equipment and depressing the transmit control, transmission proceeds in the reverse direction.

Transistor Circuits

Most of the T-R Unit logic is implemented with one basic transistor circuit. This circuit (Fig. 5a) requires two voltages, has a logical gain of 5, and exhibits all necessary logical properties. Note that if either driving transistor (Q_x or Q_y) is cut off, Q_1 will conduct due to base current in R_2-R_3 or in R_4-R_5. Thus, the *or* function is provided. Conversely, Q_1 will be cut off only if Q_x and Q_y both conduct and raise inputs x and y to ground level. This achieves the *and* function. Use of only one input provides the *not* function. Cross connection of two similar circuits (Fig. 5b), produces a flip-flop.

The advantages of this circuit over conventional *nor* circuits using resistor-coupled transistor logic (RCTL) are the elimination of the collector clamp diode and clamp voltage, and a reduction in power dissipation by elimination of the collector load resistor. In conventional RCTL circuits, the collector resistor is selected to drive the maximum number of loads and thus dissipates constant power, regardless of the number of loads actually connected. In addition, by moving the collector load resistor from the collector circuit of the driving transistor to the base

Fig. 7—The makeup of the Remote Terminal and its place in an on-line system.



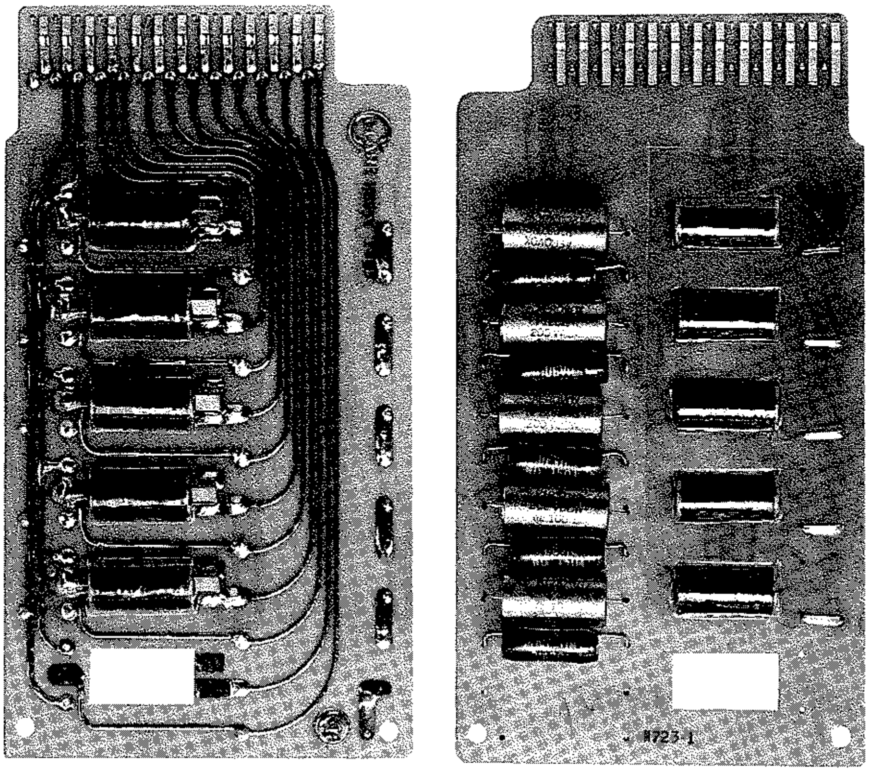


Fig. 8—The line switching for punch selection is done by plug-in packaged relays; five relays are shown.

circuit of the driven transistor, its value may be increased. Thus, each logic element requires only enough power for its own operation, and power is not wasted in those stages that are not fully loaded. Two such circuits are packaged on one submodule with provision for up to ten submodules on one printed-circuit plug-in.

REMOTE TERMINAL

The first expansion of the basic T-R Unit was into an equipment called the *Remote Terminal.* The Remote Terminal permits on-line remote inquiry to an RCA 301 System. In this application, the T-R Unit acts in response to computer command and punch-selection characters in the *reply-back* data. The ability of the basic T-R Unit to recognize and terminate blocks provides the logic which was expanded to handle the five additional characters required in the on-line application. These characters signal *go-to-transmit* and *go-to-receive* and select one of three output punches. The latter function enables distribution of received data from the remote point to subsidiary points via telegraph lines. The command and punch-selection logic were packaged in a drawer located in the unused portion of the basic unit. The T-R Unit used in the Remote Terminal is shown in Fig. 6. The paper-tape reader and up to three punches are separate and table-mounted or console-mounted.

Fig. 7 shows operation of a system employing the Remote Terminal. Messages are entered into the system on paper tape via the Remote Terminal reader. When the computer is ready to receive data, the go-to-transmit command is sent by the computer's control module to the T-R Unit via the telephone line and data subset. The T-R Unit responds with the requested block of data and receives a confirm character from the *Computer Control Module* for each correct block. Computer transmission to the remote terminal is preceded by a go-to-receive command which causes the T-R Unit to switch from the transmit to the receive mode. Each correct block of data is confirmed by the T-R Unit.

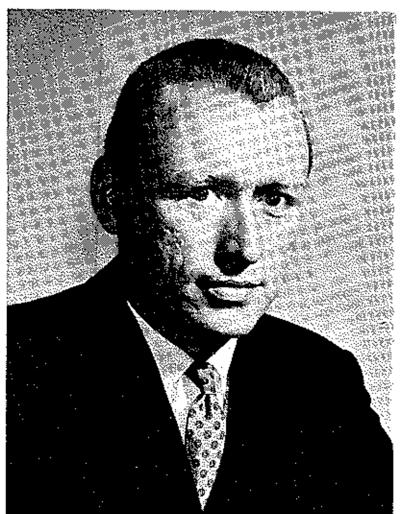
Each block of data sent by the computer is preceded by a selection code which enables the Remote Terminal T-R Unit to switch to one of the three punches via a transistor-controlled relay matrix. The perforated tape can be looped to a tape distributor for relay to subsidiary points at 10 characters/sec. A tape-feed command block is employed to create tape slack at any punch. This releases the tape disconnect on the associated tape distributor so that the last block can be processed. The relays used to couple the magnet drivers to the proper punch have mercury-wetted contacts. Fig. 8 shows such a plug-in with five relays.

SUMMARY

The Hi-Speed T-R Unit offers a high grade of subscriber data service. The speed and accuracy provided are important where information is to be entered into a data-processing system. The packaging and logic flexibility permits several product features such as card input-output, unattended operation, and high-speed remote printing.

Acknowledgment is hereby given to the personnel who successfully completed the DASPAN engineering program: E. W. Marshall, A. G. Caprio, N. C. Lincoln, E. J. Hoffman, and J. Renauro.

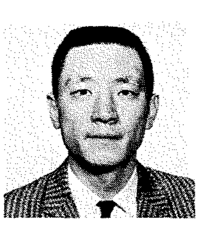
JAMES J. O'DONNELL received a BEE degree from Manhattan College, New York City, in 1956. Previously he had spent 16 months in active duty with the USAF as a radar technician; and had been employed by the General Electric Company, Syracuse, New York, as an engineering trainee for the summer of 1955. Mr. O'Donnell was assigned to BIZMAC Engineering in November, 1956 from the RCA training program. He worked on the Transcribing Card Punch and card equipment for the RCA 501, 301, and 601 systems. Mr. O'Donnell was transferred to the DCCP Engineering Dept. of EDP in 1960 and appointed Leader in the Data Communication Systems group in December. His group is presently working on point-to-point digital communication equipment such as DASPAN, MUX/ARQ-2, SCHARQ and TAT/MUX. Mr. O'Donnell is a member of Eta Kappa Nu.



Engineering and Research NOTES

BRIEF TECHNICAL PAPERS OF CURRENT INTEREST

EDITOR'S NOTE: This new feature, inaugurated in this issue, provides a media for publication of short technical papers—generally, less than 1000 words, with one or two small illustrations allowable. Especially appropriate are timely engineering techniques, new developments, and similar information that ordinarily would not warrant a full-length RCA ENGINEER paper. Normal approvals are required. Submit through your Editorial Representative.



A Low-Noise KU-Band Parametric Amplifier

by H. B. YIN, *Missile and Surface Radar Div., DEP, Moorestown, N. J.*

A nondegenerate parametric amplifier has been developed for operation in the KU-band. It was pumped at 35 Gc and utilizes an RCA gallium arsenide varactor diode having a junction capacitance of 0.3 pf and a cut-off frequency in excess of 200 Gc at —1 volt. A ferrite circulator separates input and output. An amplifier noise figure of 5.8 db was measured at a gain of 15 db and a pump power of 150 mw. No external bias was applied. Over-all size is 2 x 2 x 1½ inches (Fig. 1).

