RCA ENGINEER

Vol. 5—No. 3 • OCTOBER—NOVEMBER, 1959

OBJECTIVES

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 engineering 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.

OUR COVER

Our cover this issue features the AGACS (Automatic Ground-Air-Ground Communications System) developed under the project management of the Airborne Systems Division, DEP, for the Federal Aviation Agency's Bureau of Research and Development. The system display pictured was on exhibition at the World Congress of *Flight*, Las Vegas, Nev. Rodger Davis, AGACS Project Mgr. (see article this issue) is shown discussing equipment operation with Carlo Yulo (at console), the Task Engineer responsible for Evaluation of the System in its present phase at National Aviation Facilities Experimental Center, Atlantic City, N. J.

SYSTEMS ENGINEERING

Present-day programs in DEP and its future growth depend more and more on systems engineering, a fact which the Airborne Systems Division recognizes in its very name. In this issue, many of the developments presented by ASD engineers illustrate the importance of systems engineering.

Systems engineering, as a discipline in its own right, has been recognized for a relatively short period, although engineers have been applying the principles of systems engineering for many years. In planning and developing new products, techniques, and services, the functions of research and engineering development and design have as their major objective the organization of systems which meet the needs of our customers.

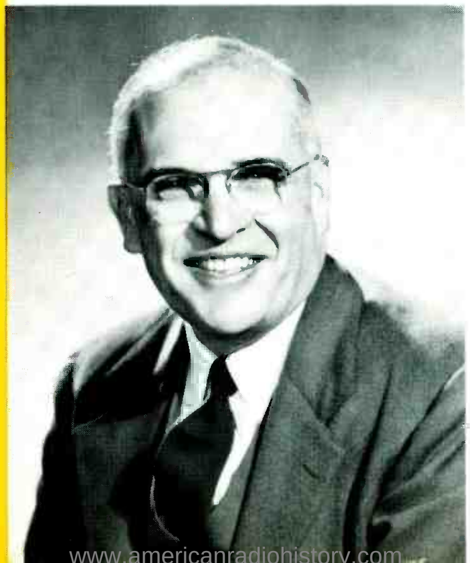
RCA's management is strongly *systems-minded.* It knows that this approach to a problem presents the best opportunity for accomplishing results and growth in our business. But systems engineers cannot work alone—they must have wide support in all forms of research, development, and product engineering. RCA provides strong support and a stimulating environment for the systems engineer—through research and development, where we are an established leader, and through access to RCA experience in all aspects of product engineering. This support encompasses not only electronics but also many other related fields.

Research and development are highly competitive. New ideas *do not lie idle*, whether they originate within RCA or elsewhere. A systems engineer must be aware of *what* is going on in research and development and *how* it may apply to his project. He must then be capable of utilizing such new concepts for solution of his problems. Feeding back information about problems needing solution to research and development engineers is important in formulating programs of research.

Today, complex systems are not developed by a single individual or wholly within single small groups. While inventions continue to come from individuals or from within small groups, the most-rapid development and implementation of entire systems usually come from large engineering teams. These may be departments or divisions, having at their command a wide scope of technical knowledge: In short, new systems must come from *coordinated operation.*

Since meeting the customer's needs are the systems engineer's objectives, the development of a system must be based on a searching analysis to determine the end use. A system is of value only when the customer can use it day by day without failure or malfunction, and with the type of men available to him. So, in the dedevelopment and design of a system, there must be included reliability, maintainability, and human engineering. We successfully continue our business—and expand—by supplying the customer with a reliable system that *fulfills his needs* satisfactorily.

Opportunities for systems engineers in the growth of RCA are extensive and challenging. *But action should not stop here.* The problems of our modern way of life are becoming more and more complex; the discipline of thinking developed in systems engineering can be extended to the solution of problems beyond the field of technology.



C B Jolliffe

Dr. C. B. Jolliffe
Vice-President and Technical Director
Defense Electronic Products
Radio Corporation of America

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THE ENGINEER AND THE PROPOSAL

MANY ENGINEERS FEEL they spend most of their professional lives working on proposals—some actually do. However, the greatest share of proposal writing is done by engineers who become involved relatively infrequently with the special problems attendant to new-business solicitation. The engineer's concern with proposals does not start only at the time he is given a writing assignment or asked to cost-estimate a piece of equipment. He has far broader opportunity for maintaining and increasing the level of RCA business, by keeping himself aware of RCA's competitive position in his field and sharing in the responsibility for monitoring the marketing potential of his ideas and/or equipment. He can initiate action on unsolicited proposals and may be called upon to assist in making the decision to bid or not to bid.

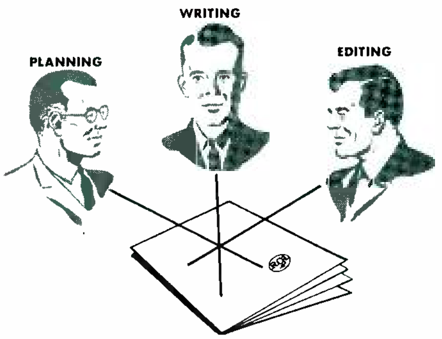
The best proposals are those which are most thoroughly custom-engineered, and no set of detailed rules can apply in every situation. Accordingly, the ideas herein are intended for broad application in preparing the formal *technical proposal* —which must present to the prospective customer a thorough picture of *what* RCA proposes, *how* RCA can accomplish it, and *why* RCA is best qualified. Cost estimates, while a very important aspect of the overall proposal, are not covered here, since they are usually handled as an item separate from the technical proposal.

PLANNING

From an engineer's point of view, proposals must be written in too little time and with too little money. However, this is a fact of life, and steps should be taken to produce the best possible results within these limitations. Thorough planning is the first step, and includes:

(1) *Familiarization with the proposal request and any attached specifications.* It is not uncommon to find proposals which, through carelessness rather than intent, are nonresponsive to the proposal request. It may be decided to submit a nonresponsive bid, but this should be done only by careful design.

(2) *The assignment of one man, with necessary authority, to be responsible for the total engineering proposal effort.* Work assignments will stem from him, and final coordination and review will be performed by him.



J. F. BIEWENER, Mgr.

Engineering Reports and Publications
Airborne Systems Division
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(3) *Determination of the final form of the proposal.* The selection made here will depend most heavily on an analysis of the marketing requirements, i.e., what will impress the customer, as well as on practical considerations of time and money.

(4) *Preparation of a schedule* for writing and producing the proposal.

(5) *Preparation of an outline.*

Proposals may differ in detail, but fundamentally they all should strive to convince the customer of RCA's *interest in* and *knowledge of* the problem, RCA's *ability to manage* the program, the *technical soundness* and *unique features* of the *proposed solution*, and its *over-all economy*.

Constant consideration of these common points will lead to the best decisions regarding the emphasis in the proposal. It may be necessary to prepare a separate management proposal (i.e., a special document describing in detail the program plan, schedule, facilities, experience, and project organization) or a summary brochure highlighting all significant aspects of the proposed program, or an extremely detailed technical exposition. Whatever documents are in order should be planned for early.

Matters of format require early consideration, i.e., layout, typography, illustrations, and printing. Cost is generally the largest factor in deciding how sophisticated the finished proposal may be. Striking layout, attractive illustrations and typography, and fine printing are all products of persons who are artists or experts in their own fields—like engineers, their skills carry a price tag.

THE PROPOSAL SCHEDULE

With a general idea of the type of document desired and with an estimate of the difficulty and complexity of the writing and editing tasks, an over-all schedule can be drawn up. It should have some flexibility, but it should not be so limp as to be useless in budgeting both time and money. The principal phases to be scheduled are:

(1) *Technical research*, to gain required background information.

(2) *Freezing on the configuration and/or program plan* to be proposed, essential in order to avoid extraneous or unrelated writing.

(3) *Writing* manuscript, roughing out illustrations, and taking necessary photos.

(4) *Editing*, both technical and literary. The importance of this and the time to execute it generally increases in direct proportion to the number of sources of written information.

(5) *Approval.* Determine exactly what person or persons must give ultimate approval on the proposal prior to its delivery to the customer, and allow time for their review.

(6) *Production*, including, when necessary, layout, artwork, drafting, typography, and printing.

Writing, while of prime importance, is only one of numerous steps in proposal preparation; engineers are often involved in all steps.

WRITING THE PROPOSAL

An over-all outline is useful in all proposal writing and is a necessity in large, complex proposals. It enables definitive writing assignments to be made, aids in coordination and integration of numerous written inputs, assures that coverage is given to essential elements of the proposal, and provides a means for monitoring the progress of writing and production.

There is no standard depth to which an outline should go, nor is there any universal outline. Generally, the depth need be only that required to define clearly the contents of each section and major subsection. The man responsible for coordinating preparation of the proposal should also be responsible for preparing the outline. The following are the basic elements as they might be arranged and written.

The Foreword or Introduction

This can be a statement identifying the proposal with a particular procuring document (proposal request) or, in the case of an unsolicited proposal, a brief reason for making the submittal. This section may also be used as a guide to the reader by describing, as succinctly as possible, the content of the material contained in the different sections of the document. Reference should also be made here to such supporting documents as the cost proposal or to any other separate volume of the proposal.

The Summary

This section should be a capsule proposal, summarizing briefly such essential information as:

(1) A precise definition of what is being proposed.
(2) The unique or outstanding features of RCA's proposal.
(3) The major reasons why RCA is best qualified to handle the program.

The Summary must serve as a "broad-brush" sketch, with the details of the rendering to be filled in by subsequent sections. Remember that some people read only this section.

The Program Plan

There are three general essentials to be included in the Program Plan, and each can be made the subject of a separate subsection.

The first is a brief, definitive *statement of work*, including the items and/or services to be delivered on the contract.

The second is the *time schedule*. This, of course, is closely related to the statement of work, and the two should be clearly keyed together.

The final essential is the *project organization*. Through charts and words, give a picture of where responsibility will lie in RCA for execution of the contract. The ties between all contributing organizations of the company should be shown. Here also is an opportunity to emphasize the advantages the customer will realize in working with a corporation having widespread interests and experience.

The Technical Discussion

The widest variations among proposals probably occur in the handling of the technical material, because of the peculiar characteristics of individual procurement conditions.

It is important to *convince the customer that RCA understands the problem*, especially where the proposal request was written in broad or vague terms, or where a study is an essential first phase of the proposed program.

The customer is primarily interested in *what the system or equipment will do*, and therefore, a subsection of the proposal should be allocated to satisfy this interest in detail. Write from the point-of-view of the user, and keep the description performance-oriented.

Next, tell *how the system or equipment accomplishes its functions*. This problem is smallest, of course, where equipment proposed has already been developed or is in production. However, in all cases, the desirable ingredients of this portion of the proposal are the same—photographs of hardware, block and logic diagrams, simplified schematics of special circuits, and clear, readable text. Keep the coverage broad, in order to facilitate broad understanding by the reader, and go into detail only on those items considered unique selling points or new advances in technology. Physical characteristics should be covered. Summarize performance data in tables, charts, and graphs.

Generally, *mathematical treatises have little place in a proposal*. When it is felt they must be used, keep them as simple as possible, avoiding repetition of obvious steps in the analysis, and be certain to define terms and symbols. Finally, state in words the significance of the mathematical conclusions.

Because of its overriding importance in modern systems, discuss the *reliability of the proposed mechanization*. Actual or estimated figures of merit for reliability are important, and should be supported with historical data and prediction analyses. Discuss areas of the mechanization where high system reliability might be jeopardized, and present alternate solutions to the problems.

If appropriate, *describe the technical services to be supplied*. A large part of many programs involves delivery of no hardware, but rather the supplying of special technical services such as systems analysis, site operation and maintenance, or field support.

The RCA Qualifications Section

While every part of the proposal should bear evidence of RCA's qualifications for the program, reserve a separate section to describe:

(1) Corporate *experience* on similar or related projects (also include here descriptions of such over-all company programs as reliability and quality control).
(2) Corporate *facilities* available for use by the project.
(3) The availability and quality of *personnel* who might work on the program.

Avoid the boilerplate approach by keeping this section of the proposal as significant and pointed as possible. Emphasize those aspects of the company's and the individual's experience which will be of special value when applied to the proposed program.

For John F. Biewener's biography, see Vol. 4, No. 6, Page 53.

The Appendices

Appendices provide an opportunity to include further expansion or detailed discussion of significant areas of the proposal. If included in the main body of the proposal, such material, while important, might serve to mask a clear, over-all understanding by the reader.

EDITING

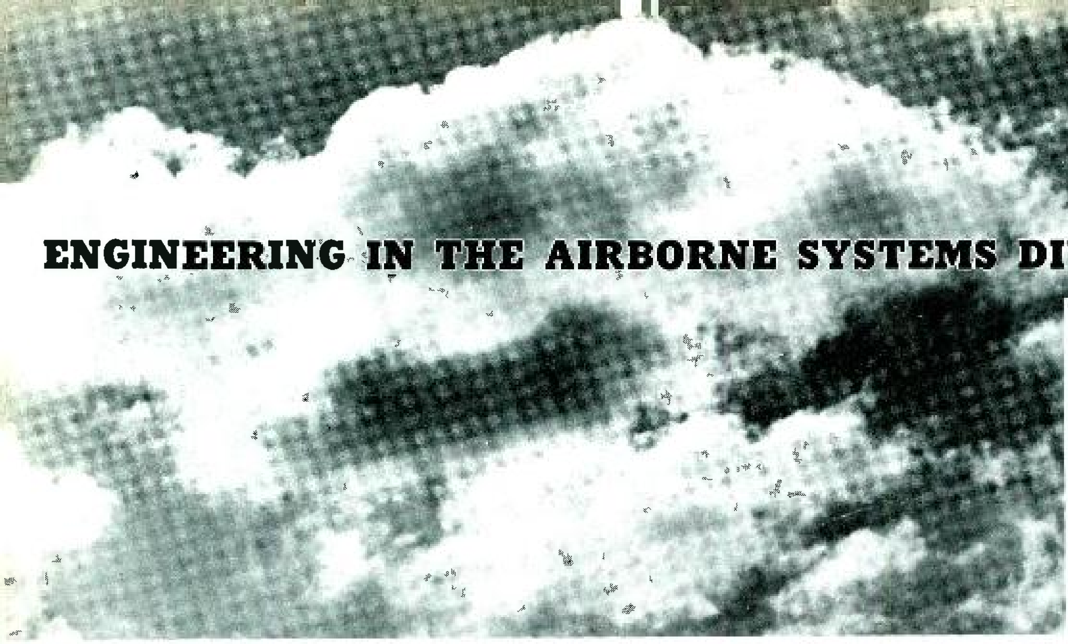
The styling, the polish, and the impact of any written document are functions of the quality of editing. While most RCA Divisions today have professional editorial staffs working in their engineering organizations, still it is highly important for the engineer-author to develop his editorial skills, since many factors (principally time) often prevent another person, no matter how qualified, from making significant improvements in proposal manuscripts.

The principal elements to be checked for in editing are *clarity*, *logic of presentation*, *consistency*, *completeness*, *accuracy*, and *emphasis*. Such basic literary factors as grammar, spelling, punctuation, and style are also the concern of the editor. These latter items are the fundamental tools of written expression and, when applied correctly, can do much to assist an author in achieving a high level of impact and communication with his words.

Editing, like writing, is an art not easily learned. Training and practice are essential steps to developing good editorial skills. All training and practice, and all knowledge of the rules, however, will not fully substitute for an alert, questioning mind carefully examining a manuscript. Furthermore, it is necessary to examine the manuscript several times in order to cover the many editorial factors mentioned above.