The amplifier construction consists of two major parts: the *bottom,* milled from a solid brass block, formed the waveguide circuitry in a cross-guide configuration, and the *top plate* forms the cover. The edge along the waveguide walls was raised so that positive contact could be made with the mating cover plate. The sizes of milled waveguide coincide with those of RG-46/U and RG-91/U. The block provided tapped holes to receive flange connectors. The pump line was a tapered ridge waveguide with the varactor diode seated in the center. The height of the ridge is such that no post is required for mounting the diode, eliminating the extra inductance introduced by such a post and achieving a maximum field concentration across the varactor diode.

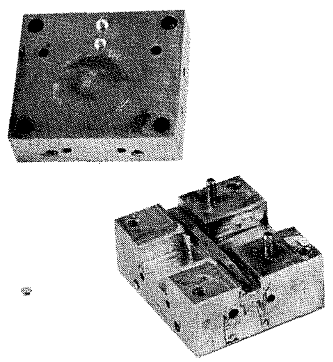


Fig. 1—KU-band paramp, 2 x 2 x 1½ inches, and the GaAs varactor diode.

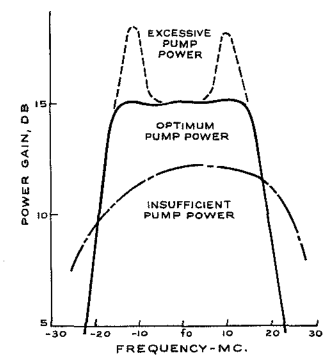
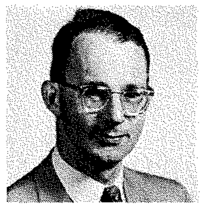


Fig. 2—Passband characteristics.

A novel, small deflecting diaphragm of thin beryllium copper is mounted on the top plate of the amplifier. Positive contact with the varactor diode was assured by pressing the diaphragm with a rubber cushion from the outside of the cover plate, avoiding excessive force that might damage the varactor diode. This amplifier construction achieved minimum soldering to reduce circuit loss, easy mounting and positive contact to varactor diode, and ease of fabrication.

By providing a double-tuned circuit external to the amplifier in conjunction with two tuning screws at the input, a typical triple-tuned bandpass characteristic was obtained (Fig. 2). Bandwidth at 3 db points was 35 Mc, and the passband was flat within 0.5 db over 30 Mc. When the pump power was changed from its optimum value, the passband varied as shown. This amplifier was also tested while cooled with dry ice. An improvement of 0.5 db in noise figure was observed, indicating that a considerable lower noise figure may be possible with RCA varactor diodes by cooling to liquid-nitrogen temperatures.

[*This work was done under contract AF-33(600)-42616*]



A Simple, Portable Ultra-High-Vacuum System for Lab Experiments

by DR. R. E. HONIG, *RCA Laboratories, Princeton, N. J.*

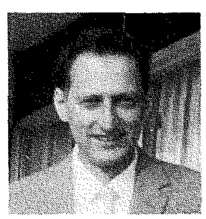
The RCA Laboratories effort on new devices is making increasing use of thin evaporated films of magnetic, superconducting, or semiconducting materials. To obtain the characteristics desired, many of these films require an extremely good vacuum during the evaporation step. Also, surface conditions must be controlled for satisfactory device performance, yet studies of surface conditions are often meaningless if there is a layer of gas on the surface. With conventional vacuum systems there is no time to make measurements because such a gas layer collects in a few seconds after the surface is cleaned.

Since gas is given off steadily from the inner surfaces of any vacuum system, the only way to get a good vacuum is to use pumps with very high pumping speed. This has been accomplished before with large and expensive equipment. But now, a portable vacuum system developed at the RCA Laboratories is small enough to be mounted on a movable "tea wagon," yet has a pumping rate of 800 liters/sec, which is about 100 times that of other systems of comparable size, and will provide a pressure as low as 10^{-11} mm-Hg (about 10^{-14} atmosphere).

The new system is made entirely of metal and can therefore be baked to a high temperature to eliminate most of the residual gas. It uses no conventional mechanical or diffusion pumps, which would inevitably contaminate the system with oil or mercury. Instead, a cooled granular adsorbent (a "molecular sieve") is used to provide a rough vacuum, followed by an ion-getter pump that ionizes the residual gas and attracts these ions to electrodes where they adhere. The third pump (the most important) consists of a metal area cooled to the temperature of liquid helium. The condensation of the gases on this cold surface provides the unusually fast pumping speed and the very low residual gas pressure.

In addition to a gauge that measures the total pressure of the gases in the system, a small mass spectrometer gives the percentages of all of the constituent gases. This information is often of great importance, for it permits a decision as to which gases are harmful and allows the processing steps to be continued until these are eliminated.

The simplicity, portability, and excellent performance of the new vacuum system makes it a valuable addition to laboratory equipment.



Square-Wave Filter Response

by I. BAYER, *Systems Lab., Surface Communications Div., DEP, New York, N. Y.*

Many digital transmission systems are designed for low bandwidth line operation, for which complicated filters are necessary. The state of the art today tends toward modular construction and the testing thereof. Since the filter, whether in modular form or otherwise, is essentially a sine-wave operation in an otherwise digital system, special tests and equipment are usually provided. Unfortunately, the

(Continued on next page)

action of the filter is usually desired to ± 1-percent accuracy. In many cases in production and field testing, this accuracy is not necessary. Under these conditions, the following system using simple digital equipment found in every digital test system, is utilized.

The system can generally be expressed as the response of a circuit to the high frequencies inherent in the leading and trailing edges of a square wave. To illustrate, assume a response as shown in Fig. 1, where F_1, F_2, F_3, and F_4 are in octave correspondence with each other. A square wave of frequency F_4, or some octave thereof, is fed into a binary counter chain and outputs tapped off at F_3, F_2, and F_1. These outputs are then fed into the filter, one at a time, and the output waveforms compared to those previously recorded using a known good filter. The waveforms will have distinctive shapes as well as varying amplitudes; i.e., suppose $F_4 = 1$ kc and $F_2 = 50$ cps. Since the edges of the 1000-cps square wave have much higher frequency components than are capable of getting through the filter, the output will be an integrated triangular wave of small amplitude. Using the 50-cps input, whose edges contain all frequencies within the response of the filter, with maximum energy at F_3, the output will be a square wave with overshoots at the leading and trailing edges. The amplitude of the square portion of the waveform will correspond to the amplitude at the 50-cps point of the filter response. All the other frequencies will have similarly distinctive configurations.

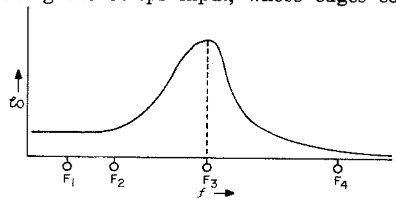


Fig. 1

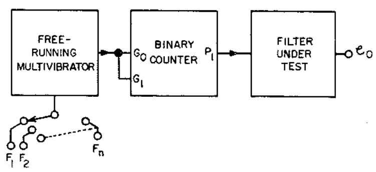
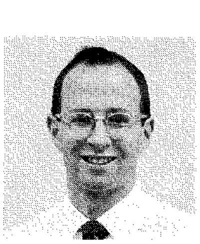


Fig. 2

There will be a small portion of the spectrum, $F_n \pm \Delta F$, that will give essentially the same output, plus or minus a few percent. Since this sort of accuracy is tolerable in this general test, it is possible that F_4, which feeds the binary chain, need not be an exact octave multiple of F_1, F_2, and F_3. The response waveforms will still be very useful. If a binary chain seems expensive or is unavailable in the test section of the system, a free-running multivibrator, with n switchable frequencies, feeding a binary counter as shown in Fig. 2, is all that is necessary.



Equalizing Parabolic Group Delay Without All-Pass Networks

by R. M. Kurzrok, *Systems Lab., Surface Communications Div., DEP, New York, N. Y.*

Parabolic group delay in the passband centers of maximally flat bandpass filters can be equalized using the conventional all-pass network, which provides compensating group delay and no amplitude discrimination. All-pass equalizers usually are lattice or bridged-*T* networks, often difficult to physically realize. The technique for equalization described herein does not use all-pass networks as equalizers.

Phase shift, Θ, in a bandpass filter that is a minimum-phase-shift network is:

$$\Theta = -\sum_{b=1}^{n} \tan^{-1}\left(\frac{X - X_{bi}}{X_{br}}\right)$$

Where: X = normalized frequency variable, X_{br} and X_{bi} are real and imaginary components of the pole positions (i.e., poles of filter transfer function), and n = number of resonant circuits. If group delay is defined as the derivative of the phase shift with respect to frequency, then:

$$d = \frac{1}{\pi \Delta f} \sum_{b=1}^{n} \frac{B_b}{1 + (A_b + B_b X)^2} \qquad (1)$$

Where: d = absolute group delay of the filter, Δf = the 3-db bandwidth of the filter, $A_b = 1/X_{br}$, and $B_b = -X_{bi}/X_{br}$. At the band center ($X = 0$), then:

$$d_o = \frac{1}{\pi \Delta f} \sum_{b=1}^{n} \frac{B_b}{1 + A_b^2} \qquad (2)$$

Letting Δd = the differential group delay at any normalized frequency X, then $\Delta d = d - d_o$.