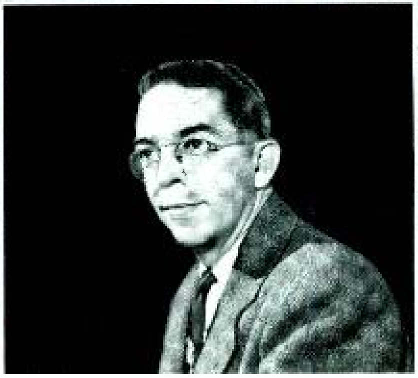
GETTING THE JOB DONE

It can be seen that there is no pat approach to a proposal. Each must be tailored to a particular product and a particular competitive situation. Even then, there is wide room for interpretation by individual authors. Preparation of a proposal is a continual series of decisions affecting the impact of communications between one person and another. This impact is of great importance in modern industry—a major determinant in the success or failure of obtaining business.



ENGINEERING IN THE AIRBORNE SYSTEMS DIVISION

J. D. WOODWARD
Chief Engineer
Airborne Systems Division
DEP, Camden, N. J.



JOHN D. WOODWARD received the B.S. degree in E.E. from Lehigh University in 1930. From graduation until World War II he worked in Airborne and Ground electronic equipment design for Bell Telephone Laboratories, United Air Lines, the consulting engineering firm of McNary and Chambers in Washington, D. C., and Bendix Radio Corporation.

In 1943 his full time services were requested by the Air Force and he served for two years as civilian Chief Engineer of the Radar Navigation Unit in the Radar Laboratory at Wright Field. For his work with the Air Force he received the Civilian Citation for Meritorious Performance.

At the end of the war, Mr. Woodward joined RCA as Supervisor of Government Communications in the Aviation Engineering Section and in 1947 he was placed in charge of the entire Aviation section. He is now Chief Engineer, Airborne Systems Division.

He is a Senior member of the IRE, a member of Aircraft Owners and Pilots Association, and a member of the American Society of Naval Engineers. He is Deputy Chairman of the Airborne Electronics Section of the American Ordnance Association.

SYSTEMS ENGINEERING, systems management, and diverse product design are the key activities within the Engineering Department of ASD. The tens of thousands of ASD designs in service for the Department of Defense include airborne systems and equipment for HF and UHF communication, Loran navigation, precision Shoran, fire-control, television, and radar—evidence of the variety of ASD activities.

From a modest start in 1945 with 60 people, including 40 engineers, ASD Engineering has grown to a diversified organization of approximately 2,000 employees, including 600 professional engineers. Even more significant than growth in size has been the development of diverse capabilities—operations analysis, system analysis and synthesis, system management, and a wide range of development and design skills.

In project management, ASD has been a leader in developing the organizational flexibility required to manage programs ranging in complexity from simple single units to the entire electronic system for an interceptor aircraft.

Past work on the equipment and systems now in operation has provided a high plateau of experience for development of tomorrow's products. These include digital communications, air-traffic-control systems, data-processing radars, automatic checkout systems, antisubmarine-warfare devices, and television systems for missiles and aircraft.

ORGANIZATIONAL FLEXIBILITY

In the early days of ASD, the customer analyzed his own system problems with a minimum of assistance from industry and contracted for specific items spelled out by detailed specifications. This was a reasonably satisfactory arrangement until system complexity increased markedly, requiring the evolution of today's Weapon System Procurement procedure, where a single contractor is chosen for full program responsibility.

A strong system-engineering organization is essential to the operation of this type of business, and during the early 1950's, the planned growth of RCA required expansion of system engineering in all departments. The Boston area was particularly attractive to ASD because of the availability of specialists in aircraft and missile systems. Therefore, a systems engineering group was started in rented quarters in Waltham, Massachusetts, early in 1955. The majority of professional engineers and supervisors were recruited in the Boston area. In 1958, this group moved into the new Burlington, Massachusetts, plant, which was built for them. During the latter part of that year, the Burlington Plant was separated from ASD and set up as the *Missile Electronics and Controls Department*, with its own engineering, manufacturing, marketing, and administrative organizations. This illustrates one of the phases of expanding engineering in a growth industry. Today, ASD in Camden is being expanded to fill the systems-engineering gap which resulted from that separation.

Another type of problem demanding organizational flexibility is the changing nature of the business. For a number of years, RCA has been active in development and production of airborne fire-control equipment; but, recognizing the trend in air defense away from interceptor aircraft, ASD has re-oriented its objectives. Effort is now concentrated in such areas as digital communications, precision airborne radars, antisubmarine-warfare systems, and weapon-system support. The latter includes automatic dynamic-test and checkout equipment for both missiles and manned aircraft. These emphasize the importance of flexible use of special skills and show the need for engineers with ability to re-orient their efforts into new fields with minimum loss of effectiveness.

The organization of the ASD Engineering Department (Fig. 1) has gone through a long evolution to incorporate the features required by a dynamic, growing business. The revisions required to keep current always present problems with the people in the organization. Human nature resists change to a degree out of proportion to the adaptability of professional engineers and supervisors. There is no magic formula for resolving such problems, but they are minimized by consideration of individual desires and skills, by clear and rapid communications, and by creating a thorough understanding of Company policies, goals, and the objectives to be achieved by the specific changes.

PROJECT MANAGEMENT

Effective management of large engineering projects has been a challenge to industry for many years. The project involving only a few engineers can be managed very well by a small integrated group, where all the necessary skills function under the line authority of a single supervisor. In contrast to this, large projects can involve several hundred engineers scattered throughout RCA's and subcontractors' organizations. With such a widespread array of talent, there is no practical way to collect it all into one organization for the duration of the project, nor is it practical for the line management responsible for one portion of the project to manage the overall job with sufficient objectivity.

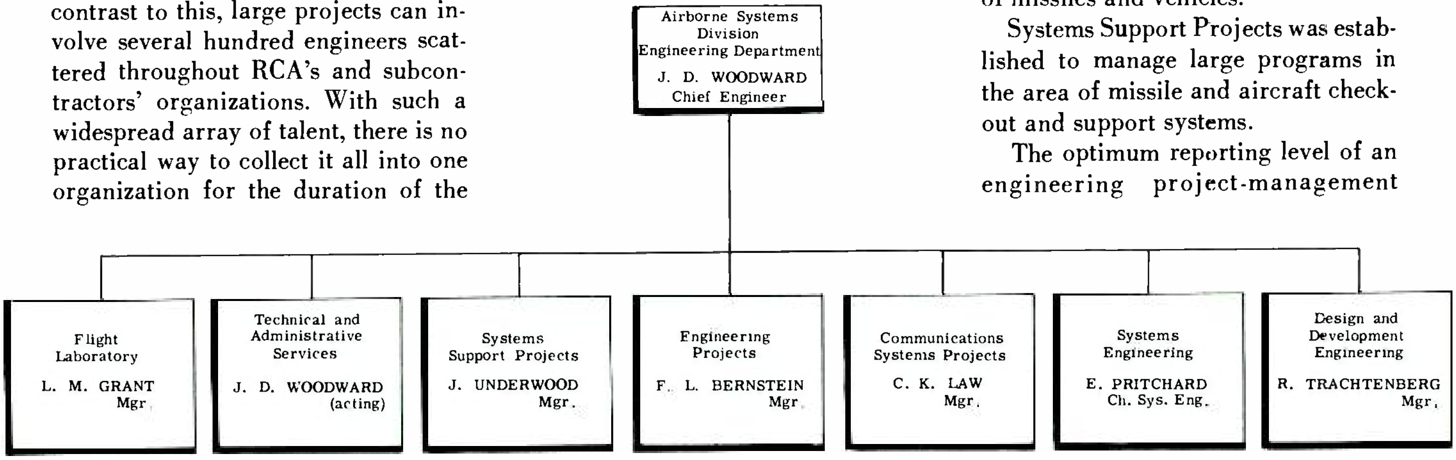


Fig. 1—Engineering Department, Airborne Systems Division.

The best management compromise is to establish a special group for the express purpose of managing the overall project on a functional basis. The term *functional* means that the management group establishes goals, interprets customer requirements, assigns tasks, and performs other normal management tasks, except that it does not have line authority over the engineers carrying out the respective tasks. It is a management group that in effect subcontracts the major areas of work on the projects. By having full freedom to cut across internal organizational boundaries and to deal directly with subcontractors outside RCA, it can operate with complete objectivity and is not saturated with the multitude of duties associated with accomplishing the detailed tasks.

While the role of the functional manager may seem to be a difficult one, because he must achieve his goals by diplomacy, reasoning, and negotiation, he is not really at a serious disadvantage. Even a line manager can accomplish little by the sole use of power, and he, too, must use the same common-sense approaches as the functional manager in dealing with his people.

The most-effective positive control available to either line or functional manager is financial. Concentrating both technical management and financial control with the project manager gives him the needed positive controls.

In addition to managing current projects, the Engineering Department must take initiative in planning future extensions of current programs and in planning and exploring new areas. In ASD Engineering, the planning for new areas of business and the direction of study programs are among the responsibilities assigned to the systems-engineering organization and the project-management groups. A division of responsibility for new business between these two functions may appear complicated. However, in a large business such as conducted by ASD, there are many product lines, and the group managing a specific line (such as communications) is more intimately familiar with customer problems and plans than the systems group. Thus, the specific project group can be most effective in bringing in new follow-on business.

In ASD, the two current project-management functions reporting to the Chief Engineer are *Communications Systems Projects* and *Systems Support Projects.* Additional project-management groups can be established as required by future programs. Communications Systems Projects was started to manage the Air Force Time-Division Data-Link Project. Later, it was given responsibility for the Automatic Ground-Air-Ground Communications System (AGACS) for the Federal Aviation Agency, since this program was a logical extension of time-division-multiplex techniques into a new area of digital communications. The programs of Communications Systems Projects now include broad areas of air-traffic control and communications systems for a variety of missiles and vehicles.

Systems Support Projects was established to manage large programs in the area of missile and aircraft checkout and support systems.

The optimum reporting level of an engineering project-management group varies with the size and nature of the program. A very-large project cutting across many organization boundaries should report to an appropriately high level. If a small project is managed from a high level, there will be a communication problem between the decision-making manager and the engineers. If the opposite situation exists, where the large project is managed from a low level, the functional manager will not have sufficient stature relative to the line managers of individual tasks nor will he

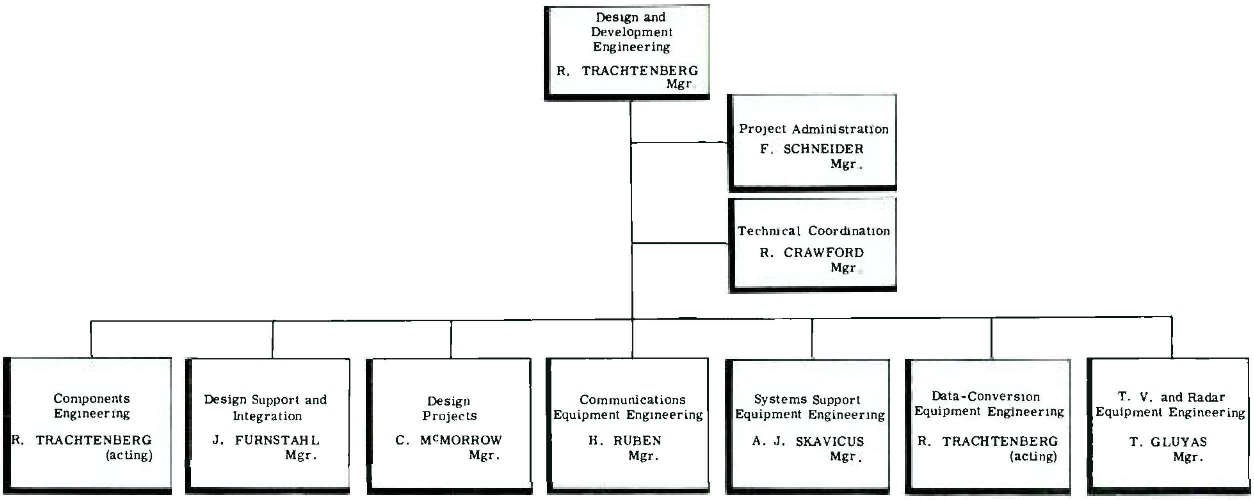


Fig. 2—Design and Development Engineering, Airborne Systems Division.

have sufficient stature in the eyes of the customer. Each project must be critically analyzed from this viewpoint in preparing management plans.

DEVELOPMENT AND DESIGN

Development and design are integrated in the largest of the functions in ASD Engineering. The various groups shown in Fig. 2 cover the breadth of ASD programs. ASD business requires the design of equipment to detailed customer specifications on a black-box basis, as well as the design and integration of much equipment for systems where RCA, working from broad customer objectives, prepares the specifications. The development and design organization is based on groups of equipment specialists.

FLIGHT LABORATORY

The Flight Laboratory (Fig. 3) is unique to ASD and provides a means of evaluating, in flight, those system parameters that are difficult to simulate in the conventional laboratory. The Flight Lab is located at New Castle, Delaware, and is staffed with specialists in installation, modification, maintenance, operation, and flight-test engineering. Extensive data accumulation, reduction, and processing facilities are available there. Many types of jet and conventional aircraft have been operated in ASD flight-test programs.

TECHNICAL ADMINISTRATION AND SERVICES

These functions include budgeting and monitoring of manpower, finances, and facilities; the engineering model shop; blueprint and photographic services; and engineering reports and publications.

The Camden Model Shop is a recent addition to the ASD Engineering Department; it provides service to all engineering organizations in the Camden area. The 30,000 square feet of floor space contain 200 machines of various types from simple hand presses to precision lathes and milling machines. Electroplating, riveting, and heliarc welding, in accordance with the most strict military specifications, are included in the special skills available from over 400 model makers and wiremen.

Blueprint and photographic services also are provided for all RCA organizations in the Camden area.

A unique feature of the engineering reporting activity is the ASD Motion Picture Productions Facility. Staffed with directors, writers, and cinematographers, this group is devoted to producing motion pictures for reporting, training, engineering, and marketing purposes for all divisions of RCA.

The service capabilities complete the Engineering Department organizational picture. In combination with the associated manufacturing, marketing, and administrative functions, it provides ASD with the *integrated ability* to design, produce, and sell—at a profit—a wide variety of electronic systems and equipment.

Fig. 3—Airborne Systems Division Flight Laboratory, located at the New Castle County Airport, just south of Wilmington, Delaware. Here, engineering specifications can be translated into flight-test programs and the programs then executed. This capability is utilized throughout an airborne electronics system program, from the proposal stage, through development, design, flight-test planning and execution, and reporting of test results. It provides an important evaluation capability through in-flight tests that simulation programs often cannot provide.

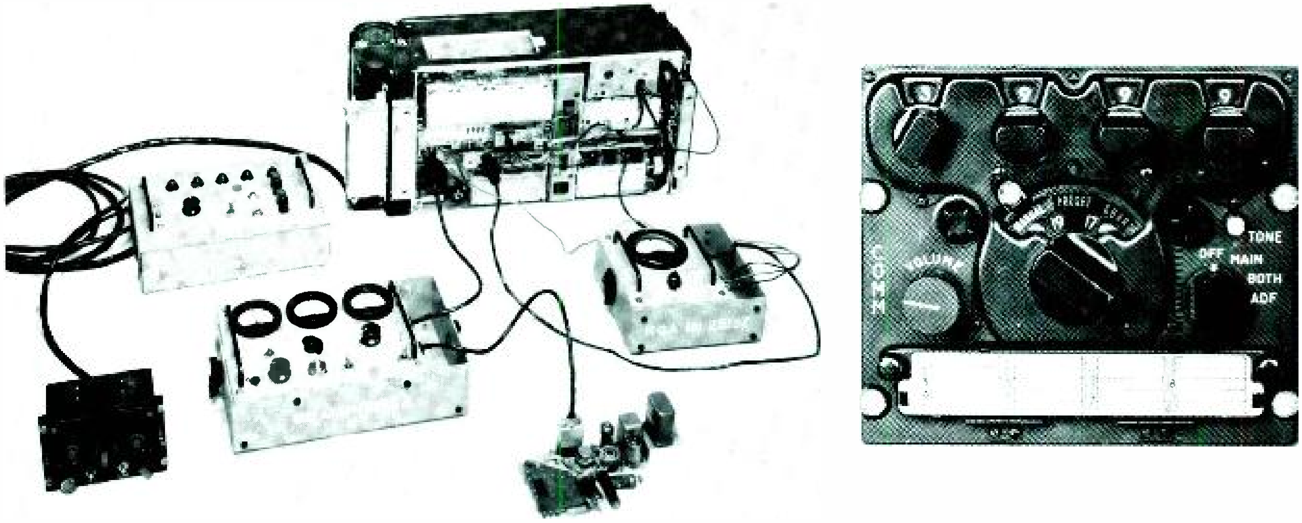


Fig. 1 — The AN/ARC-34 and associated test equipment. Inset: control panel set at 399.9 mc.

VOICE COMMUNICATIONS FOR U.S.A.F.

by

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RCA IS ONE OF THE principal suppliers of airborne communications equipment for the U. S. Air Force. The major types which have been developed and produced by the Airborne Systems Division include long-range (over-the-horizon) voice communications, short-range (line-of-sight) voice communications and data-link communications. A brief description of RCA's contributions to the development of long-range and short-range airborne voice communications is presented herein.

OVER-THE-HORIZON COMMUNICATIONS

The high-frequency band of 2 to 24 megacycles is used for over-the-horizon communications. Such operation is made possible by reflections from the ionosphere and is known as sky-wave propagation. The propagation path is quite variable from hour to hour or even during intervals of minutes; it is dependent on frequency and is subject to blackouts in the auroral regions and to multipath interference in the presence of more than one reflection path. In spite of these shortcomings, this is the best frequency band for long-distance communications, and the Strategic Air Command is equipped with the AN/ARC-21 Receiver-Transmitter, built and designed by RCA. Prior to the days of the ARC-21, it was necessary for the Air Force to carry a radio operator of considerable skill and training to operate the nonautomatic h-f communications equipment. The ARC-21 features automatic channel selection from 44,000 crystal-controlled channels, automatic tuning, and automatic loading into antennas of the wide range impedances required because of the dimensional and other installation restrictions imposed by the air frame. Modification of this equipment for single-sideband operation became necessary in line with the USAF decision to change over to that type of communications. The designation of the single-sideband version of the ARC-21 is the AN/ARC-65.

LINE-OF-SIGHT COMMUNICATIONS

The second major category of airborne voice communications is for command purposes under line-of-sight conditions. This type of communications is available in every military aircraft, for it supplies the link between the aircraft and the control tower at the landing field. It is also used for air-to-air communications and is the only communications equipment carried by high-performance fighter aircraft. This class of equipment also represents a major activity of the Airborne Systems Division.

Prior to World War II, the medium-frequency range was used for purposes of command communications. These frequencies are subject to ionospheric reflections and have the same type of variable propagation characteristics found at high frequencies. Operation is hindered by atmospheric noise which varies during the day and from place to place. These disadvantages led the Air Force to develop VHF equipment for combat aircraft.

WORLD WAR II, VHF EQUIPMENT

Although desired for frequency stability, the use of quartz crystals was not initially contemplated since units in sufficient quantities did not exist nor were large-scale manufacturing sources set up. It was not until 1942 that the USAF was able to proceed with a crystal-controlled British design known as the SCR-522. Even then, the logistics of supplying the proper crystals for each air base and theater of operations was a major World War II problem. This equipment operated in the range of 100 to 156 megacycles and provided four crystal-controlled channels. By 1945, it was quite evident that the 100-to-156-mc VHF band did not contain a sufficient number of channels to meet the needs of airborne military communications and the decision was made to change over to the 225-to-400-mc UHF range.

UHF EQUIPMENT

Requirements for UHF equipment were set up to take advantage of ad-

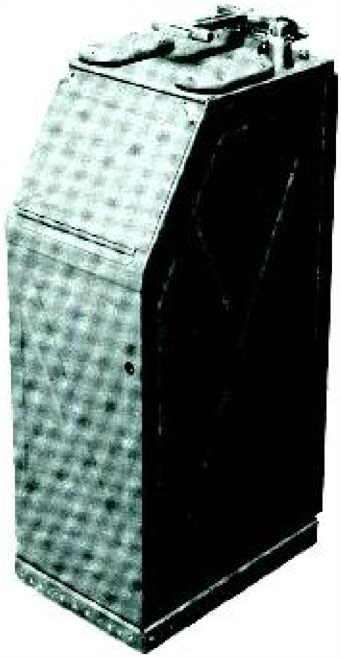


Fig. 2 — The AN/ARC-66, custom-packaged for space-premium aircraft.

vances in radio technology. The band was divided into 1750 channels spaced at 100 kilocycles, and frequency-synthesizer circuits were to be developed. These provide the channels with small numbers of quartz crystals permanently installed in each equipment so that the logistic problems of crystal banks could be eliminated. Twenty preset channels were specified to provide for operational convenience and flexibility. Manual channels and direct-reading features were required so that the operator could select any channel in the band by means of a few knobs. For example, the control panel in Fig. 1 shows a manual selection of 399.9 megacycles. In addition to the main receiver and transmitter, an independent guard channel receiver was also specified as a part of the equipment to permit reception of signals on the guard frequency at all times, regardless of the channel selected for the main equipment. Switching was required to permit the use of main, guard, or both receivers. All tuning was to be automatic and convenient.

By 1949, these requirements were met by several USAF-sponsored developments. It was USAF policy at this time to require strict adherence to the use of joint Air Force/Navy-approved components. These included miniature tubes, and as a result, the UHF command sets which went into production weighed in excess of 85 pounds and were at least two cubic feet in volume.

MINIATURIZATION

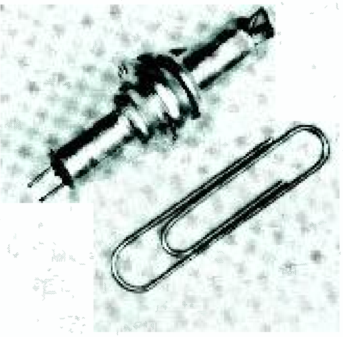
The disadvantages of large and heavy electronic equipments received increasing recognition from the USAF, and in 1949, RCA bid successfully for a development contract to miniaturize the UHF command receiver-transmitter. The resulting equipment was the AN/ARC-34. The weight of this equipment was 48 pounds. Its volume of one-cubic foot was half that of the earlier versions (AN/ARC-33 and -27), which were just starting in production in 1949.

The AN/ARC-34 was one of the first to use subminiature tubes. New versions of the pencil tube were specially developed by the RCA Electron Tube Division for use in the receiver and to permit design of an unpressurized transmitter which would operate to 50,000 feet of altitude. Small plug-in modules were used to permit high density. Some of these were hermetically sealed. Others, for the first time in RCA, employed printed wiring, the technique widely used today. Plug-in assemblies were used throughout.

More-complex circuits than had previously characterized communications equipment were required to provide automatic tuning, and special test equipment was designed and supplied to the USAF to permit maintenance by technicians with a minimum of training. The test equipment connected is also shown in Fig. 1.

The AN/ARC-34 has been produced in large quantities. It has been used in many space-premium interceptors. However, a special configuration was needed for the F-104, the Lockheed Starfighter. This equipment, designated AN/ARC-66, is shown in Fig. 2.

Fig. 3 — Low-noise pencil tube.



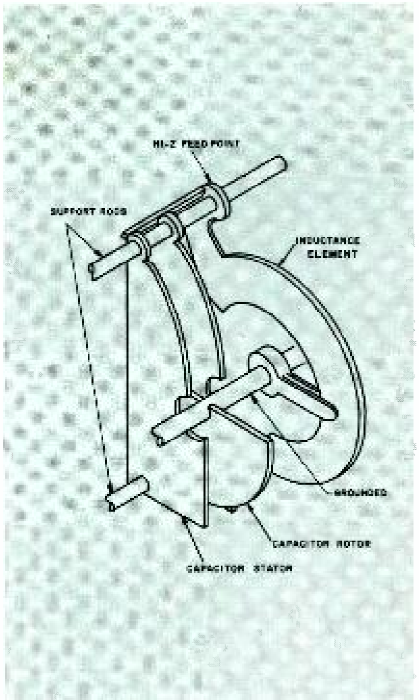


Fig. 4 — UHF tuning arrangement for AN/ARC-62.

The AN/ARC-66 uses cooling air from a central source in the air frame, which is ducted into the bottom of the equipment, and it employs a 400-cycle power supply. AN/AIC-10 interphone amplifiers are part of its package.

As the AN/ARC-66 illustrates, there was need for custom packaging to fit space-premium aircraft and for a new UHF command set to provide the flexibility required in the most advanced aircraft. RCA was the successful bidder for development of the AN/ARC-62 to meet this need. Here, another major step in miniaturization is evident — a reduction to 33 pounds in less than half a cubic foot, as compared to the 48 pounds and one cubic foot of the AN/ARC-34.

SILICON TRANSISTORS

The AN/ARC-62 utilizes silicon transistors for the 3-mc, second i-f and all lower-frequency circuits. The RCA Electron Tube Division has also contributed to this program by development of a new low-noise pencil tube shown in Fig. 3. The UHF tuner contains two r-f stages and each uses a circuit in which both inductance and capacitance are varied. The circuits have been refined to obtain a 7-db noise figure, constant gain, and adequate selectivity throughout the operating range. Fig. 4 shows the arrangement of variable inductance and capacitance, providing excellent performance. This avoids some of the critical dimensions of previous designs. The transmitter is based upon use of the RCA 6816 tube, developed for this particular application.

The AN/ARC-62 i-f circuits are broadly tuned to minimize de-tuning caused by application of AGC to the transistor amplifiers. All of the selectivity is derived from a crystal filter.

Squelch circuits used in the past have been dependent upon gain and input power variations and have, therefore, required frequent readjustment in the field. A new circuit, which is insensitive to such variations and whose operation depends upon signal-to-noise ratio, was developed (Fig. 5).

MULTICHANNEL CRYSTAL CONTROL

Two methods for providing a large number of crystal-controlled channels have been used by RCA. One employs a master oscillator which is phase locked to a frequency derived from a multitude of crystal oscillators. The second method, selected for the AN/ARC-62, employs direct injection into a double-superheterodyne system. With this arrangement, the variable-tuning elements must be positioned mechanically. This is accomplished by means of individual positioning mechanisms located within the separate modules (Fig. 6). This positioner provides 100 discrete shaft positions in response to command signals from the remote-control box.

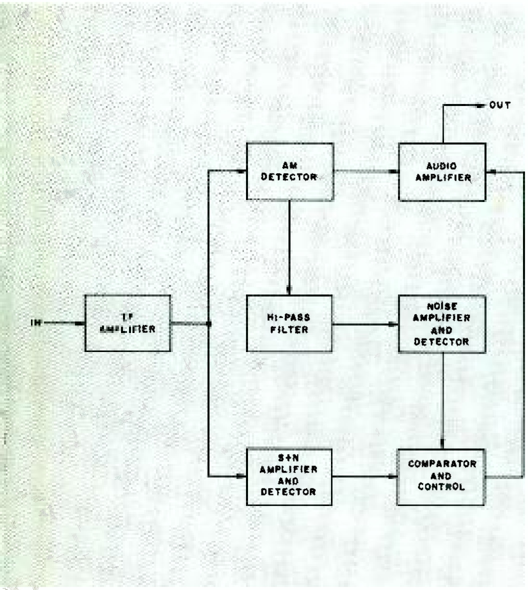


Fig. 5 — Method for signal-to-noise-ratio squelch for AN/ARC-62.

COMPACTNESS AND OPERATING EASE

Packaging flexibility, an essential for the AN/ARC-62 is provided by an arrangement in which modules can be mounted in several different configurations on top of a base plate which serves as a plenum for cooling air and which carries the necessary interconnections between modules.

In a modern interceptor, not only is the cockpit extremely crowded, but the pilot wears special clothing which limits his ability to move. He is surrounded by a formidable array of instruments and controls. Furthermore, he is in control of a high-performance aircraft to which he must constantly devote his full attention. Under these conditions, field experience has shown that pilots have gotten into difficulty by selecting the wrong UHF channel or from the necessity for looking down at the UHF set control box and being distracted. This problem is overcome in the AN/ARC-62 by providing a small remote indicator on the instrument panel directly in front of the pilot to display channel number or operating frequency.

SUMMARY

This HF and UHF communications development is an example of a type of work being done by the Airborne Systems Division. The specifications are determined from operational requirements and are often revised in accordance with the field experience during the useful life of a given equipment. Maintenance provisions must accommodate handling and repair by personnel of minimum skills. Improved circuits and mechanical features for greater reliability are always needed. Ingenuity in reducing size and weight continue to be a necessity. Flexibility to suit varied installation arrangements makes possible wider application of our designs. All these are key factors which constantly influence airborne communications engineering.

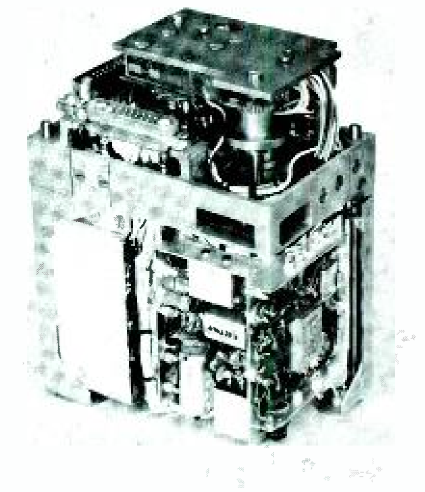


Fig. 6 — Mechanical positioner as part of first i-f module of the AN/ARC-62.

R. TRACHTENBERG is Manager, Airborne Design and Development Engineering, ASD. He received his BSEE from the University of Illinois in 1937, and MS in Industrial Management from MIT in 1954.

Mr. Trachtenberg joined RCA in 1937 as a student engineer and was assigned for several years to home instrument engineering. In 1942 he was transferred to Government work and engaged in projects on airborne radar altimeters, tail warning devices, other radar applications, and communications.

Equipments on which he supervised design included the AN/ARC-34 UHF command set, the AN/ARC-65 single-sideband HF set, AN/ARR-48 data link, later data link equipments, and the AN/APN-110 altimeter. Included were advanced designs for specific application in modern weapons systems including the B-58, F-108, and Bomarc. These designs meet the latest environmental requirements as well as the weapons systems operational needs.

Mr. Trachtenberg is responsible for the design of television, radar, data conversion equipment, and support equipment for a variety of systems, in addition to communications equipment.

He was awarded a Sloan Fellowship at MIT in 1953, and is a member of Tau Beta Pi and a Senior Member of IRE. He holds several U.S. Patents.

AUTOMATION COMES TO AIR TRAFFIC COMMUNICATIONS

by

R. E. DAVIS, Mgr.

Air Traffic Control Projects
Airborne Systems Division
DEP, Camden, N. J.