For a maximally flat bandpass filter with *two or more* resonant circuits,

$$\Delta d_f \cong \frac{C X_f^2}{\pi \Delta f_f} \qquad (0 < X_f < 0.4)$$

Where: Δd_f = differential group delay of filter, X_f = normalized frequency variable of filter, f = frequency, f_o = center (i.e. resonant) frequency of filter, and Δf_f = 3-db bandwidth of filter.

For narrow-bandwidth filters, ($\Delta f_f / f_o \leqq 2\%$):

$$X_f \cong \frac{2\,|f - f_o|}{\Delta f_f} \qquad \text{Then:} \qquad \Delta d_f = \frac{4C\,|f - f_o|^2}{\pi (\Delta f_f)^3} \qquad (3)$$

This is a parabolic differential group delay function that is concave *upward.*

For a single-tuned circuit (i.e. maximally flat filter with one resonator):

$$\Delta d_e \cong \frac{-X_e^2}{\pi \Delta f_e}$$

Where: Δd_e = differential group delay of equalizer, X_e = normalized frequency variable of equalizer, f = frequency, f_o = center (i.e. resonant) frequency of equalizer, and Δf_e = 3-db bandwidth of equalizer.

For narrow-bandwidth equalizers ($\Delta f_e / f_o \leqq 2\%$):

$$X_e \cong \frac{2\,|f - f_o|}{\Delta f_e} \qquad \text{Then:} \qquad \Delta d_e = \frac{-4\,|f - f_o|^2}{\pi (\Delta f_e)} \qquad (4)$$

This is a parabolic differential group delay function that is concave *downward.*

For equalization, $\Delta d_f + \Delta d_e = 0$; then, substituting from Eq. 3 and 4 and rearranging:

$$\Delta f_e = C^{-1/3} \Delta f_f \qquad (5)$$

For maximally flat bandpass filters, Eq. 1 becomes:

$$d = \frac{1}{\pi \Delta f} \sum_{r=1}^{n} \frac{B_r}{1 + (A_r + B_r X)^2} \qquad (6)$$

Where: $A_r = csc\,[(2r - 1)/2n]\pi$

$B_r = -ctn\,[(2n - 1)/2n]\pi$

Eq. 2 becomes:

$$d_o = \frac{1}{\pi \Delta f} \sum_{r=1}^{n} \frac{B_r}{1 + A_r^2} = \frac{D_o}{\pi \Delta f} \qquad (7)$$

Using a parabolic approximation for differential group delay:

$$\frac{CX^2}{\pi \Delta f} \cong d - d_o \qquad (8)$$

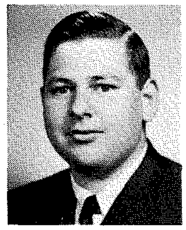
The constant C is selected at a value of $X = 0.2$. A table of values of C and D_o for n from two to eight resonators is:

n	2	3	4	5	6	7	8
C	1.414	1	1.083	1.236	1.414	1.604	1.799
D_o	1.414	2.000	2.613	3.236	3.864	4.494	5.126

This technique should be applicable to RF and IF amplifier chains in which single-tuned and double-tuned circuits can be readily used in alternate coupling networks.

Reference: 1) M. Dishal, "Dissipative Bandpass Filters," *Proc. IRE, 37,* Sept. 1949.

High-Power Silicon Epitaxial Varactor Diodes




by M. KLEIN AND H. KRESSEL, *Semiconductor and Materials Div., Somerville, N. J.*

High-power, high-frequency varactor diodes are fabricated by the diffusion of boron into n-type epitaxial silicon. The use of thin high-resistivity epitaxial layers on low-resistivity substrates produces devices having low series resistance and high breakdown voltage. After mesas are chemically etched, the diodes are mounted directly to the base of a unique package having very low thermal resistance. Contact is made by a strip of gold foil bonded to the top of the pellet. This type of contact is more rugged than the spring contact generally used by the industry in the fabrication of varactor diodes, and provides lower contact resistance.

Characteristics. Breakdown voltages between 150 and 200 volts are typical, but diodes having higher breakdowns, in excess of 250 volts, have also been fabricated. Breakdowns are usually sharp with very little leakage. Cutoff frequencies, measured at the specified breakdown voltage of 150 volts, are in excess of 25 Gc, with some diodes achieving cutoff frequencies greater than 75 Gc. *Of major importance* is that the power dissipation of the diode is greater than 5 watts (with a heat sink). This value, although conservative, *is higher than those of any diode available today.*

Typical values of capacitance for the diodes are in the order of 15 to 70 pf at zero bias and 1 to 7 pf at breakdown. Curves of capacitance as a function of voltage indicate that most of these diodes have nearly abrupt junctions. Diodes have also been fabricated with junction capacitances greater than 80 pf at zero bias, but these units had cutoff frequencies lower than those of the smaller devices.

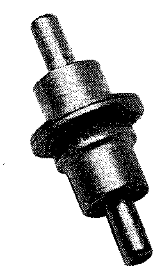


Fig. 1—RCA high power epitaxial silicon varactor diode (Dev. No. VD500 series).

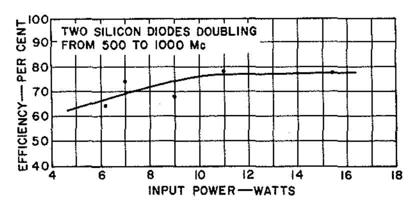
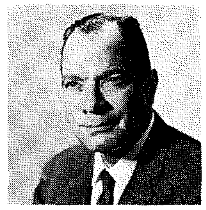
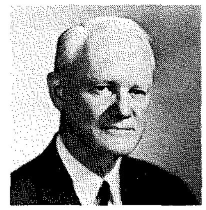


Fig. 2—Efficiency as a function of input power for two RCA silicon varactor diodes doubling from 500 to 1000 Mc. (Data courtesy of J. E. Saultz and R. Risse)

Applications. Several diodes have been used as harmonic generators in experimental circuits built by J. E. Saultz (DEP Applied Research) and R. Risse (DEP-ACCD). Used as doublers from 750 to 1500 Mc, two diodes in series have yielded 10 watts with 76 percent efficiency. In doubler service from 500 to 1000 Mc, an efficiency of 78 percent was achieved with an input of 15.5 watts. Other operating conditions are shown in Fig. 2. A *single* diode having a breakdown voltage of 350 volts was used as a doubler from 280 to 560 Mc. The output power was 7.1 watts with an efficiency of 62 percent; this performance is equivalent to that achieved with the *six* lower-breakdown diodes previously used.

Acknowledgement. The authors wish to thank Dr. A. Blicher for his valuable advice and Mr. M. Haley for his assistance in fabricating the devices.

Versatile New Character Generator for Computer Printout

by M. ARTZT AND C. J. YOUNG, *RCA Laboratories, Princeton, N. J.*

Printers to record the output of a computer fall into two general classes: 1) those in which completely formed letters are chosen and printed from cast type and 2) those which with a single "head," form any desired character by printing dots or line segments selected from a matrix of possible dots or segments. A typical matrix printer has a line of styli, each electromagnetically controlled, which is moved to scan a small raster and print successive vertical lines of dots to form a character. Any single-head printer needs a character generator to convert the coded output of the computer into signals that cause the proper dots to be printed. Existing character generators require complex circuitry to generate the signals, or to choose signals stored in some form of memory, and are therefore too expensive to be used with low-cost printers. In view of the interest in EDP and in DEP in printout systems, a very simple character generator for use with inexpensive, low-speed, single-head printers has been devised.

In the new generator, the sources of the character signals are lines with opaque and transparent segments, produced photographically on a glass mask which is outside of the face of an unmodulated, 3-inch cathode-ray tube. Each line on the mask is tailored to a specific character. A standard 6-digit code, which could be the output of a computer, causes the cathode-ray tube to scan the proper line on its face. The light from this scanned line is focused on the mask line corresponding to the character to be printed, and the light penetrating the mask strikes a large-area photocell to give the series of character signals. At present, each character is formed on a small raster scanned on a monitor tube, but the signals could control a single-head printer or the thin-window cathode-ray tube developed in RCA Laboratories for recording on Electrofax paper.

The present system is capable of generating 62 characters at a rate of 200 characters/sec, goals suggested by EDP, but the character rate is limited to this low value only because of our choice of a low-cost cathode-ray tube with a phosphor of relatively long persistence.

The new generator has a high degree of versatility. Minor changes would yield the seven simultaneous outputs needed for a typical seven-stylus printer. A different mask is all that is required to accommodate a different printer of higher or lower quality, i.e., one with more or less dots per character, or to change the type font produced by any such scanning printer. Many existing character generators would have to be rebuilt for either of these changes. Furthermore, calculations have shown that changing to a recently-developed, very-fast, ultraviolet-emitting phosphor in the cathode-ray tube, and to an ultraviolet-sensitive photomultiplier, would make the system capable of accepting character codes and providing character signals at the rate of 60,000 characters/sec. This rate would accommodate printout systems as fast as any yet developed or in design.