PUSHBUTTON communication has been a pilot's dream for many years. The first step toward making this dream a reality occurred during August, when RCA delivered an experimental model of a system called AGACS (pronounced "AJAX"). AGACS is an automatic ground-air-ground communication system developed for the Federal Aviation Agency to automatize the routine communications between air-traffic controllers and pilots.

AUTOMATIC DATA TRANSFER

The AGACS concept utilizes two-way time-division digital data transfer over existing ground and air communication links to provide an automatic mutual exchange of information. Controller-initiated routine flight instructions and advisory information are translated into pulse trains, and then transmitted sequentially in roll call to selected aircraft, where these binary pulses are converted into a direct-reading display for the pilot. When the aircraft is interrogated, pilot-initiated routine flight information is similarly translated and transmitted to the controller, where it is converted into a direct-reading display.

Emergency messages are provided by a voice override capability. A selective memory function incorporated in AGACS provides both the controller and pilot with a direct-reading display of the last message received from each other.

Within a two-minute roll-call cycle, up to five-hundred two-way messages are processed; these messages are contained within a single-frequency channel, such as is presently used for voice communications.

Wherever possible, the equipment fabricated for AGACS utilizes off-the-shelf hardware and standard techniques in order to furnish the most reliable equipment in the shortest possible time. The experimental system thus produced will be used in a one-year program of experimentation and modification at FAA's national aviation facilities experimental center. These tests are expected to evolve the parameters required for the system. FAA intends to derive the system through experience, rather than rely on theoretical considerations alone.

AIRBORNE SUBSYSTEM

The pilot's display and message-insertion unit is shown in Figs. 2 and 3. It uses servo loops to position tapes on which direct read-out information has been printed. The upper part of the panel displays information received from the controller and calls the pilot's attention to new information by flashing an amber light underneath the button labeled *acknowledge*. In pushing the *acknowledge* button, the pilot closes the loop, informing the ground controller that he has noted a new message.

When the pilot wishes to contact the controller to request information or file a position report, he uses the lower portion of the panel. Here, he selects the phase describing the action, and sets the four alpha-numeric characters as corollary information. After composing the desired message by turning these knobs, the pilot depresses the *report* button, which is then illuminated green from within, remaining lit until the message is read out to the ground equipment and acknowledged by the ground controller. The time shown in the lowest window is automatically inserted in the report. In a similar fashion, altitude is automatically inserted in each return message.

The altitude display unit (Fig. 4) shows ground-to-air information in the upper window and, in the lower window, the data being automatically inserted in the return.

The data processing unit is a single box mounted in a standard ATR rack tray. It ties in information displays to the existing communications sets, which have been modified for handling data. The incoming pulse trains from the receiver are examined by the data processing unit, which recognizes the synchronizing pattern, checks the incoming message for address and parity, and if correct, stores the message and decodes the outputs for the display

Fig. 1—Cecil Barnett, a key engineer in the development of AGACS, at the ground controller's experimental console.

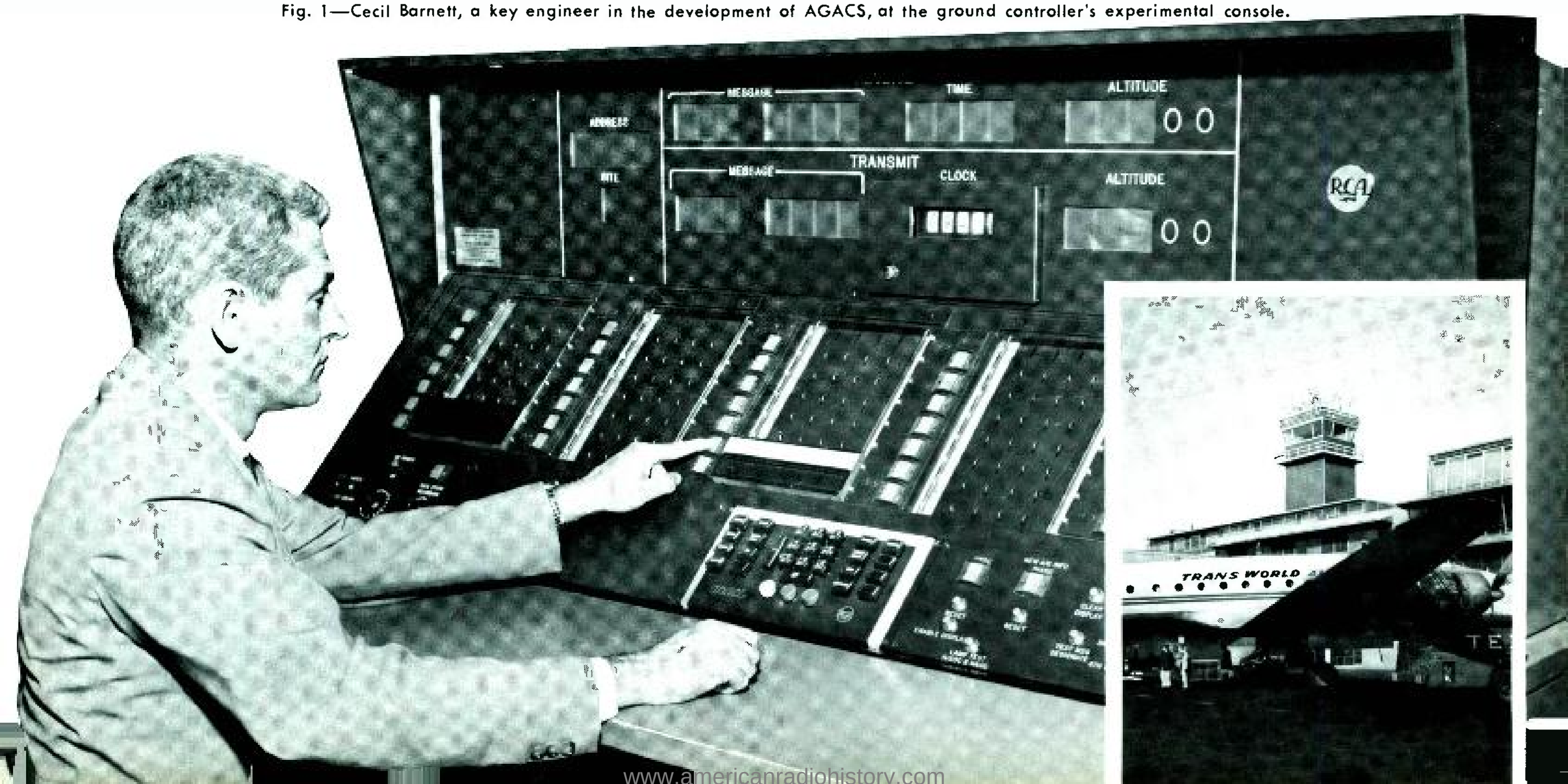


Fig. 2—Airborne display and insertion unit.

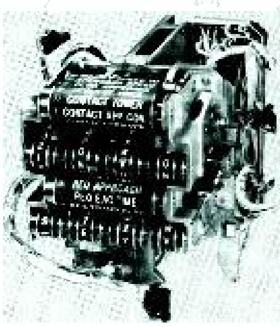


Fig. 3—Airborne display and insertion unit; internal view showing tape drives.

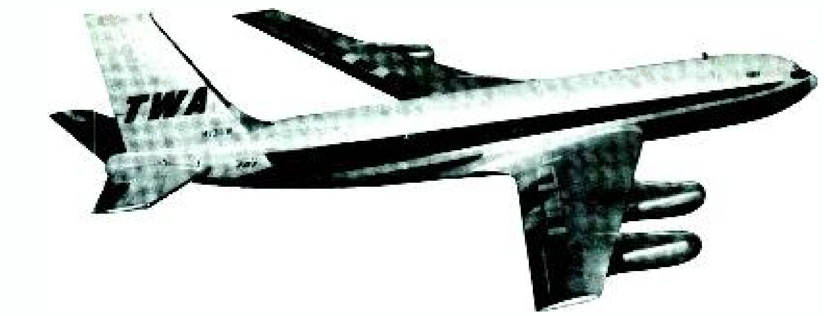
units. The unit also takes inputs from the displays to construct the air-to-ground messages and provides all the timing for the airborne subsystem. Fig. 5 shows the functions performed in the data processing unit and its tie-in to the displays.

The synchronizing pattern detector looks at both the pattern and the length of the bits in the sync pattern. The pattern must be correct for acceptance; however, a tolerance that can be adjusted to be more or less discriminatory of the incoming signal is placed on the length of the bit.

A master programmer (a binary counter) is started by the pulse of the sync pattern, giving all timing instructions to the data processing unit and other units.

The programmer generates the sampling pulses for the incoming data and shifts the detected data into a shift register. When all of the address bits are in the shift register, instructions are given to check for aircraft address and universal address or, at the pilot's option, the test address and universal address. If this address is correct, the remainder of the message is shifted into the shift register and an overall message parity check is made. If this is correct, the data is shifted from the shift register in parallel to a long-term storage unit.

Fig. 4—Altitude display unit and altitude sensor-encoder.



At this time, a keying signal for the transmitter is generated. After 32 milliseconds, a sync pattern is generated and, at the time of the *start* pulse, the air-to-ground message is inserted into the shift register according to the information set up by the displays. Following the sync pattern, this message is then shifted out, and an overall message parity bit is inserted at the end. During the time of the air-to-ground message, the keying signal remains on and a modulator gate signal is generated. Here, r-f energy appears only during the time of the modulator gate signal. The long-term storage unit is connected to a Kirchhoff adder, which performs a digital-to-analog conversion. One-wire analog signals for each word of the message are then furnished to the displays. The data processing unit, on command of the pilot, selects the proper information from the displays to form either a C or a D message reply. No action by the pilot gives a C reply; information insertion gives a D reply.

R-F EQUIPMENT MODIFICATIONS

The r-f equipment being modified consists of two of each of the following: (1) AN/ARC-34 UHF Transceiver, (2) Bendix TA-20B VHF Transmitter, and (3) Bendix RA-18C3 VHF Receiver.

Two systems of modulation are to be evaluated with the experimental system. The first is frequency-shift-keying (FSK), which causes positive or negative shifts in carrier frequency with changes in data modulation. A set of airborne VHF and UHF transmitters and receivers has been modified for this service. A second set of equipment modified for FSK-AM involves shifts in audio subcarrier in accordance with the way in which data AM-modulates the carrier. This system provides minimum modifications to existing airborne equipment.

The FSK system will have a deviation of ± 10 kc in the VHF spectrum and ± 20 kc in the UHF spectrum. This gives a bandwidth requirement of approximately 40 kc in the VHF spectrum and 80 kc in the UHF spectrum.

The AM system uses a subcarrier of 4.5 kc shifted ± 1.5 kc. This results in an audio spectrum somewhat less than 10 kc wide. This modulation system will be used for both the VHF and UHF equipment. The carrier in FSK or the subcarrier in FSK-AM are never transmitted, since a non-return-to-zero system is used. Modifications of the VHF equipment to handle data using FSK carrier are illustrated in Figs. 6 and 7.

The receiver is modified by removing the power supply and inserting, in its place, an additional i-f strip that amplifies and demodulates the data signals. The transmitter is modified by increasing the frequency of the low-frequency oscillator crystals and inserting a balanced modulator between the oscillator and the next mixer. A data signal is generated by using two oscillators, one for mark and the other for space. These signals are divided down by a factor of five in a locked oscillator, whose output

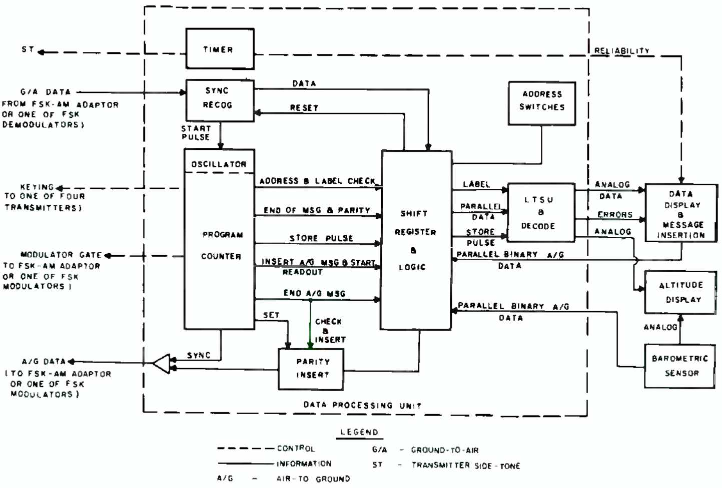


Fig. 5—Data-processing unit.

R. E. DAVIS (see cover) received his diploma in Physics from the University of Rochester in 1940. Since then, he has had wide experience in the development, installation, and flight testing of electronic control and communications systems for airborne applications at Wright Field, Sperry Gyroscope, and RCA. Among these projects were the development of the E-1 steering adapter for coupling bombsights to automatic pilots, the installation and flight testing of radio and telemetry equipment of EQT-33 drones, and the development of the air-speed and mach control system for the B-47 aircraft. At Sperry, Mr. Davis was responsible for the development of the remote control system for the MB-29 and the coupling to navigational equipment; there, he was also project manager on the development of a microwave command-guidance weapon system using a two-way time-division data link. He directed an air-traffic-control study program on a landing-control system using a two-way data link, automatic tracking, and airborne instrumentation.

Mr. Davis joined RCA in 1958 as a communications engineer responsible for technical coordination on a classified military communications system. He subsequently became AGACS project manager and is now Manager, Air Traffic Control Projects. He is a member of the AIEE, and a past chairman of the Transportation Division of the New York Section of the AIEE. Mr. Davis was one of the speakers in the IRE lecture series on Missile Guidance. He has presented papers at the IRE National Electronics Conference and the IRE-RTCA meeting.

is then fed into the balanced modulator. The difference frequency from the balanced modulator is an FSK signal having a center frequency equal to that of the original low-frequency crystal oscillator.

A center-frequency crystal is used to generate a carrier for AM signals. In data operation, the transmitter power supply is left on continuously, and the transmitter is keyed by using bias circuits with the amplifier tubes originally present. The antenna relay is switched from *receive* to *transmit* at the same time. This FSK modulator replaces the power supply of the transmitter. The two power supplies are then combined on a separate chassis.

The ARC-34 is modified for FSK operation by removing the guard receiver and inserting a modulator-demodulator very similar to the one described above, but using different frequencies. This modification is completely transistorized.

All modified equipments retain their original AM functions. In fact, it is possible to receive voice on the data channel when data is not being transmitted. Pressing the microphone button in the aircraft will automatically put the set in voice operation.

The FSK-AM modulator is very simple in operation. The data processing unit gates 3-kc and 6-kc square waves derived from the basic clock in accordance with the air-to-ground data. All that is required externally is a low-pass filter which starts its cutoff at about 8 kc.

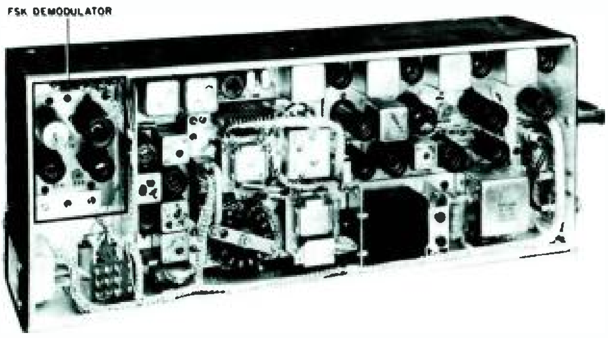


Fig. 6—VHF receiver, RA-18C, modified for FSK.

Fig. 7—VHF transmitter, TA-20B, modified for FSK.

The demodulator in its simplest form would consist of a 3-kc and a 6-kc filter, each followed by an envelope detector. However, a data rate of 750 bits per second gives only four cycles of 3 kc per bit of information, which makes it difficult to derive a leading edge for synchronizing purposes. An effective method is to beat the two tones upward in frequency, separate the side-bands, and use an ordinary FM discriminator for detection. Either method uses the high-quality audio channels (ATCSS) of the r-f equipment for the data function.

GROUND SUBSYSTEM

Automation of communications is provided in AGACS for the ground controller as well as the pilot. The ground controller's experimental console is shown in Fig. 1. This console and the racks of ground equipment were developed in the Surface Communications Division. The controller presses a button to display the last transmitted message and received reply for the aircraft associated with the selected flight progress strip. The controller can, by means of the data-insertion handset on the desk, compose and send traffic-control messages to individual aircraft tied into the system.

Both incoming and outgoing messages are shown in plain-language readout as a light projection on the rectangular ground-glass panels at the back of the console. The sloping panel contains flight-progress strips mounted in movable holders. These strips contain data on individual aircraft flight plans.

Fig. 8 shows a typical flight-progress strip used by the present controllers for manual updating of each flight's progress. The left-hand box shows the identity of a particular aircraft, its speed, and the time it is estimated to arrive at the next fix reporting point. The next box on the top row shows the time that it reported over the previous fix point, while the string of characters underneath this box show the route that the aircraft is expected to fly. These strips then provide to the controller a convenient memory for each of the aircraft under his control. Under present procedures, the controller contacts the airplane by voice to request the pilot's estimate of his time of arrival; similarily, the pilot reports his actual time of arrival at the fix reporting point.

In another of FAA's programs, the printing of information on the flight program strip will be accomplished automatically through a data processing central now being developed. The communication link is being automatized in the AGACS program; the con-

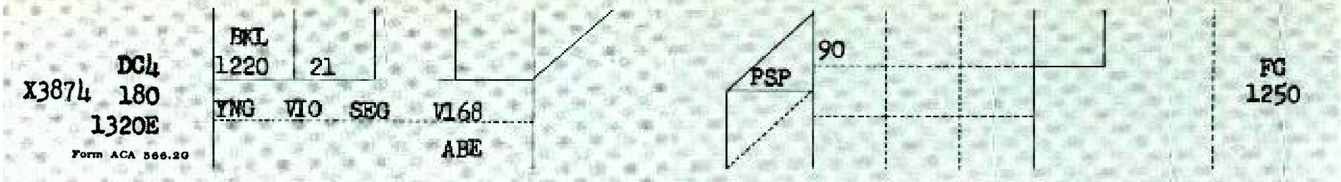


Fig. 8—Flight-progress strip.

sole furnished by RCA still retains the manual flight strips for the initial tests. but will ultimately integrate with the data processing central to complete the automation of the controller's tasks.

INFORMATION ROUTING

Fig. 9 shows the routing of information from the controller's keyboard through the digital data-handling equipment to the telephone lines which tie this central station to the r-f transmitters and receivers located at remote sites. Each ground-to-air message originated at the control center is routed to a selected peripheral site where it is transmitted to the airplane. The message sets up the display in the selected aircraft and triggers the air-to-ground reply. The reply is received at the peripheral site that originated the interrogation and is routed back over the telephone lines to the control center. As soon as the reply is received, a message is sent out to the next aircraft. The reply from each aircraft is checked against the message sent out, and the repeated back portions of the message are automatically compared with the quantity transmitted to the airplane. The central station is triggered to re-interrogate this aircraft if the proper comparison does not result.

The central station equipment performs many other automatic checks to insure the highest reliability for traffic control. Among these are parity checks on words within a message and on the over-all message; and a bit-by-bit comparison of outgoing messages during transmission. This bit-by-bit comparison is accomplished by monitoring the outgoing r-f transmission, feeding this information back on the second pair of the telephone line, and comparing each bit. This insures that the entire loop, including telephone lines and r-f equipment, is continuously accurate and operable. A magnetic tape records all outgoing and incoming messages and stores the time from a master clock so that the magnetic tape can be played back and printed in direct-reading, plain-language copy, using an electric typewriter.

The multiplexer, display, and insertion group of digital equipment is fabricated in an open-rack construction using a minimum number of types of standard printed-circuit boards to facilitate experimentation and modifications during the evaluation phases of the program.

The storage of information from the five hundred aircraft that can be handled by this automatic communication system is accomplished in a magnetic drum. This permits the controller to recall the latest communication with any specific aircraft. It further serves as the store of information for the automatic roll-call sequences. Data is fed to the telephone lines through digital data subsets furnished by the Bell Telephone Company and routed to the remote transmission point using Schedule 4, private-line service. At the peripheral site, digital data subsets convert the information into d-c levels for coupling to the r-f group.

CONTROLLER OPERATIONAL PROCEDURES

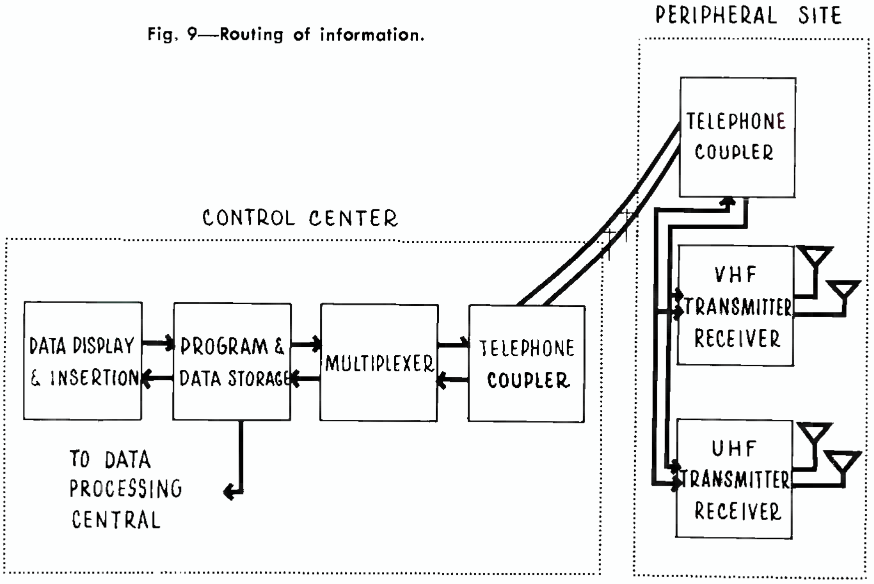
The controller selects a specific aircraft that he wishes to enter into the system by composing the address and the basic information from the flight plan with a keyboard. As he composes this information, a character at a time, it flashes onto the ground-glass screens in front of him. After composition, the controller pushes a *transmit* button which enters that airplane into the system; the system begins to interrogate this aircraft on the roll call. The airborne equipment automatically responds to this interrogation, sending back roll-call replies which are checked by the ground equipment and entered into the drum. Attention of the controller is required only when an amber light is illuminated to indicate when new information is received from that aircraft or, if a red light is illuminated, to indicate loss of contact with that particular aircraft. These lights are associated with the aircraft by a particular flight-strip holder and will operate lights adjoining that strip holder regardless of its position on the tray. To call up information for display purposes, the controller simply pushes the illuminated button.

The foregoing description is typical of only one of the many controller sequences possible with this equipment. Evaluation tests at the National Aviation Facilities Experimental Center at Atlantic City are designed to determine the utility of the many possible operational techniques and establish those which will serve as a basis for any future system to be used for nationwide implementation.

The experimental system now being tested is not intended as a specific prototype. Before the characteristics of the AGACS engineering models can be completely determined, additional work will be performed in such areas as optimization of data rates, revision of message structure, and automatic reporting of position.

Ultimately, automatic airborne equipment, such as AGACS, adaptable to the varying communication requirements of all users of this air-traffic control system —commercial, military, and general aviation—is expected to be available for use with the automatic ground system. When this occurs, *automatic communication* will truly become a *key element* in air-traffic control.

Fig. 9—Routing of information.



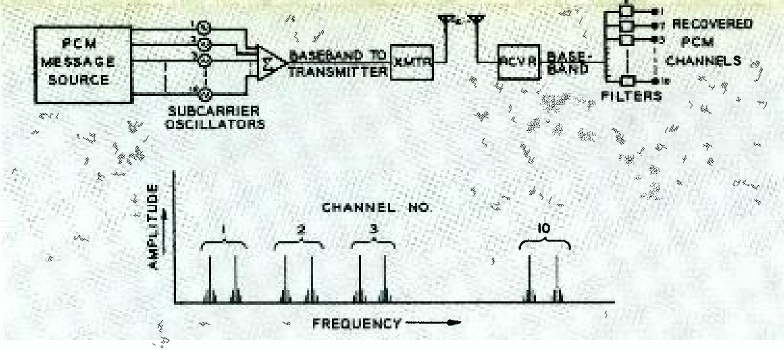


Fig. 1—Frequency-division multiplex transmission system.

TIME-DIVISION DATA LINK: NEW GROUND-AIR COMMUNICATIONS CONCEPT

By

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Airborne Systems Division
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Today, the needs for effective ground-air communication systems are increasing rapidly, a result of the requirement for more-complicated ground control environments and the many, widely deployed, high-speed aircraft.

A ground control environment is a complex of data-gathering facilities, data-communications links, and data-processing and computer subsystems. Efficient utilization of aircraft, military or civil, depends upon the ability of this environment to provide the pilot with the information he needs.

Generally, both must have up-to-the-minute information about air traffic. Ground radars and other data-gathering devices can provide ground computers with information basic to the solution of the air traffic problem. This information can be transmitted to the pilot by voice; however, the large numbers of aircraft and the slow rate of information transfer in voice systems have presently saturated voice communication facilities.

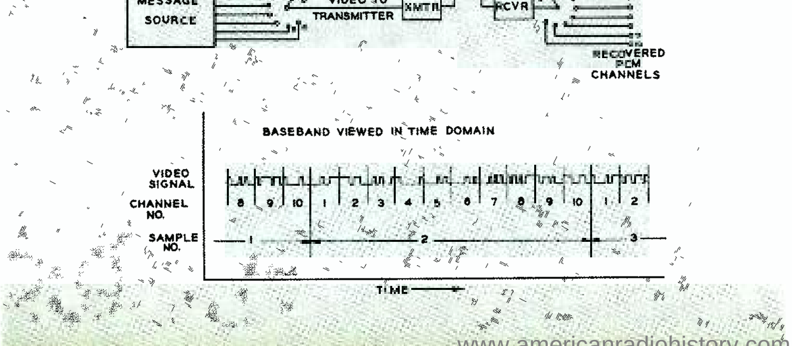
WHY A DATA LINK

Present and future requirements dictate the need for employing a more-efficient digitally coded transmission system in as many of these control applications as possible—a *data link.*

The need for a military and civil data link has been recognized for over ten years. Most of the development, however, has been to military requirements. The Navy *Discrete Address* program, for example, has been underway for some time. The early work was done by the Navy at NRL and within the Air Force at Rome Air Development Center and the Air Force Cambridge Research Center. The first systems were multichannel time-sequential systems and versions of FM-FM telemetry systems. Some of the first operating equipment was developed in conjunction with sponsored studies by the Air Force on an *Automatic Ground-Controlled Approach System.*

In 1951, a study of air-defense problems sparked development of the *Semi-Automatic Ground Environment*, or SAGE. This, in turn, brought on the requirement for an operational data-link system for the control of interceptors within this environment.

Fig. 2—Time-division multiplex transmission system.



The currently operational *frequency-division* system was developed on an accelerated basis to meet this requirement. This has been designated as an interim system by the Air Force and is to be replaced by a *time-division* system. RCA is currently under Air Force contract to deliver operational time-division data-link equipment for this purpose.

WHY TIME DIVISION DATA LINK

It is informative to examine briefly the difference between *time-division* multiplexing and *frequency-division* multiplexing. As the names imply, separation of information is accomplished either in the time domain or the frequency domain. As a simple example, consider a ten-channel pulse code modulated link. For this link, assume that each sample to be transferred via this link is quantized into 8 binary digits, and 10 samples per second are required from each of the ten channels. If the ten channels are to be frequency-multiplexed, ten subcarriers are selected and each is modulated at an 8 x 10 or 80-bit-per-second rate. The resulting base band will appear approximately as shown in Figure 1.

This base band may be amplitude- or frequency-modulated on a carrier and transmitted, received, and demodulated to obtain the base band. At the receiving terminal, the individual subcarriers are separated by filtering and then further demodulated to obtain the quantized levels.

If these ten PCM channels are time-division-multiplexed, each channel will be sequentially allocated or commutated into a time slot in a frame of 10 such allocations. In order to maintain the sample rate, this frame length must be 1/10 of a second, and the bit rate must be increased by a factor at least equal to the number of channels—in this case ten. This is shown in Figure 2. Therefore, the modulating signal consists of a serial binary pulse train at a rate of about 800 bits per second. After modulation on the carrier, transmission, reception and demodulation, the channel content must be regained by a process of electromechanical or electronic decommutation. Figure 2 indicates a simple decommutation process. The decommutator must be synchronized with the commutator at the transmission end of the link. In

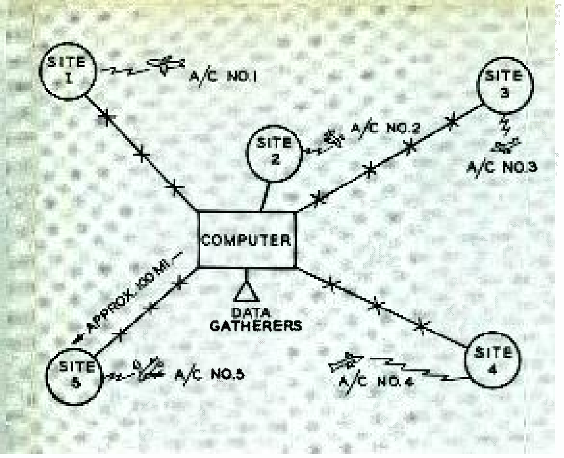


Fig. 3—Typical multi-site control environment.

practice, this requires each sample or sample frame to contain an identifying or synchronizing signal and results in bit rates slightly higher than those quoted above.

When used for airborne surface-to-air control links, the information channels of the ten-channel link just considered are intended to go to a particular aircraft. For simplicity, consider that these channels are equivalent to aircraft addresses. For the frequency-division-multiplex scheme, the airborne equipment will select and react to the information on one of the subcarriers, while in the time-division-multiplex method, the airborne equipment will look for and react to a particular time interval. Accomplishing this decommutation requires accurate synchronization.

In operational use, several advantages are gained from using the time division approach. To appreciate this conclusion, one must examine a typical data-link complex for a control environment.

Figure 3 shows such a system, perhaps for an air-traffic control sector. Inasmuch as radio frequencies, such as VHF (108 to 160 mc) and UHF (200 to 500 mc), are allocated for use in air-ground-air communication (and these frequencies are line-of-sight limited) several transmitting (and receiving) sights are required to cover a geographical area several hundred miles on a side. The surface-to-air transmitting sites shown in Figure 3 provide contiguous coverage for aircraft at altitudes of several thousand feet. In such an operation, the control computation facility for this sector is made cognizant of the position of each aircraft through the data gatherers. It selects the closest transmitter site, i.e., Site IV for aircraft 4 and Site I for aircraft 1, routing the messages to be transmitted over the ground circuits. Consider for a moment that this sector is implemented with a frequency-division-multiplex data link. Assume that aircraft 2, which, say, is looking for subcarrier 2 for its information, is at such an altitude that it can see several transmitter sites. The plane must be flying at a not-unusual altitude of 17,000 feet or more to be in this position, bearing in mind that other subcarriers are simultaneously carrying information for aircraft 3, 4, and 5; as a result, all transmitters must be operating simultaneously. In this case, the transmitters must all be on different carrier frequencies to avoid destructive radio-interference patterns. Thus, the sector must be subdivided by frequency-coverage regions, requiring several radio-channel changes by each aircraft flying through the control sector.