The new character generator will be combined with a low-cost, single-head serial printer which is being developed as a simplified version of our earlier multihead printer. In addition, the phosphor now used will be replaced by one with a faster decay and the new generator will be tested with the thin-window cathode-ray tube system that uses Electrofax paper for high-speed output.

PEN *and* PODIUM

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RCA VICTOR RECORD DIVISION

The Application of Electroforming to the Manufacture of Disk Records — A. M. Max: American Society for Testing and Materials Symposium on Electroforming, Dallas, Texas, Feb. 6, 1962

Technical Aspects of Disk Records — A. M. Max: Scientific Research Society, Sigma Xi Butler Univ., Indianapolis Branch, Feb. 21, 1962

Factors Which Influence the Structure of Electrodeposits — A. M. Max: New York Branch American Electroplaters Society, Feb. 17, 1962 and Wichita, Kansas, Joint Meeting American Society for Metals and American Electroplaters Society, Mar. 20, 1962

Plastics in Phonograph Records—C. J. Martin: *Journal of the Society of Plastics Engineers*, April 1962.

Factors Which Influence the Structure of Electrodeposits—A. M. Max: American Electroplaters Society; Cleveland Branch, April 6, 1962; Philadelphia, May 28, 1962.

NATIONAL BROADCASTING COMPANY, INC.

Television Standards Converter at NBC — E. P. Bertero: NAB Convention, Chicago, Apr. 1962

Interleave Sound — J. L. Hathaway: NAB Convention, Chicago, Apr. 1962

Color Kinescope Recording—V. J. Duke: NAB Convention, Chicago, Apr. 1962

Lighting for Color Television — E. P. Bertero and A. Walsh: NAB Convention, Chicago, Apr. 1962

BROADCAST AND COMMUNICATIONS PRODUCTS DIVISION

The Design of a New Solid State Tone Multiplex Equipment—F. M. Brock: Pennsylvania Electric Association, Jan. 1962

Directional Attachments for Microphones—M. Rettinger: Audio Engineers Society Ninth Spring Convention, Los Angeles, Calif., Mar. 21, 1962

Automatically Stabilized True View Radar—C. Moore: RTCM and CIRM Meeting, Atlantic City, N. J., Mar. 23, 1962

DATES *and* DEADLINES

Professional Meetings and Calls for Papers

Meetings

June 24-29, 1962: American Soc. for Testing Materials Ann. Mtg., Statler Hilton and Sheraton-Atlantic Hotels, New York, N.Y. *Prog. Info.*: ASTM Hqrs., 1916 Race St., Phila. 3, Pa.

June 25-27, 1962: 6th Natl. Conv. on Military Electronics (Mil-E-Con), IRE-PGME; Shoreham Hotel, Wash., D.C. *Prog. Info.*: J. J. Slattery, F316, The Martin Co., Baltimore 3, Md.

June 25-30, 1962: Symp. on Electromagnetic Theory and Antennas; The Technical University of Denmark, Oster Voldgarde 10G, Copenhagen K., Denmark. *Prog. Info.*: H. Lottrup Knudsen, above address. (*USSR expected to undertake two sessions.*)

June 27-29, 1962: Joint Automatic Control Conf., IRE-PGAC, AIEE, ISA, ASME, AIChE; New York Univ., University Hts., NYC. *Prog. Info.*: Dr. A. J. Hornfeck, Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.

June 28-29, 1962: 4th Natl. Symp. on Radio Frequency Interference, IRE-PGRFI; Del Webb, Town House Hotel, San Francisco, Calif. *Prog. Info.*: R. G. Davis, Dept. 58-25, Lockheed Missile & Space Co., P.O. Box 504, Sunnyvale, Calif.

July 2-6, 1962: Ionosphere Conf., Inst. of Physics & Physical Soc.; London, England. *Prog. Info.*: J. A. Ratcliffe, Radio Res. Sta., Ditton Park, Slough, Bucks, England.

July 9-13, 1962: 1st Intl. Conf. on Paramagnetic Resonance, IUPAP; Hebrew Univ., Jerusalem, Israel. *Prog. Info.*: Prof. W. Low, Dept. of Physics, The Hebrew Univ., Jerusalem, Israel.

July 16-18, 1962: Lunar Missions, ARS; Pick-Carter & Statler Hilton Hotels, Cleveland, O. *Prog. Info.*: B. Chifos, ARS, 500 Fifth Ave., New York 36, N.Y.

Aug. 14-16, 1962: Intl. Conf. on Precision Electromagnetic Measurements, IRE-PGI, NBS, AIEE; NBS Labs, Boulder, Colo. *Prog. Info.*: Dr. G. Birnbaum, Hughes Res. Labs, Malibu, Cal.

Aug. 15-17, 1962: Nuclear Propulsion, ARS, ANS, IAS, Naval Post-Graduate School, Monterey, Calif. *Prog. Info.*: B. Chifos, ARS, 500 Fifth Ave., New York 36, N.Y.

Aug. 21-24, 1962: Western Electronics Show and Conf. (WesCon), IRE, WEMA; Memorial Sports Arena and Statler-Hilton Hotel, Los Angeles, Calif. *Prog. Info.*: Dr. David Langmuir, % WESCON, 1435 S. La Cienega Blvd., Los Angeles 35, Calif.

Aug. 27-29, 1962: Conf. on Metallurgy of Semiconductor Materials, AIME; Ben Franklin Hotel, Phila., Pa.

Aug. 27-31, 1962: American Physical Soc., Seattle, Wash. *Prog. Info.*: H. A. Shugart, Univ. of Calif., Berkeley 4, Calif.

Aug. 29-Sept. 1, 1962: 1962 Cong. on Intl. Federation of Information Processing Societies (IFIPS), IRE, ACM, AIEE, AFIPS; Munich, Germany. *Prog. Info.*: Dr. E. L. Harder, Westinghouse Electric Corp., E. Pittsburgh, Pa.

Aug. 29-Sept. 5, 1962: 5th Intl. Cong. for Electron Microscopy, Electron Microscope Soc. of America, Natl. Inst. of Health, NSF, ONR, AEC, OOR, AFOSR; Sheraton Hotel, Phila., Pa. *Prog. Info.*: Electron Microscope Soc. of America, 7701 Burholme Ave., Phila. 11, Pa.

Calls for Papers

Aug. 27-31, 1962: 67th Summer Mtg. Mathematical Assn. of America and American Mathematical Soc., Vancouver, British Columbia. *DEADLINE*: **7/6/62** to AMS Hqrs., 190 Hope St., Providence 6, R.I.

Aug. 27-31, 1962: American Physical Soc., Seattle, Wash. *DEADLINE*: Abstracts, **6/22/62** to H. A. Shugart, U. of Calif., Berkeley 4, Calif.

Sept. 3-7, 1962: Natl. Adv. Technology Management Conf., IRE-PGEM, AIEE, ASCE, AIChE, etal; Opera House, Worlds Fair Grounds, Seattle, Wash. *DEADLINE*: **7/3/62** to Georges Brigham, 805 Logan Bldg., Seattle 1, Wash.

Sept. 28-29, 1962: 12th Ann. Broadcast Symp., IRE-PGB; Willard Hotel, Washington, D. C. *DEADLINE*: **6/20/62** to Dr. William Hughes, E.E. Dept., Okla. State Univ., Stillwater, Okla.

Oct. 15-18, 1962: Space Phenomena & Measurements Symp., IRE-PGNS, AEC, NASA; Detroit, Mich. *DEADLINE*: 100-wd abstracts, **7/1/62**; rough draft of paper, **9/1/62** to M. Ihnat, AVCO Corp., 201 Lowell St., Wilmington, Mass.

Oct. 21-26, 1962: Soc. of Motion Picture & Television Engineers (SMPTE) Conv., Drake Hotel, Chicago, Ill. *DEADLINE*: Abstracts, **7/1/62** to Topic Chairmen. For info. contact Jack Behrend, Prog. Chm., Behrend Cine Corp., 161 E. Grand Ave., Chicago 11, Ill.

Oct. 25-27, 1962: 1962 Electron Devices Mtg., IRE-PGED; Sheraton Park Hotel, Washington, D.C. *DEADLINE*: Approx. **8/1/62.**

Oct. 30-31, 1962: Spaceborne Computer Engineering Conf., IRE-PGEC; Disneyland Hotel, Anaheim, Calif. *DEADLINE*: 4 cps. 1000-wd. summary, **6/15/62** to Dr. R. A. Kudlich, AC Spark Plug Div., General Motors Corp., 950 N. Sepulveda Blvd., El Segundo, Calif.

Nov. 4-7, 1962: 15th Ann. Conf. on Engineering in Biology & Medicine, IRE, AIEE, ISA; Conrad Hilton Hotel, Chicago, Ill. *DEADLINE*: 50-wd. abstracts, **6/1/62**; 900-wd. digest manuscript, **8/1/62**; to Prog. Committee, P.O. Box 1475, Evanston, Ill.

Nov. 12-14, 1962: Radio Fall Mtg., IRE-PGBTR, RQC, ED, EIA; King Edward Hotel, Toronto, Ontario, Canada. *DEADLINE*: Approx. **7/15/62**, abstracts. *For Info.*: V. M. Graham, EIA Eng. Dept., 11 W. 42 St., New York 36, N. Y.