When implemented with a time-division data link, the serial nature of the information intended for each aircraft permits keying of the appropriate transmitter site for transmission of that message. All other transmitters are turned off. As a result, a single radio-frequency channel can be employed for the entire sector.

Aside from this basic and important gain, other advantages are accrued. Principal among these is increased transmission reliability because of the capability of obtaining more-efficient utilization of sideband power.

Thus far, the discussion has implied one-way, surface-to-air operation of the data link. With the time-division data-link system, no such limitation is imposed. Existing military and civil data links provide for air-to-surface transmissions. Generally, however, the air-to-surface message is a reply to a surface-to-air interrogation.

Taking the simple time-divided, ten-channel link described earlier, assume that the data rate is increased by a factor of three (about 2400 bits per second), while the sampling rate is maintained constant. Further, assume the transmitter carrier keyed on only for the duration of a channel (aircraft address). This is illustrated in Figure 4. Now, space is provided for a reply message of the same length as the interrogation with sufficient time to absorb propagation intervals (12.6 microseconds per nautical loop mile). Under these conditions, interrogations and replies can occur on a non-interfering basis using the same or different radio-frequency channel.

MESSAGE REQUIREMENTS

In the multisite operation for which the time-division data link is most applicable, the airborne equipment is faced with the problem of receiving and processing essentially asynchronous messages, most of which are not intended for it. Further, because of the necessity for pulse coding, the mechanics of interpretation, display, and/or automatic utilization of the message content must be well ordered. For the most part, binary digital codes are used and the meanings of the individual bits in the message format are defined by rigid message standards. The message format and the message standards are the grammar and dictionary of the data link.

Figure 5 shows a generalized message format. Since data-link transmissions are nonsynchronous, each message must contain synchronization information. It is the purpose of this sync to initiate the fixed program of the airborne message decoder so that the processing is in synchronism with the received message. Generally, this sync is an easily recognized, but unique, pattern or code. It is desirable that the code differ from any of the possible codes that could be contained in the rest of the message. In addition,

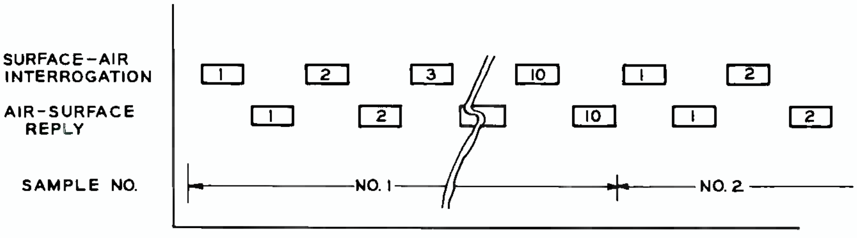


Fig. 4—Two-way time-division multiplex transmission utilizing keyed carrier.

Fig. 5—Generalized message format.

the code must be such that it can be produced by noise with very low probability. An effective method of satisfying the first of the above criteria is the use of a bit rate in the sync that is different from, and not a submultiple of, the bit rate of the remainder of the message. To combat noise-triggering of the sync recognition system, a greater number of bits must be used than that required for a noiseless channel.

The address portion of the message identifies the message as being directed to discrete airborne equipment, to the exclusion of all other airborne equipment. The number of address bits required is a function of the maximum number of different addresses the system must be capable of handling. For instance, consider an air-traffic control environment into which any one of 50,000 aircraft, each with a fixed address, may enter. In order to avoid confusion, each must have a discrete address, so that 50,000 separate address codes are required. A binary code of sixteen bits, which provides $2^{16} = 65{,}536$ discrete codes, would be required. The number of codes and hence the number of bits in the code can be reduced if the aircraft addresses are not fixed but may be controlled by the pilot. Then the number of codes required will be determined by the maximum number of aircraft the environment may be expected to control at one time. Reply messages may repeat the originating address for ground-checking purposes. Generally, a reply is associated timewise with the interrogation, and address repeat-back is not a necessity.

The label portion of the message identifies the type of information the message contains. Often the total number of bits of information required by an aircraft is large, but the rate at which each class of information is required is different. For instance, terminal area vectoring instructions may be required at a rate of once per minute, while way-point identification may be required only once per 10 minutes. To include the total of each class of information in a single message would not be efficient. In addition, different aircraft may require different types of data. The number of label bits required is based on the maximum number of different types of messages the environment may be required to transmit. Four label bits will provide for $2^4 = 16$ different message types.

The remainder of the message contains the information. A message identified by a given label will have the information bits assigned according to an established message standard. For instance, the first eight bits of the information group may contain course deviation instructions with the most significant bit occurring first and the least significant bit last. The reference for the course may be magnetic north at the aircraft's position. Then the range of the data would be 0° to 358.59375° with a granularity of 1.40625°. The most significant bit would have a weight of 180°; the next most significant, a weight of 90°; the next, 45°; the next, 22.5°, and so on down to the least significant bit having a weight of 1.40625°. Thus, there would be $2^8 = 256$ discrete headings to which the data may correspond. A continuous set of headings cannot be encoded, and a quantization error can result. In this case, the quantization error would have a rectangular distribution about the discrete value and would have a range of 1.40625°. The number of bits assigned to any quantity transmitted should be such that the quantization error does not contribute significantly to the over-all system error.

The remaining bits of the information portion of the message may be similarly encoded to give discrete instructions, clearance altitude, and time on course; and additional messages will contain similarly encoded quantities of different meaning.

Error-checking bits are also included in the message and, by suitable coding techniques, it is possible to provide error correcting. Generally, error correcting is not incorporated in data links because this technique requires large numbers of additional bits, and the single-error parity check is utilized. A parity check bit is added to each group of bits to be checked and contains a mark or space in accordance with the parity criteria, even or odd, such that the total number of marks in the group, plus the parity bit, will satisfy the criteria. For example, if the parity check is over a group of nine information bits and the parity criterion is even, the parity bit would be a mark if the total number of marks in the nine information bits was odd and a space if the total was even. The parity check will assume no error if there are 0, 2, 4, . . .8 errors and will assume an error if there are 1, 3, 5, . . . 9 errors. However, there are usually a number of parity checks in a message, and the possibility of acceptance of an incorrect message is small.

TIME DIVISION DATA LINK EQUIPMENT

In a general data-link system, a source of data to be transmitted, say, a computer, provides the message encoder with the data and identification of the intended addressee. The data is identified by a label which describes the type of data and/or the manner in which the data is to be utilized by the addressee. Each message is a set consisting of address, label, and information. The computer can provide the encoder with data for many such sets.

The multiplexer then accepts the messages from the encoder, constructs a total message for transmission and drives the transmitter in accordance with the established multiplex criteria.

Generation of the surface-to-air message quantities is the function of the ground terminal of the data link. The data source generally contains the encoding system at its output section. The information is then transferred to the multiplexer, which in many applications is remotely located. Point-to-point communication links, often over telephone lines, are used for this purpose. The multiplexer accepts the input signals and constructs the ground-to-air message in accordance with the message format.

In constructing the ground-to-air message, the multiplexer is programmed to insert those portions of the message which are fixed, such as the synchronization pattern. Generally, multiplexing equipment also performs parity checks throughout the process of construction of the ground-to-air message and its transmission, indicating when errors occur. The multiplexer provides data signals to the modulator of the transmitter and turns the transmitter carrier on with a keying signal. Various modulation techniques may be employed in a time-division data-link system. Most common are frequency-shift keyed carrier and two-tone AM or FM. The choice is often a function of receiver availability when implementation of a program requires the use of equipments already in the field. FSK is generally utilized in new design programs. There are, of course, other modulation techniques that have merit, including phase-shift keying and keyed carrier. The receiving system in the aircraft demodulates the transmitted signal and provides inputs to the digital data-processing equipment, which decodes each message. The decoder continuously inspects the receiver output for the synchronization pattern and, upon recognition, initiates a fixed program of data processing. This program first checks the discrete-address portion of the message and the program continues only if there is agreement with the assigned aircraft address. If there is agreement, the decoder performs the necessary parity checks in accordance with the parity criteria and, if all parity checks are passed, accepts the message. Upon acceptance, the label portion of the message is used to establish storage routing. Thus, the content of a properly addressed and correctly processed message will be stored such that the data-decoding equipment will process the information for the utilization for which it is intended.

Storage may be effected by reading the data onto an automatic drum of an airborne computer or by reading into bi-stable elements, such as relays and flip-flops. Decoding of the stored data is a function of utilization; for instance, heading information may be utilized to generate a steering error signal. In order to provide an error signal, a subtraction process must be performed with the minor arc difference between the stored steering instruction and the aircraft heading being displayed. Rather than displaying this error to the pilot, the signal may be used to drive an autopilot which, in turn, will cause control surfaces to move such a way as to correct for the error. Other stored data may be utilized by digital-to-analog voltage conversion with the analog voltage driving a display meter. It is also possible to convert the stored data to current analogs, shaft rotations, and other mechanical analogs. In addition, if the display is to be presented on a radar display, the stored data may be used to generate pulses delayed in accordance with the value of the data or widths in accordance with this value. Practical systems generally employ various combinations of these.

If the system is two-way, the message decoder program is extended to provide a message encoding function, which controls the construction and generation of the reply message. Digitalized quantities obtained from aircraft instruments, pilot insertion, and/or an airborne computer are sampled in accordance with the label instructions of the received ground-air message. The message encoder generates the complete message, including synchronization pattern, address, and label, if required, information and parity check bits, and provides both keying and modulating signals to a transmitter. The ground receiver demodulates the signals and the receiver output pulse train is decoded and transferred to the data source of the ground-air messages. This transfer will be over additional point-to-point links in the case of a remotely located site. The air-ground messages constitute an additional data input to the ground environment, and the data link, in a two-way system, may be considered as another data-gathering subsystem.

Among the civil applications is that of air traffic control. RCA is presently developing an experimental automatic Air-Ground-Air Communication System for the Federal Aviation Agency that utilizes time-division data-link principles. Commonly referred to as AGACS (pronounced "AJAX"), this system is the subject of another paper in this issue. (See R. Davis, *Automation Comes to Air-Traffic Communications.*)

Time-division links, providing coverage of a wide geographical area on a single frequency, automatize and greatly increase rapidity of information transfer, while greatly reducing the burden on both controller and pilot and conserving frequency assignments.

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Mr. Garrett has participated in internal and external coordination for the USAF Time-Division Data-Link program and has served as Project Engineer on command and long-range data link developed under USAF contract. He is a technical consultant on the application of time-division data link to USAF *Century*-series aircraft and Air Defense Command ground environments. Mr. Garrett is presently engaged in advanced data-link development programs as a Leader, Communications Systems Projects, ASD.

G. S. KELLNER received his BSEP from Cornell University in 1954. He is now a candidate for an MS in Systems Engineering and Operations Research at the University of Pennsylvania. Mr. Kellner has five years experience in development, design, and project engineering of communication systems. He has worked on the design and development of the AN/ARC-62, specializing in transistor intermediate frequency and audio development. He was responsible for the original development of the airborne digital equipment of the USAF Time Division Data Link program and, subsequently, for the technical coordination of all data-link digital equipment. For the past two years Mr. Kellner has participated in internal and external coordination of the data-link program. He is technical consultant on the application of data-transmission systems to military environments. Mr. Kellner has a patent application pending for signal-to-noise ratio squelch systems. He is presently a Leader, Communication Systems Projects, ASD.

ADVANCED COMMUNICATIONS PROBLEMS

By

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CONTINUED ADVANCEMENT in airborne communications relies upon progress on many fronts: new techniques, new or improved components, exploitation of new theories, and new analytic tools to guide system and component development. Such progress can be aided by the proper orientation to the needs of the future.

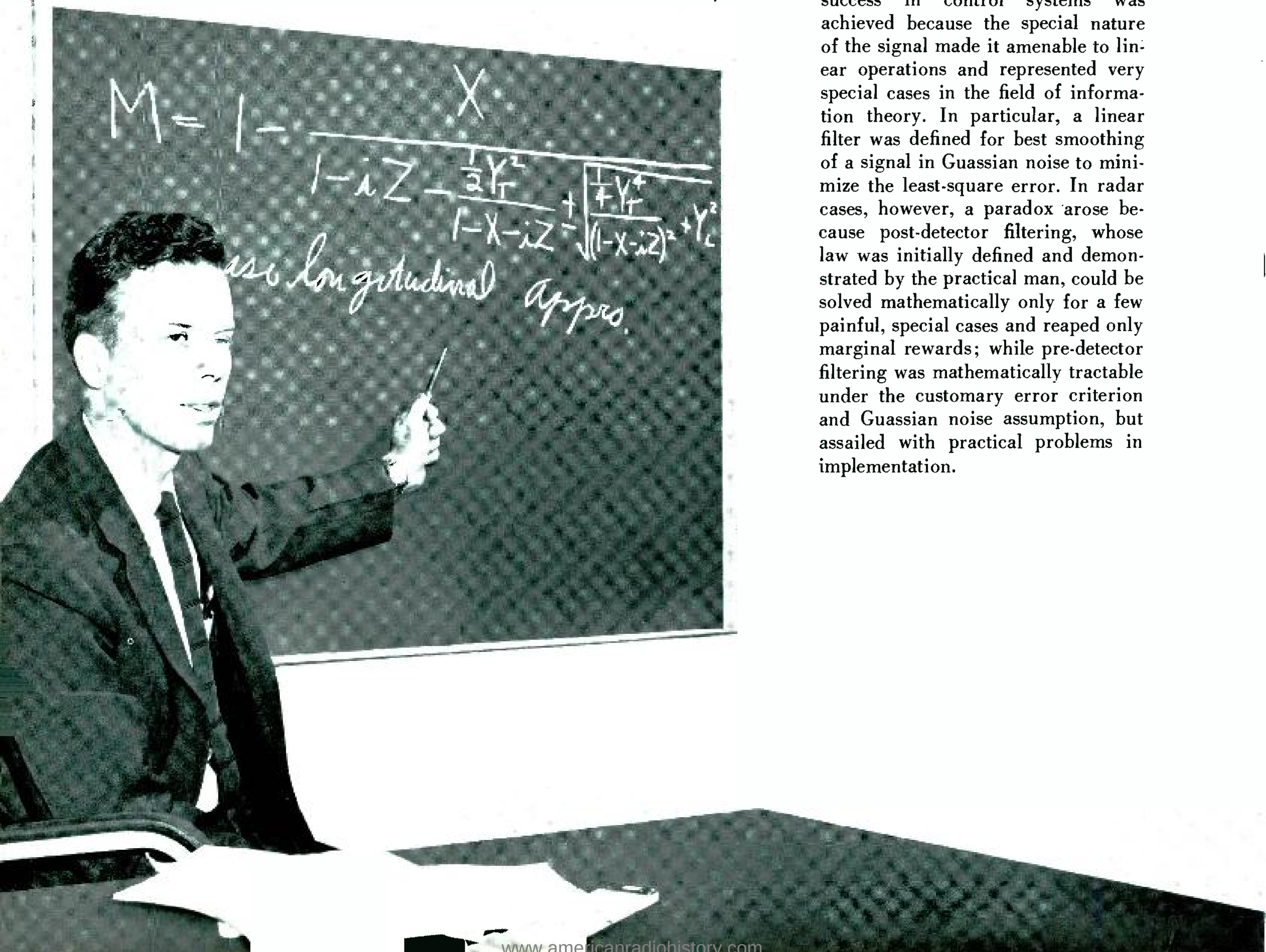
Satellites have created real requirements that were science fiction only a few years ago. Yet, in general, these problems are equaled in engineering difficulty by communications problems closer to earth and much less romantic. The following discussion outlines only a few of the more salient areas being pursued by ASD: special modulation systems to solve general filter problems, special high-altitude communications problems, and systems application of nonstandard modes of propagation.