Nov. 12-15, 1962: 8th Ann. Conf. on Magnetism & Magnetic Materials, IRE-PGMTT, AIEE, AIP; Penn-Sheraton, Pitts., Pa. *DEADLINE*: Approx. **8/18/62.** *For info.*: Prof. Fredk. Keffer, Physics Dept., Univ. of Pitts., Pittsburgh 13, Pa.

Nov. 29-30, 1962: 1962 Ultrasonics Symp. IRE-PGUE; New York City. *DEADLINE*: **8/13/62**, to R. N. Thurston, Bell Telephone Labs, Murray Hill, N. J.

Dec. 4-6, 1962: FJCC (Fall Joint Computer Conf.), AFIPS (PGEC, AIEE, ACM); Sheraton Hotel, Philadelphia, Pa. *DEADLINE*: Abstract, summary and paper, **7/1/62**, to E. G. Clark, Burroughs Research Ctr., Paoli, Pa.

Dec. 6-7, 1962: IRE Conf. on Vehicular Communications, IRE-PGVC; Mayfair Hotel, Los Angeles, Calif. *DEADLINE*: **8/15/62**, to W. J. Weisz, Motorola, Inc., Comm. Div., 4545 W. Augusta Blvd., Chicago 51, Ill.

Feb. 11-15, 1963: 3rd Quantum Electronics Conf., IRE, SFER, ONR; Paris, France. (Exhibition of working experiments & advanced devices—Feb. 8-15.) *DEADLINE*: Resumé, **11/1/62**, to Madame Cauchy, Secrétaire, 3ème Congrès d'Electronique Quantique, 7, Rue de Madrid, Paris VIIIe, France.

April 17-19, 1963: Int'l Special Tech. Conf. on Non-Linear Magnetics, IRE-PGEC, PGIE, AIEE; Shoreham Hotel, Washington, D.C. *DEADLINE*: **11/5/62**, to J. J. Suozzi; BTL Labs, Whippany, N.J.

May 20-22, 1963: Natl. Symp. on Microwave Theory & Techniques, IRE-PGMTT; Miramar Hotel, Santa Monica, Calif. *DEADLINE*: **1/19/63**, to Dr. Irving Kaufman.

June 19-21, 1963: Joint Automatic Control Conf., IRE-PGAC, AIEE, ISA, ASME, AIChE; Univ. of Texas, Austin, Tex. *DEADLINE*: Abstracts, **9/30/62**, manuscripts, **11/1/62**, to Otis L. Updike, Univ. of Virginia, Charlottesville, Va.

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Characteristics and Application of RCA EDGE—R. E. Montijo, AMA Meeting, Hotel Astor, New York City; May 15, 1962.

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Character Recognition by Use of Moment Invariants—V. M. Andreone: *MSEE Thesis,* University of Pennsylvania, 1962.

A Thin-Film Memory System—D. E. Murray: *MSEE Thesis,* University of Pennsylvania, 1962.

Selected Problems in Driving Thin-Film Superconducting Transmission Lines—W. R. Lile: *MSEE Thesis,* University of Pennsylvania, 1962.

A Survey of RCA Achievements in Design Automation—J. B. Paterson: Philadelphia Chapter IRE, Feb. 6, 1962

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The Application of the RCA 601 in Life Insurance Data Processing—E. H. Perlman: Life Office Management Association, Drake Hotel, Chicago, Illinois, Mar. 19, 20, 21, 1962

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Placement of Technical Papers for Maximum Effectiveness—C. A. Mayer: IRE International Convention, New York City, Mar. 28, 1962

A Wide-Band Microwave Deflection Amplifier Tube—R. McMurrough and H. J. Wolkstein: IRE International Convention, New York City, Mar. 28, 1962

A Five-Watt 432-Megacycle Transmitter Using the 6939 Twin Power Pentode—J. M. Filipczak: QST, March 1962 Issue

Some Recent Developments in Photomultipliers for Scintillation Counting—R. M. Matheson: 8th Scintillation and Semiconductor Counter Symposium, Washington, D. C., Mar. 1-3, 1962

Electronic Image Converter and Intensifier Tubes — G. A. Morton: American Optical Society Meeting, Washington, D. C., Mar. 16-18, 1962

Derivation of Ideal Electrode Shapes for Electrostatic Beam Focusing—W. W. Siekanowicz: *RCA Review,* Mar. 1962

Stable Low-Noise Tunnel-Diode Frequency Converters—F. Sterzer and A. Presser: *RCA Review,* Mar. 1962

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Re-Entry and Orbital Heat Transfer — E. McAssey: Polytechnic Institute of Brooklyn, New York, Jan. 9, 1962

The Design of an Information Retrieval Language—B. Sams and R. Colilla: *Communications of the ACM,* Jan. 62

Tiros I, II, and III Design and Performance—A. Schnapf: IAS 30th Annual Meeting, New York City, Jan. 24, 1962

Patents Granted TO RCA ENGINEERS

As Reported By RCA Domestic Patents, Princeton

PRINCETON LABORATORIES

3,028,341—Superconductors, April 3, 1962; F. D. Rosi and J. J. Hanak

3,028,500—Photoelectric Apparatus, April 3, 1962; J. T. Wallmark

3,028,505—Non-Coincident Magnetic Switch, April 3, 1962; J. A. Rajchman

3,029,353—Variable Pulse Delay Using Semiconductor Impact Ionization Effect, April 10, 1962; R. D. Gold

3,029,400—Color Television Bandpass Network Utilizing a Cancellation Trap, April 10, 1962; M. D. Nelson

3,029,361 — High Temperature Plasma Confinement Using a Travelling Electromagnetic Field, April 10, 1962; K. G. Hernqvist

3,030,436—Color Synchronizing Apparatus, April 17, 1962; A. C. Schroeder

3,030,444 — Transistor Television Receivers, April 17, 1962; J. O. Preisig

3,030,585 — Frequency Modulation Detector Circuit, April 17, 1962; I. M. Meth

3,030,611 — Reversible Counter, April 17, 1962; W. S. Pike

BROADCAST AND COMMUNICATIONS PRODUCTS DIVISION

3,028,557—Limiter Circuit, April 3, 1962; C. E. Peterson

RCA VICTOR HOME INSTRUMENTS DIVISION

3,028,830—Ultrasonic Transmitter Mechanism, April 10, 1962; G. L. Grundmann

3,028,831—Mechanical Resonator, April 10, 1962; G. L. Grundmann and J. E. Albright

3,029,317 — Frequency Selective Negative Feedback Recording Circuitry, April 10, 1962; J. J. Davidson

3,029,339—Variable Tuning Circuit, April 10, 1962; W. Y. Pan

DEFENSE ELECTRONIC PRODUCTS

3,028,832—Ultrasonic Transmitter, April 10, 1962; A. G. Lazzery

3,030,452—Regulation of Head Spacing by Air Bearing Means, April 17, 1962; J. M. Uritis

3,031,516—Method and Materials for Obtaining Low-Resistance Bonds to Thermo-Electric Bodies, April 24, 1962; L. Pessel

SEMICONDUCTOR AND MATERIALS DIVISION

3,029,340—Transistor Detector-Audio Amplifier, April 10, 1962; J. W. Englund

3,031,406—Magnetic Cores, April 24, 1962; J. J. Sacco, Jr.

ELECTRON TUBE DIVISION

3,029,360 — Heater Wire Coating Process, April 10, 1962; R. W. Etter

3,030,440 — Vertical Aperture Correction, April 17, 1962; O. H. Schade

3,031,316—Method and Material for Metalizing Ceramics and for Making Ceramic-to-Metal Sales, April 24, 1962; D. J. Cavanaugh

A Dielectric Drum Storage System—E. C. Hutter: *IRE Transactions on Electronic Computers,* Mar. 1962

Magnetic Attitude Control of the Tiros Satellites—E. Hecht, W. P. Manger: American Astronautical Society, Wash., D.C., Mar. 16, 1962

Observations from a Space Vehicle — M. V. Sullivan: New York Chapter of Society of Photographic Scientists and Engineers, Mar. 21, 1962

Optical Instrumentation for Tiros—M. Harper: *Journal of Applied Optics,* Mar. 1962

Space Observation Systems — E. C. Hutter: Student Chapter of IRE & AIEE, Air Force Institute of Technology, Wright Patterson Air Force Base, Dayton, Ohio, Feb. 15, 1962

Military Digital Communications—L. E. Mertens: University of Pennsylvania, Mar. 1962

Thermoelectric Cooling and its Applications—W. Grossman: Drexel Institute of Technology, Philadelphia, Pa., Feb. 1962

Mathematical Analysis of Redundant Systems Solving the Problems with Matrix Algebra—D. Weinstock: IRE 8th National Symposium on Reliability and Quality Control, Jan. 10, 1962 and Proceedings

Tunnel Diode Digital Circuits Using Composite Characteristics—B. Rabinovici and J. Klapper: *Electronics,* Feb. 16, 1962

Design of Interstage Coupling Apertures for Narrow-Band Tunable Coaxial Bandpass Filters—R. M. Kurzrok: *IRE PGMTT Transactions,* Mar. 1962

Passband VSWR of Maximally Flat Bandpass Filters—R. M. Kurzrok: *IRE PGMTT Transactions,* Mar. 1962

BMEWS—R. R. Welsh: IRE Prof. Group on Product Engineering and Production, May 15, 1962.

Log-Normal Distribution and Maintainability in Support Systems Research—Dr. H. I. Zagor (RCA) and R. L. Bovaird (Hughes Aircraft); *Naval Research Quarterly,* Vol. 8 No. 4, Dec. 1961.

Engineering NEWS *and* HIGHLIGHTS

Malcarney, Smith, Bain Promoted to New Executive Positions

Promotion of **Arthur L. Malcarney** to Group Executive Vice President of RCA was announced on May 15 by RCA President **Dr. Elmer W. Engstrom.** Concurrently, Dr. Engstrom announced the promotion of **Theodore A. Smith** to Executive Vice President for Corporate Planning, and **Walter G. Bain** to Vice President, Defense Electronic Products.

Mr. Malcarney has served since 1957 as Executive Vice President, Defense Electronic Products. In his new assignment he will have over-all responsibility for Defense Electronic Products, Electronic Data Processing, and the Manufacturing Services staff.

Mr. Smith, who has been Executive Vice President, Electronic Data Processing, will assume staff responsibility for developing over-all Corporate objectives and programs as well as coordinating RCA division and subsidiary plans into the Corporate planning. He will report to Dr. Engstrom.

Mr. Bain, who joined RCA in 1959 as Vice President and General Manager, Communications and Aerospace, Defense Electronic Products, assumes the direction of RCA's defense and space operations, reporting to Mr. Malcarney.

Mr. Malcarney's staff is: **W. G. Bain,** Vice President, Defense Electronic Products; **C. B. Jolliffe,** Vice President and Technical Consultant; **A. L. Malcarney,** Acting General Manager, Electronic Data Processing; **F. Sleeter,** Vice President, Manufacturing Services.

Mr. Bain's staff is: **S. W. Cochran,** Division Vice President and General Manager, Surface Communications Division; **C. A. Gunther,** Chief Defense Engineer, Defense Engineering; **J. M. Hertzberg,** Division Vice President, Defense Marketing; **I. K. Kessler,** Division Vice President and General Manager, Aerospace Communications and Controls Division; **B. Kreuzer,** Division Vice President and General Manager, Astro-Electronics Division; **S. N. Lev,** Division Vice President and General Manager, Moorestown Missile and Surface Radar Division; **T. W. Massoth,** Manager, Administration; **J. H. Sidebottom,** Division Vice President and General Manager, Major Systems Division; and **H. R. Wege,** Vice President and General Manager, Data Systems Division.

DR. BROWN AWARDED CITATION

Dr. George H. Brown, Vice President, Research and Engineering, was one of six engineering-industry leaders recently honored with a *Distinguished Service* citation from the University of Wisconsin at the 14th annual "Engineers Day" dinner of the University's College of Engineering.

Dr. Brown, who was the principal speaker at the dinner, discussed research progress in both radio and television, including color television and RCA's space-communications program for NASA. A native of Wisconsin, Dr. Brown was graduated in 1930 from the University of Wisconsin with a BSEE and was awarded the *Wisconsin Public Utilities Association Fellowship* for 1930-31. In 1931, he received his MS from the University of Wisconsin and was awarded a *Regents' Fellowship* for the next two years. He received his PhD in 1933 and his professional Engineer's degree in 1942, both from Wisconsin.

DR. BERG NAMED FELLOW, ACS

Dr. Morris Berg was elected a *fellow* of the American Ceramic Society at its National Meeting in New York, May 1, 1962. Dr. Berg heads the Ceramics & Glass Technology Groups at the Lancaster Chemical & Physical Laboratory, ETD. He was one of the recipients of the *David Sarnoff 1962 Outstanding Achievement Team Award in Engineering* (RCA ENGINEER, Vol. 7, No. 6).
—*J. D. Ashworth*

Responsibilities of DEP Major Systems Division Broadened

The responsibilities of the DEP Major Systems Division have been broadened in order to improve RCA's efforts and capabilities in obtaining and managing new major systems projects and in fulfilling its existing contractual obligations for major systems programs.

The Major Systems Division will now have direct project responsibility for the following programs: BMEWS, 621-A Program, RELAY Satellite Program, DYNASOAR Communications Program, and MINUTEMAN Command and Control Communications Program.

The principal responsibility of the Major Systems Division will be management surveillance of large scale defense and space systems projects, especially where support from more than one division is necessary.

The Project Management concept for operation of major customer programs has been formalized within the DEP organization to provide for successful completion of all phases and requirements of a program or project, including its support and operational efforts. Sole responsibility for project performance is delegated to a single manager who is so placed in the organization that he has complete control of all business elements required to ensure program completion within requirements.

Major Systems Division's New Programs Responsibilities

The Major Systems Division has been given added responsibilities for the programs already mentioned in order to strengthen the implementation of our major systems programs and take full advantage of the RCA/DEP defense resources, facilities, and manpower.

In essence, this organization alignment combines the technical and scientific know-how now existing in the various programs with the qualified and seasoned program management and field support operations already in the Major Systems Division. This Division, in carrying out its BMEWS responsibility, has developed a primary capability to perform major government systems programs in accordance with schedule and cost requirements.

In assuming responsibility for these additional programs, *the Major Systems Division will make no changes in their organizations, their locations, or their existing relationships with the various DEP divisions.*

In the future, as new programs are obtained, they will be organized and implemented according to customer requirements and with full consideration of the management and technical load involved at the time such programs are initiated. These program management activities will continue to be located at the point where the work will be done in association with the lead division. The lead division will also provide administrative and personnel support.

Program Administration and Systems Development Engineering

The organization structure of the Major Systems Division, as of May 15, is as follows:

The staff of **J. H. Sidebottom,** Division Vice President and General Manager, Major Systems Division, consists of: **D. C. Koenitzer,** Manager, Program Administration; **W. L. Richardson,** Administrator, Major Systems Programs; **D. Shore,** Chief Systems Engineer, Systems Development Engineering; **J. J. Guidi,** Manager, BMEWS Program; **C. K. Law,** Manager, DYNASOAR Program; **J. M. Osborne,** Manager, MINUTEMAN Program; **W. M. Pease,** Manager, 621-A Program; and **R. M. Wilmotte,** Manager, RELAY Satellite Program.

The *Program Administration* activity will comprise a small staff of key personnel experienced in various elements of program management who will assist in the management surveillance of the DEP major systems programs and participate in the planning and execution of new programs as they are developed. This organization will assist in the formulation of program controls and administrative functions within our present programs and plan the management concepts most adaptable to new efforts.

The *Systems Development Engineering* organization will comprise a limited staff of key systems and project engineering personnel with diverse capabilities responsible for developing systems concepts and program plans for new major systems utilizing the individual capabilities of various DEP divisions. The Systems Development Engineering organization will provide a focal point for development of over-all systems concepts and project teams by drawing upon the various capabilities throughout DEP and other RCA divisions for developing proposals and project teams for new systems contracts.

In effect, these two functional organizations will operate as DEP Staff activities but will not duplicate other DEP Home Office Staff functions already available for major programs, such as product assurance, defense engineering, and defense marketing.

Marketing Realignment

The Marketing functions previously within MSD will be reassigned to the other DEP divisions according to their specific capabilities, product lines, and organization. Marketing operations for future major systems will be handled by the lead division within DEP assisted by the DEP Home Office Staff Defense Marketing activity. The present projects being handled by the Marketing organization in MSD will be assigned to DEP Divisions and, in most cases, the MSD Marketing personnel will be transferred with the projects for which they have had and will have continuing responsibility. This change in organizational concept will accent the need for DEP Divisions to market major systems efforts and will eliminate the competitive marketing aspects of a separate major systems organization.

...PROMOTIONS...
to Engineering Leader and Manager

As reported by your Personnel Activity during the past two months. Location and new supervisor appear in parenthesis.