THE GENERAL FILTER PROBLEM

One investigation concerns the problem of obtaining a best estimate of a signal in the presence of noise or channel perturbations; that is, the general filter problem. Figure 1 portrays a general communication system. The channel filter problem in the past was: given signal statistics, noise statistics, and an error criterion, what is the best *receiver* filter to provide an output that is the best estimate of the signal? The more-general problem asks the same question, but allows the signal to be altered in the transmitter; that is, pre-filtered, coded, or modulated in a manner to aid in discriminating against noise.

The background of these ideas lies in the development of statistical communication theory and, more generally, in information theory.

Evidence of the tools developed by this former theory has long been observed in the control field and to a lesser extent in the radar area. Here, techniques have been offered to aid in formulation and solution of the classical filter problem of extracting signals located in noise. Early practical success in control systems was achieved because the special nature of the signal made it amenable to linear operations and represented very special cases in the field of information theory. In particular, a linear filter was defined for best smoothing of a signal in Guassian noise to minimize the least-square error. In radar cases, however, a paradox arose because post-detector filtering, whose law was initially defined and demonstrated by the practical man, could be solved mathematically only for a few painful, special cases and reaped only marginal rewards; while pre-detector filtering was mathematically tractable under the customary error criterion and Guassian noise assumption, but assailed with practical problems in implementation.



The author, discussing some of the mathematics basic to advanced communications problems.

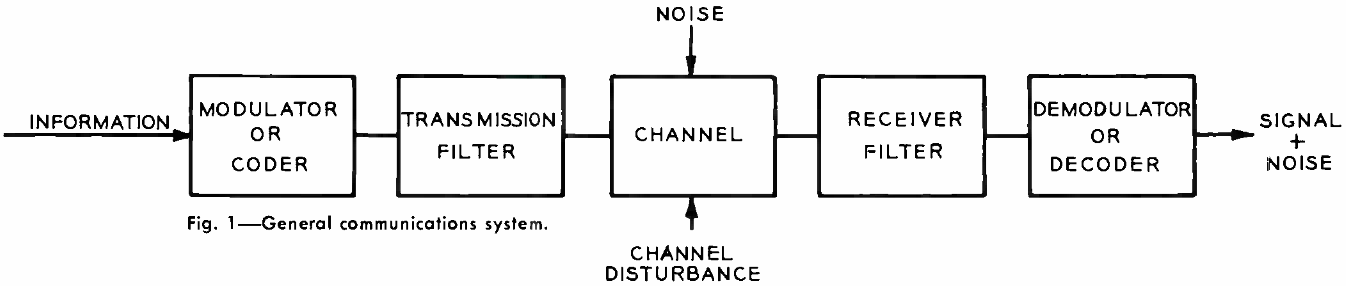


Fig. 1—General communications system.

All of these theories were singularly impractical in their practical application to communications circuits in their crude state. The doctrines of information theory dangled in front of communication engineers the "carrot" of possible great gains but did not specifically define any laws for accomplishing them. It was evident, however, to the workers that since optimum filtering was dependent upon both the characteristics of signal and noise, attention should be paid to the signal, which was a controllable variable. Thus, coding or modulation of the signal in a special manner has been exploited in both radar and communications field.

A simple and special example of one of these is redundancy-coding to combat specific frequency-sensitive absorption in the transmission channel. Here, a signal can be coded with one set of symbols on several frequencies for a space and with an orthogonal set for a mark. At the receiver, the optimum (for this case) decoding is performed by a correlation with a stored coded mark or space. A second and somewhat similar example is the process of determining how a transmission medium has "coded" the signal by a characteristic such as multipath and pre-coding at the transmitter, and filter at the receiver to counter path distortion.[1]

Here, *noise* is used in a generic sense and includes the class of functions which are deterministic (but have properties of a member function of a stochastic process) as well as those which are random by mathematical definition.

Returning to the problem formulation, in Figure 1 the blocks marked *modulator* and *transmitter filter* are specifically designed to optimize the system behavior in some desired manner for the particular channel perturbations. To date, no general solution to this coding problem is foreseen. The specific problems take the following form: given an analytic or statistical description of the basic signal to be transmitted, a similar description of the noise or channel perturbation, and the definition of the error minimization criterion, what is the dictated coding-filtering operation?

Thus, for every different type of noise, signal, and error criterion, a new problem is formulated. The problems solved to date fall into a narrow class bounded by the rising walls of mathematical complexity associated with the deviations from linearity, simple stochastic processes, and simple error criterions. Part of the effort in ASD is an attempt to develop the rules which define the equipment where some of these assumptions have been eased and to evaluate the performance gain by so doing.

If the problem were approached in its general form, where

$$F(s) = F(s_0 \ldots . s_n)$$
$$G(N) = G(N_0 \ldots . N_n)$$
$$J(y) = J(y_0 \ldots . y_n)$$

are joint distributions of signal (s), noise (N), and both (y), then given a set of samples y, what is the best estimate, $\hat{s}$, to s_0? If, for example, a least-square criterion were used, the best estimate is found by minimizing the following integral:

$$\int\int (s_0 - \hat{s})^2 \, L(y,s) \, dy \, ds$$

where $L(y,s)$ is the joint probability distribution of y and s. This leads to:

$$\hat{s} = \frac{\int s_0 \, L(y,s) \, ds}{J(y)}$$

This expression defines the Wiener filter when the distributions of both signal and noise are Guassian with zero means.

If, now, s is allowed to become an independent variable the problem takes on another degree of freedom. The problem of allowing s to be an independent variable has been approached, thus far, by assuming a particular form for s (code or modulation) and then evaluating this form in the presence of noise. The evaluation is accomplished by computing the mean-square error or, more generally, the ratio of the auto to the cross correlation function of the extracted signal and noise.

If a code is chosen, it can be correlated mathematically against the noise in a straightforward though laborious manner. At present this is being done in a mathematical manner and equipment is being fabricated to check it experimentally. Basically, a large ratio of auto-correlation of the coded signal to cross-correlation of the coded signal and to the interference means that the subsequent extraction problem is simpler and more liable to be successful. A future problem is this extraction for a particular signal coding. Since it is difficult mathematically to solve the filter problem except for simple signal and noise statistics, it may have to be proven by analysis rather than synthesis; that is, filter configurations will be assumed, evaluated, and catalogued.

A future communication need will be a class of flexibly programmed communication computers which will perform the operations of variable coding to maintain fixed reliability,

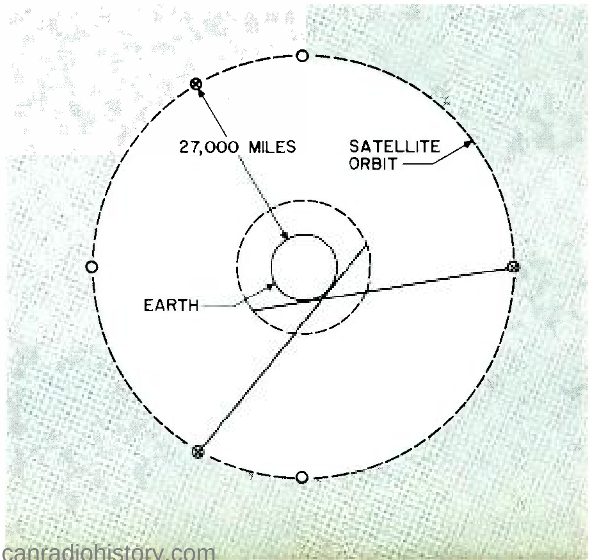


Fig. 2—Synchronous satellite system.

cuing, routing, and circuit evaluation. The key to a successful implementation is the employment of sequential decoding and the use of integrated electronics to meet size and flexibility requirements. A determined effort is in progress now to find those coding or mapping functions from signal space to decision space that can be simply implemented.

The theoretical work is being backed up by component developments. For example, a special attempt is being made to develop delay lines which will have large controllable delays in small physical volume by the use of printed circuit techniques. These delay lines will make up "matched filters" to be used in the modulation and demodulation circuits. If such components can be realized, it will afford a major advance in the practical implementation of these coders and modulators. Actually, these components are necessary to exploit even the simple theories in airborne application; and even greater strides in component improvement are necessary to meet the demands of the more-refined theory.

A second area of component development is the employment of digital devices as the modulators and demodulator. Such methods are, of course, natural for coding of digital communications. The developments center more on the validation of the theories rather than upon development of particular components, since other parts of the company are actively engaged in such device development.

The employment of parametric oscillators as r-f correlators and tunnel diodes as simple and reliable shift registers hold promise for overcoming past mechanization limitations that have not allowed full realization of theoretical gains.

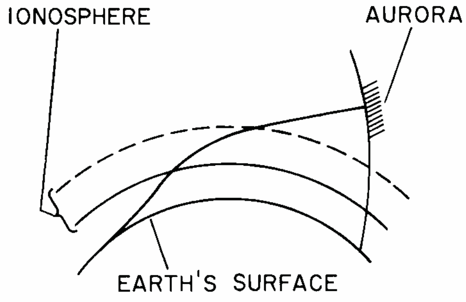


Fig. 3—Auroral communication.

In summary, ASD is attempting to advance in the field of signal-to-noise filtering by theoretical studies on coding signal extractions and component developments for these applications. By these advancements ASD is prepared to meet and master requirements of future communication systems. These may typically demand lower primary-power requirements through more-efficient filtering and operation in the presence of "intelligent" noise.

HIGH-ALTITUDE COMMUNICATION

The need to communicate with high-speed high-altitude vehicles at extreme ranges defines a series of problems in all phases of a communication system. One of these problems is the effect of the formation of an ion sheath about a high-altitude vehicle.[2] Although such a sheath was predicted at low altitudes (100,000 to 200,000 feet) recent evidence indicates that the conditions at 600,000 to 1,200,000 feet are also such as to support such a sheath. The principal concern with such a sheath, the blanking out of transmissions through it, unfortunately has not been verified in recent satellite observations. However, the reflection characteristics of such an ion sheath about a vehicle exaggerates the vehicle's actual size.

The problem of an ion sheath consists of, first, the determination of the characteristics of the sheath such as, its size, electron density, and collision frequency; and second the propagation of electromagnetic waves through it. The latter, in its basic form, is a propagation problem similar to the transmission of a signal in the ionosphere. The sheath has a normal-incidence critical frequency and, in general, a complex propagation constant that allows the determination of the index of refraction and the absorption per unit thickness. When the typical simplifying assumptions of no magnetic field, nonionized medium, etc. are removed, then the solution is more practical and unfortunately more difficult. Such answers then provide guideposts to help invent methods to employ this sheath to the advantage of the communication system. An allied problem is the design of an antenna to operate in a medium which is a conductor in certain frequency ranges.

The communication to a vehicle beyond the line of sight has presented problems since the advent of radio. One solution lies in area of propagation and a second in the design and employment of an orbital communications relay.[3] Commercially, such a relay holds great promise for a world communications system, and of course, it implies valuable military significance. An ideal communication relay system would be three or four equatorial, synchronous satellites,[4] as shown in Figure 2. At about a radius of three earth diameters, the satellites have a period that is synchronous with earth rotation; hence, the vehicle would be suspended above a fixed location and could act as a relay. It would be necessary, if desired, to cover the polar regions with a non-synchronous polar orbit. Disregarding the difficulty of obtaining such a precise orbit, voice relay requires powers near 100 watts at 1000 mc coupled with high-gain ground antennas. Television would step up power demands three times.

The design of such a system demands special and unique techniques to maximize performance and to minimize the primary power consumption. This might include very large antennas and special modulation methods to enhance the signal in the presence of noise, as has been discussed above. Another typical subsystem problem is extra-terrestrial noise. The noise encountered in the regions above the ionosphere is predominately cosmic noise and is a parameter which is not fully catalogued. The knowledge of the characteristics of this noise is necessary in the system design, especially as it influences antenna design.

PROPAGATION PROBLEMS

Although an orbiting relay would solve many of the problems of communicating to distant conventional aircraft, it is necessary now and in the future to maintain such communication in the absence of any form of a relay. Communications over long distances has in recent years shifted from the exclusive use of h-f to modes of transmission which were formerly considered anomalous and even disturbing. Meteoric, aurora, magneto-ionic-duct, and tropospheric-duct communications are such examples. ASD is studying these different modes

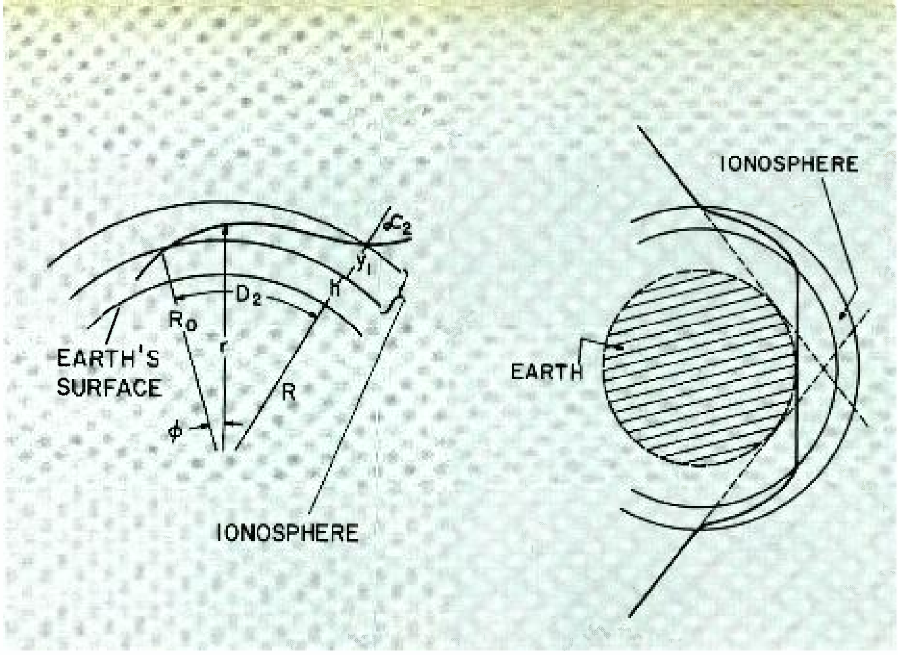


Fig.4—Left: conventional ducting. Right: Pederson-type ducting.

of propagation with particular regard to their system application.

Auroral communication[5] employs reflection from the ionized column centered about the lines of the earth's magnetic field, as shown in Figure 3. In the presence of aurora disturbances, the increased ionization strongly absorbs the normal h-f communications and leads to the so called polar blackouts. During this time, communications above and below the aurora belt are possible by both specular and nonspecular reflection from these auroral columns. In general, the area of best communication from such a mode is an elliptical-shaped region, with its major axis oriented east and west and centered about the transmitting station. Thus, crudely speaking, the aurora acts as a near-vertical mirror and allows communication near the transmitter, but does not provide communication through the auroral zone.