RCA Service Company

H. Sanders: from Ldr., Sr. Engrs., BMEWS, to *Mgr., Systems Integration* (R. A. Hubbard; BMEWS—Home Office)

W. M. Leonard: from Mgr., Operations & Equip. Control to *Mgr., ZI Operations* (J. W. Tyler; Site ZI—BMEWS Colorado Springs)

R. W. Peirce: from engr. to *Ldr., Engineers —BMEWS* (S. A. Fougere; Site III—BMEWS, England)

K. R. Lewis: from engr. to *Ldr., Engineers* (E. E. Terrien; TITAN Project)

R. E. Stewart: from engr. to *Mgr., Installation & Maintenance Eng.* (E. E. Terrien; TITAN Project)

W. C. Connell: from engineer to *Mgr., Technical Operations & Plans* (F. Ise; DAMP Ship)

F. Ise: from Ldr., Support Svc. Engr., to *Mgr., Shipboard Instrumentation* (J. Kaeser; DAMP Ship)

M. Michalchik: from engr. to *Ldr., Engineering Staff* (H. C. Gillespie; Comm. Prods.)

R. H. Tuten: from engr. to *Ldr., Engineers* (S. N. Levin; BMEWS Project)

J. E. R. Fox, Jr.: from engr. to *Ldr., Engineers* (R. F. Knipmeyer; TITAN Project)

A. E. Rose: from engr. to *Ldr., Engineers* (C. D. Ettinger; Field Projects GSO)

Semiconductor & Materials Division

G. L. Finne: from engr. to *Engr. Ldr., Equipment Development* (H. V. Knauf, Jr.; Somerville)

Electron Tube Division

T. J. McCudden: from Mgr., Prod. Eng., Indpls. Plant to *Mgr., Tube Prod. Eng., Harrison Tube Plant* (C. A. Dickinson; Prod. Engr., Harrison)

R. Wissolik: from engr. to *Mgr., Comm. Eng.* Harrison (J. T. Cimorelli; Harrison)

J. J. Carroll: from engr. to *Mgr. Prod. Eng.* (Mgr., Power Tube Mfg.; Lancaster)

G. E. Mandell: from Mgr., Prod. Eng. to *Supt., Power Tube Mfg.* (Mgr. Power Tube Mfg.; Lancaster)

Broadcast and Communications Products Division

D. H. McConnell: from salesman, Ind. & Machine Tool Operations to *Mgr., Engineering* (N. R. Amberg; Indus. & Automation Prods. Dept.)

M. K. Wilder: from engr. to *Ldr., Design & Development Engineers* (N. E. Edwards; Microwave Eng.)

Electronic Data Processing

R. J. Linhardt: from Eng. to *Ldr., Design & Development Engrs.*

Home Instruments Division

R. D. Flood: from Mgr. Remote Control Eng. to *Mgr., Elec. Eng.,* RV (L. M. Krugman; Indianapolis)

G. C. Hermeling: from Mgr., Tuner Eng. to *Mgr., Tuner & Remote Engineering* (L. R. Kirkwood; Indianapolis)

Editor's Note: Beginning with this issue, the RCA ENGINEER will list all advancements into and within engineering management in this *Promotions* column. Selected news about new or realigned staffs will appear in the companion column *Staff Announcements.* Official source for the *Promotions* information is your personnel activity, and *Promotions* will normally publish information received in the two months prior to an issue's closing date. Source for *Staff Announcements* are official RCA Organization Notices ("bluelines") and Editorial Representatives.

Data Systems Division, DEP

G. M. Haramia: from Ldr. D&D Eng. to *Mgr. D&D Eng.* (A. E. Fogelberg; Van Nuys)

J. C. Schira: from engr. to *Ldr., D&D Eng.* (L. M. Seeberger; Van Nuys)

W. E. Plaisted: from engr. to *Ldr., Systems Eng. Staff* (G. V. Nolde; Van Nuys)

W. A. Miller: from engr. to *Ldr. D&D Eng. Staff* (R. E. Wilson; Van Nuys)

F. G. Snyder: from engr. to *Ldr. D&D Eng. Staff* (R. E. Wilson; Van Nuys)

A. S. Newdorf: from Ldr. Publications Eng. to *Mgr., Eng. Projects Publications* (S. Hersh; Van Nuys)

E. A. Kelty: from Ldr., Proj. Adm. to *Mgr., Eng. Projects Adm.* (W. M. McCord; Van Nuys)

Major Systems Division, DEP

N. Alperin: from Ldr. Sys. Projects to *Mgr. Info. Proc. Applications* (G. Murray; Moorestown)

I. Malkin: from engr. to *Ldr. D&D Eng.* (N. Alperin; Moorestown)

W. Lawrence: from engr. to *Ldr. D&D Eng.* (H. Birnkrant; Moorestown)

Missile & Surface Radar Division, DEP

R. Buford: from engr. to *Ldr. D&D Eng.* (R. Orth; Moorestown)

J. Drenik: from engr. to *Ldr. D&D Eng.* (F. Klawsnik, Moorestown)

B. Buy: from Ldr. D&D Eng. to *Mgr. Equip. D&D* (F. Tillwick; Moorestown)

R. Bugglin: Engr. to *Ldr. D&D Eng.* (O. Chayie; Moorestown)

G. Caldwell: from engr. to *Ldr., Eng. Sys. Projs.* (L. Nelson, Moorestown)

A. Sietz: from Ldr. Eng. Sys. Projs. to *Mgr. Sys. Projects* (A. Leder, Moorestown)

Surface Communications Division, DEP

B. Bossard: from engr. to *Ldr., Tech. Staff* (S. J. Mehlman; New York)

J. A. Wade: from engr. to *Ldr. Tech. Staff* (A. M. Creighton, Tucson)

R. L. Patterson: from engr. to *Ldr. Tech. Staff* (D. R. Green; Tucson)

W. Buchsbaum: to *Ldr., Tech. Staff* (G. T. Ross; New York)

W. A. Castner: from Sr. Proj. Ldr. Tech. Staff to *Mgr., Eng. Adm.* (H. J. Laiming; Cambridge)

S. J. Cascio: from engr. to *Ldr., Design & Dev. Engrs.* (P. J. Riley; Cambridge)

STAFF ANNOUNCEMENTS

Data Systems Center, DEPDSD, Bethesda, Md.: **Dr. D. C. Beaumariage,** Manager of the new Bethesda Data Systems Center, has named **David A. Negrin** Manager of Systems Engineering. Prior to joining RCA, Mr. Negrin was Assistant Department Manager of the SACCS Department of System Development Corp., Paramus, New Jersey. The systems skill center of the Bethesda activity includes the Information Technology group headed by **Dr. Jack Minker.** This group came to the Data Systems Center from DEP-AED, Princeton, when Project ACSI-MATIC recently was transferred to DEP-DSD. Dr. Minker has announced the formation of four groups and their leaders as follows: **W. D. Climenson,** Leader, Language Analysis and Document Handling; **C. Perhacs,** Leader, Systems Analysis; **W. G. Reed,** Leader, Information Systems; and **Dr. B. H. Sams,** Leader, Programming Systems. **Donald R. Meng,** who was previously Manager, Systems Design and Plans, at the 1725 K Street facility (Washington, D.C.) of the Data Systems Center, has been appointed Manager, ELCO Program, reporting to Dr. Beaumariage. **Sidney Kaplan,** formerly at MSD, Moorestown, has been named Manager, Advanced Information Storage and Retrieval.— *J. Carter*

SC&M Div., Somerville: **D. Ludlum** has been named as Administrator, Operations Planning, on the staff of **R. Lane.**
—*G. R. Remoff*

Home Instruments Div., Indianapolis: **C. W. Hoyt** has been named a Staff Engineer in Home Instruments Engineering, reporting to **E. I. Anderson,** Chief Engineer.
—*A. J. Walsh*

RCA Communications, Inc., New York: **T. D. Meola,** formerly Vice President and European Manager, RCA Communications, Inc. has returned to New York Headquarters in the capacity of Vice President, Operations, RCA Communications. **Sidney Sparks,** formerly Vice President, Operations and Engineering was made Executive Vice President and elected to the Board of Directors of RCA Communications, Inc. **Eugene D. Becken,** formerly Vice President and Chief Engineer, Operations and Engineering Department is now Vice President and Chief Engineer, Engineering Department, RCA Communications, Inc.
—*W. C. Jackson*

NEW RCA EDUCATIONAL SERVICES DEPARTMENT IN RCA SERVICE CO.

The RCA Service Co. is now responsible for a unique organization to custom-design and package educational programs, materials, and equipment for schools, industry, and government—RCA Educational Services.

Harold Metz, Division Vice President, RCA Educational Services, RCA Service Co., will head the new department which combines the long-established RCA Institutes organization and the new Educational Operations activity and Educational Advisory Services, which were organized to project modern training concepts.

The organization of the new Department is as follows: RCA Institutes, Inc., New York, N. Y., **G. F. Maedel,** President; RCA Educational Operations, Cherry Hill, N. J., **Ernest W. Lareau,** Manager; RCA Educational Advisory Services, Cherry Hill, N. J., **John W. Wentworth,** Manager; and RCA Educational Programs, Cherry Hill, N. J., **James S. Winston,** Manager.

PROFESSIONAL ACTIVITIES

ETD, Harrison: At the Second Hudson County (N.J.) Science Fair, the following ETD engineers were part of a group of nearly 100 representative technical, medical, and military people in judging this event sponsored by the Jersey City State College and the *Jersey Journal:* **Edward Byrum, Robert Nelson, William Christian, Preston Theall, Robert Rauth, Tom Ford,** and **Earl Thall.** Two courses were recently completed by engineers in the Harrison area: *Report Writing,* and *RCA 501 Programming.* Eighteen ETD engineers completed the programming course, which was presented with the cooperation of the ETD Data Systems Group, and RCA-EDP, Cherry Hill. The following were recent lectures sponsored by the Harrison Engineering Education Committee: **N. S. Freedman:** *Silicon-Germanium, A High Temperature Thermoelectric;* **C. A. Meyer:** *Placement of Technical Papers for Maximum Effectiveness;* **K. Forrestal,** *Operations and Procedures in the International Division;* **B. McPherson:** *Nuclear Radiation Testing of Tubes;* **C. Gonzales:** *The TV Set as a System;* **T. Sieben** and **K. Uhler:** *Reed Switches;* **C. M. Morris:** *Novar Tubes;* and **R. D. Reichert:** *Frame Grid Tubes.—T. M. Cunningham*

DEP-MSD, Moorestown: **R. O. Yavne,** Advanced Systems Planning, attended course on *Inertial Guidance,* April 23 thru May 4, at the University of California, Los Angeles.—*I. N. Brown*

DEP—SurfCom, Camden: **C. W. Fields** has been named Secretary-Treasurer, Philadelphia Chapter, IRE-PGEWS.

DEP Central Engineering, Camden: **W. A. Gottfried, W. B. Reagan, F. X. Thomson, S. Levy, J. M. Weil, F. M. Oberlander, C. H. Kreck** and **J. R. Hendrickson** were guests of the DuPont Company at a symposium on "New Materials" held in Wilmington, Delaware, February 27-28, 1962. **S. Levy** was recently appointed to membership in the National Education Committee of the Society of Plastics Engineers. Mr. Levy is also part-time Lecturer in Plastics Technology at the Philadelphia College of Textiles and Science. **J. A. Clanton** became a member of the Society of Plastic Engineers effective January 1962. Also in January, he completed a five months course in *Polymer Science* at the Philadelphia Textile Institute. **Dr. L. Pessel** was recently appointed Vice-Chairman of the EIA Working Group, P-74W/G studying solderability, fluxes, and soldering of component parts. **J. W. Kaufman** serves on the executive committee of the local section, American Society for Metals; is ASM delegate to the Delaware Valley Engineering and Technical Societies Council; is National Chairman of the Sustaining Membership Sub-Committee of ASM; and was RCA's representative at *Engineers' Week* ceremonies at Philadelphia in February 1962. **J. R. Hendrickson, Sr.,** was recently appointed to membership (1) in the E-10 Committee on *Radioisotopes and Radiatron Effects* of the ASTM; and, (2) in the Advisory Committee to the Civil Defense Director, State of New Jersey.
—*C. H. Kreck*

DEP-SurfCom, Cambridge, O.: Each year, the Cambridge Engineering Society, Cambridge, Ohio, gives a dinner in honor of the outstanding high school seniors in Guernsey County. At this year's event, Dr. H. N. Crooks was the principle speaker with a talk entitled *The Engineer in Electronics.* The Cambridge Engineering Society, Cambridge, Ohio, has elected **Paul J. Riley,** Manager, Reliability and Value Engineering, to be Vice-President for the coming year. A graduate study program for engineers in the Cambridge plant began in March. Courses will be conducted by Ohio State University at Muskingum College.
—*P. J. Riley*

G. G. Thomas

THOMAS NAMED ED REP FOR LANCASTER POWER TUBE OPERATIONS

George G. Thomas has been named to replace **Harold Lovatt** (who is retiring) as RCA ENGINEER Editorial Representative for Power Tube Operations and Operations Services, ETD, Lancaster, Pa.

George G. Thomas graduated from Iowa State College 1925 with BSEE. He started with General Electric Company, Schenectady, New York, in 1925, and was Manager of Radio Receiver Quality Control at the time of his transfer to RCA in 1930. In 1930 he became Assistant Manager of Test Methods and Equipment at the Camden Plant of RCA. In 1934 he was promoted to Manager Test Engineering, and in 1935 was made Superintendent of Quality Control. He was transferred to ETD in 1942, with the opening of the Lancaster Plant, and held the position of Plant Quality Control Manager until 1953 when he became Administrator of Quality Control, Cathode Ray and Power Tube Operations. In 1957 he assumed the responsibility of Administrator of Quality Control, Industrial Tube Products—the position he now holds. He is a Senior Member of American Society for Quality Control, and a past Chairman of its Harrisburg-York-Lancaster Section.
—*J. F. Hirlinger*

R. E. PATTERSON, DEP-SURFCOM, HEADS INDUSTRIAL-MILITARY GROUP FOR STREAMLINING TECHNICAL PUBLICATIONS SPECS

RCA is playing a vital role in a joint effort by the DOD, industry, and the military services to simplify and reduce the number of technical publications specifications and to standardize such documents among the services. The National Security and Industrial Association, a long-standing advisory group to the DOD, has established a *Publications Procurement Task Group* for this purpose. Heading the Group is **R. E. Patterson,** Manager of Data Control, Surface Communications Division, DEP, 1-5, Camden. Objective of the program is to establish a family of approximately 40 related specifications that would supersede approximately 280 existing specifications and documents. The Standardization Division of the Defense Supply Agency is sponsoring the program. Recently, an Ad Hoc Industry Advisory Committee was established to advise the DOD.—*C. W. Fields*

WOLL AND STORY NAMED TO HEAD PHILADELPHIA IRE AND AIEE SECTIONS

Dr. H. J. Woll, Mgr., DEP Applied Research, Camden was recently named Chairman of the Philadelphia Section of the IRE; he had served the previous term as Treasurer. **T. H. Story,** DEP Camden, was named Chairman of the Philadelphia Section of the AIEE; he had served as Vice-Chairman.

ELEVEN CHILDREN OF RCA EMPLOYEES AWARDED FIRST RCA NATIONAL MERIT SCHOLARSHIPS

Eleven high school seniors—7 boys and 4 girls—are the 1962 winners of the most recent RCA aid-to-education program, the new *RCA National Merit Scholarships* for children of RCA employees. In this new program, each year RCA will sponsor, in cooperation with the National Merit Scholarship Corporation, a maximum of 15 four-year college scholarships, carrying stipends up to $1,500 annually, for the children of RCA employees. The program also provides, in some instances, for needed financial aid to the colleges selected by the RCA Merit Scholars. The 1962 Merit Scholars, selected for scholastic aptitude, leadership ability, and good citizenship are:

Rosemary Crum, 17, will enroll at Ohio State University, Columbus, Ohio, in Hospital Pharmacy. Her mother, **Thelma R. Crum,** is with DEP-SurfCom, Cambridge, Ohio, where she is a Tester (Assembly).

Lee W. Gross, 17, will enroll at Gettysburg College, Gettysburg, Pa., in French, leading toward a teaching career. His father, **H. A. Gross,** is with the ETD, Lancaster, Pa., where he is Manager, Tube Process Quality Control, Entertainment Tube Products Department.

Martha L. Haller, 17, will enroll at Allegheny College, Meadville, Pa., in English, leading toward a teaching career. Her father, **C. E. Haller** (deceased) was with ETD, Lancaster, Pa., where he was Group Supervisor, Engineering and Manufacturing, Power Tube Design and Development.

Alan S. Keizer, 17, will enroll at Cornell University, Ithaca, N. Y. in Physics. His father, **E. O. Keizer,** is a Member of the Technical Staff, RCA Laboratories, Princeton.

Richard J. Meyer, 17, will enroll at Swarthmore College, Swarthmore, Pa., in creative writing. **C. A. Meyer** is with ETD, Harrison, N. J., where he is Manager, Commercial Engineering Technical Services, Entertainment Tube Products Department (and an *Engineering Editor* of the RCA ENGINEER).

Marylouise Mierau, 17, will enroll at University of Michigan, Ann Arbor, Mich., in Premedicine, leading toward a career as a doctor. Her father, **C. E. Mierau,** is with the RCA Service Company, New York area, where he is a Mobile Microwave Technician, Technical Products Services.

LeBaron C. Moseby, 17, will enroll at the University of Pennsylvania, Philadelphia, Pa., in Mathematics. His father, **L. C. Moseby, Sr.,** is with DEP-ACCD, Camden, N. J., where he is a Class A tester.

Margaret C. Nekut, 18, will enroll at Bucknell University. Her father, **Anthony G. Nekut,** is with ETD, Lancaster, Pa., where he is Engineering Leader, Tube Application Engineering, Industrial Tube Products Department.

David L. Reiskind, 17, will enroll at Rensselaer Polytechnic Institute, Troy, N. Y. in Engineering. His father, **H. I. Reiskind** (deceased) was with RCA Victor Record Division, Indianapolis, Ind., where he was Manager, Engineering.

Robert W. Roundy, 17, will enroll at University of California, Berkeley, Calif., in Biochemistry. His mother, **Orlean Roundy,** is with ETD, Los Angeles, Calif., where she is an Order Clerk, Warehouse Distributor Products Department.

John C. Slaybaugh, 17, will enroll at Princeton University, Princeton, N. J. in Electrical Engineering or Astrophysics. His father, **C. W. Slaybaugh,** is with NBC, New York, N. Y., where he is Director, International Enterprises, Enterprises Division.

Editorial Representatives

The Editorial Representative in your group is the one you should contact in scheduling technical papers and announcements of your professional activities.