Meteoric-burst scatter communication presents a mode of operation not influenced by the solar disturbances that increase the path absorption to h-f. The penalty that must be paid is the greater systems complexity and the restricted range of usage. The region of intense ionization of the meteor trails is centered at altitudes near 80 to 100 km. and geometry restricts the communications range to about 600 to 1300 miles for a single hop. The system loss encountered in multiple hops is quite high and such operation would in general be prohibited.

Tropospheric and ionospheric scatter modes of propagation have thus far been considered to demand system gains which are prohibitive for airborne applications.

The utility of conventional h-f has been increased by increased knowledge of the characteristics of the ionosphere and in particular, methods of rapidly evaluating the state of the ionosphere at a given time. One of the interesting problems regards the communications to a vehicle in or above the ionosphere and beyond the line of sight. Evidence of such signals was collected from recent Russian satellites and has been recorded in the journals. It is therefore just as possible to communicate with stations above the ionosphere as with ones below. The ducting of signals is shown in Figure 4 and represents one of the solutions to the physical problem of propagation in the ionosphere. That is, a ray can be returned to the earth in the conventional manner, or in the Pederson-type ray, ducted and then transmitted above the ionosphere. It is, then, not unreasonable that if the characteristics of the ionosphere are well-known at all times, reliable communications can be maintained at all ranges on a quiet day. The quiet-day stipulation is added, since experience has shown that even if ionospheric conditions are known, an ionospheric storm can increase the absorption to a prohibitive level.

An interesting point-to-point communication mode is the magnetoionic duct. A ray entering the ionosphere encounters several modes or paths of propagation since the medium is anisotropic. Many of these modes at frequencies below the plasma frequency are refracted or reflected back to the ground or absorbed. One mode, the extraordinary quasi-longitudinal, is not reflected but is propagated with low loss along the earth's magnetic field direction through the lower ionosphere into the exosphere and back down its field line to the earth at a conjugate location on the earth. Such a mode holds some promise for communication from ground-to-ground and also from space vehicles to ground. It is interesting to note that Commission 4 of the URSI has as one of its tasks the investigation of the commercial application of this mode.

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DR. A. H. BENNER (pictured in the lead photo for the article), Manager Systems Analysis and Synthesis, ASD, received a B.S. in Electrical Engineering in 1944 from the University of Kansas and a Ph.D. in Electrical Engineering from Pennsylvania State College in 1951.

From 1944 to 1946 he was a 1st Lt. in the Signal Corps where he was concerned with field and fixed radio. From 1946 to 1949 he was an electronic design engineer at the Ordnance Research Laboratory in State College, Pa. While at the Ordnance Laboratory he worked on stabilization servos for torpedo control systems and on an ultrasonic echo ranging transmitter.

From 1949 through 1950, Dr. Benner was a project engineer at the Ionosphere Research Laboratory. He worked on the problem of predicting maximum usable frequency for long-distance ionospheric back-scatter. He was the project engineer on the theoretical and experimental investigation of vertical-incidence ionospheric absorption at 150 kilocycles. In addition to the problem of the formulation of a theory to explain this low-frequency absorption, the project consisted of the design, installation, and operation for two years of equipment to measure absorption, polarization, and group heights of vertical incidence.

Dr. Benner has been with RCA since October 1950. As an engineering leader he was in charge of projects on modulation studies, filter research, communication systems error analysis, statistical signal and noise problems, and reliability analysis.

He was the technical systems manager of the Optimum Shipboard Study Program. This project formulated the best shipboard Talos weapon system for future missile ships. The study included a simulation of the problem and a complete analytic and equipment study leading to equipment specifications.

Dr. Benner has published 13 technical papers and is a member of Sigma Xi, Tau Beta Pi, and a senior member of the IRE.

ENGINEERING VERSATILITY SAVES $50,000,000

By

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THE *AN/ARC-65 program represents a saving of over $50 million to the Air Force.* This economy was made possible by RCA through converting the double-sideband AN/ARC-21 to the single-sideband AN/ARC-65, rather than embarking on the design, manufacture, and installation of a totally new single-sideband set.

The AN/ARC-21, an outstanding state-of-the-art h-f communications transceiver, was an important step in solving the Strategic Air Command's problem of maintaining continuous contact with its world-wide fleet of aircraft. It was recognized, however, that conventional double-sideband (dsb) communications were subject to severe interference and fading which could be greatly reduced by single-sideband (ssb) operation. The principal barriers to achieving practical ssb communications were filter techniques and frequency stability. When ASD engineers found solutions to these problems and were able to apply them economically to the AN/ARC-21, the present SAC h-f Communications set, the AN/ARC-65 (see photo), was made possible.

Among the outstanding features of the AN/ARC-21 that had caused its selection earlier as the standard Air Force h-f communication set were:

1) *44,000 frequency channels* between 2.0000 and 23.9995 mc at intervals of 0.5 kc.
2) *Completely automatic tuning;* the operator sets the desired channel into a remote control panel, and tuning is then automatic.
3) *Choice* of voice (high-level amplitude modulation), telegraph keying of the unmodulated carrier (c-w), and frequency-shift keying (teletype).
4) *Frequency stability* of ±150 cps at 10 mc to ±300 cps at 20 mc.

FEASIBILITY OF CONVERSION TO SSB

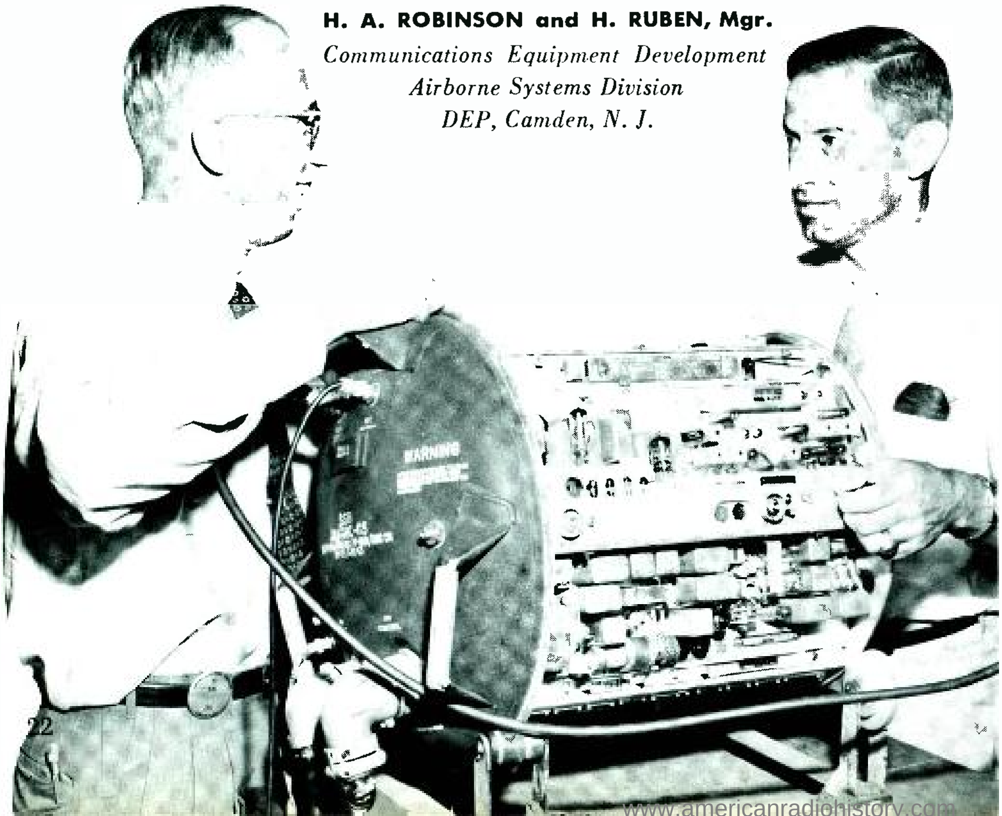
When the Air Force indicated in 1956 that it would like to standardize on ssb ASD's H-F Communications Engineering Group reviewed the design of the AN/ARC-21 and considered the feasibility of converting it. Recognizing the basic virtues of the equipment, they sought to devise the minimum modifications necessary. The resulting design for conversion was facilitated by two major factors:

1) The modular mechanical design of the receiver-transmitter unit permitted modification or replacement of any of the nine major subassemblies.
2) The frequency-control system with its inherently high stability had the potential for a further increase in stability within the then-current system parameters.

The preliminary evaluation verified the feasibility of converting the AN/ARC-21 to ssb. Further, it was found that all modifications could be confined to the receiver-transmitter unit and that even those modifications could be made on a subassembly basis. As a result, no changes in wiring between the receiver-transmitter and other units (subcontrol panel, master control panel, power supply, antenna coupler) were required. Work then began on an engineering model using RCA funds.

Presentations were made to the Air Force showing how they could capitalize upon their large inventory of AN/ARC-21 equipment through a modification program. Through this proposed conversion program, the Air Force could take full advantage of the operational training and maintenance experience it had developed over a period of several years. The conversion would enable them to outfit aircraft with ssb equipment far faster than with newly developed equipment and at a small fraction of the cost of completely new equipment.

Extensive flight as well as laboratory tests on the engineering model substan-



HARRIS A. ROBINSON, (left) received his BSEE in 1929 and his MSEE in 1931 from the University of Pennsylvania. Mr. Robinson was employed in 1929 by the General Electric Company, where he was assigned to the development of the first airborne h-f superheterodyne receiver for the U. S. Army. He entered the Special Receiver Engineering Group of RCA at Camden in 1931. Design and development work in military and aircraft receivers led to his appointment in 1939 as leader of the Aircraft Receiver Group. With the formation of the Aviation Section in 1944, Mr. Robinson has continued actively in airborne communication engineering design as a group leader. Mr. Robinson has received thirteen U. S. Patents in communications. He is a Senior Member of Sigma Xi, Eta Kappa Nu, and the IRE Professional Groups on Aeronautical and Navigational Electronics, and on Military Electronics.

H. RUBEN, (right) received his BSEE from New York University in 1935. Mr. Ruben has 24 years of engineering and production experience, with 19 years at RCA, of which the past 10 years were as Group Leader and Manager. He was active in the development of mobile receiving equipment as well as in the design of commercial airborne communication and navigation receivers. He directed the development of the AN/ARC-21 transmitter and antenna coupler as well as the power supplies and support test equipment. Since 1953, Mr. Ruben has been Manager of the Airborne HF Communication Group, ASD, where the AN/ARC-65 single-side-band HF transceiver and the AN/APN-110 High-Altitude Pulse Altimeter were designed for the B-58 aircraft. He was recently made Manager, Communications Equipment Engineering, ASD. Mr. Ruben is a Senior Member of IRE and member of the Professional Group on Aeronautical and Navigational Electronics.

tiated the feasibility of ASD's plan. Sufficient interest was generated that the Air Force made available six AN/ARC-21 equipments for modification to ssb. Improved h-f communication was noted immediately.

As a result, the Air Force contracted in 1957 for 16 prototypes to demonstrate the practicality of modifying production equipment and to demonstrate the performance of the equipment in the field. The anticipated theoretical improvements in communications were verified in a striking manner. Voice signals on ssb were received clearly when propagation conditions made conventional dsb communication submarginal. The excellent communications which were obtained by SAC with these prototypes led the Air Force to change the final order for AN/ARC-21 equipment to AN/ARC-65 sets. In addition, approximately 5,000 AN/ARC-21 sets that had been previously delivered were contracted for modification.

New equipment and modified units are being built simultaneously. A special task force of Air Force and RCA personnel is visiting each SAC base where AN/ARC-21's are removed and AN/ARC-65's are installed. The AN/ARC-21's are repacked and returned to Camden for modification.

The AN/ARC-65 equipment is being employed by SAC for long-range communications on B-47 and B-52 bombers, and on KC-97 and KC-135 refueling aircraft. In addition, it is used extensively for both voice and teletype in the Presidential Super-Constellation *Columbine* and is being included in the new VC-137 jet transports being used by the President and high government officials.

CHARACTERISTICS

The AN/ARC-65 transmits the upper sideband, which is derived by the filter method. Carrier suppression is at least 40 db and intermodulation is 30 db. In addition to ssb, the equipment may be operated as a-m equivalent, in which carrier and one sideband are emitted. This mode allows communication with standard a-m receivers and permits reception of a-m transmissions. It possesses stability which insures a deviation of not more than 22 cycles at any r-f frequency. A summary of the performance characteristics of the two sets is given in the Table I.

Table I—PERFORMANCE CHARACTERISTICS

Characteristic	*AN/ARC-21*	*AN/ARC-65*
Frequency Range, mc	2.0000–23.9995	Same
Available Channels	44,000	Same
Channel Spacing, cps	500	Same
Transmission Modes:		
Voice	a-m, dsb	s-c, ssb, a-m Equivalent
Telegraphy	c-w	Same
Teletype	fsk	Same
Altitude Range, ft	0–70,000	Same
Temperature Range, °C	—55 to +55	Same
Automatic Tuning	rcvr, xmtr	Same
Power Output:		
Carrier, w	100	Suppressed
Voice Modulation	90 to 100%	230w peak envelope power
Bandwidth (voice), kc	8	4
Frequency Stability:		
at 10; cps	150	17
at 20; cps	300	22
Receiver Selectivity, kc	8	4
Receiver Sensitivity for 10-db signal-to-noise ratio, µv	3–5	1–1.2

The ssb suppressed-carrier technique is one in which one sideband is removed at the transmitter and the r-f carrier is suppressed. The remaining sideband is transmitted. At the receiver, a locally generated r-f carrier of the same frequency as that suppressed at the transmitter is used to translate the ssb signal back to its original position in the audio frequencies. Conventional a-m systems, such as the AN/ARC-21, transmit the r-f carrier together with the two identical sidebands, each of which represents the spectrum of the original modulating signal.

The principal advantages of ssb suppressed-carrier communications are:

1) *Bandwidth requirements* are reduced by one-half of that needed for a-m systems, thus doubling the channels available.
2) *Selective fading* is significantly reduced.
3) *Interference* from adjacent signals is markedly lessened, since no carrier is present at the receiver to heterodyne with the interfering signal.
4) *Less transmitter power* is required for a given radiated power.

The entire output of the transmitter is concentrated in one sideband, resulting in much more efficient use of that power. It was these advantages that led the Air Force to standardize upon ssb operation for h-f communication.

Widespread adoption of the ssb suppressed-carrier technique was retarded for years by the size and complexity of the equipment and the requirement for extreme frequency stability. The problem of frequency stability in airborne applications was particularly knotty because of the extremes of environmental conditions encountered — temperature, humidity, condensation, vibration, shock altitude, etc. These problems were even more complicated by the military requirements for rapid, remote selection of any desired frequency channel among the thousands available.

CHANGES REQUIRED

One of the keys to the conversion of the AN/ARC-21 equipment was the development within RCA of suitable electromechanical filters that could be economically produced in large quantities. These filters are highly stable, small, light, thermally insensitive, and rugged enough to operate within the required environment. These qualities made them ideal for attenuating the carrier and undesired sideband frequencies in the transmitter.

The requirement for communication with a-m stations was met by a modification that transmitted an equivalent a-m signal by radiating the carrier at half-amplitude together with one sideband at half-amplitude. This signal can be received on a conventional a-m receiver by its envelope detector. Reception of a-m signal by the AN/ARC-65 set is provided by switching to an auxiliary diode envelope-detector.

The frequency stability and automatic tuning of the AN/ARC-21 set are among its most carefully engineered features. In the conversion to the AN/ARC-65, the basic frequency-control units were found to be adequate for ssb operation. The only change necessary was to improve the stabilized reference crystal. A crystal having a frequency stability of four parts in ten million was substituted for the former reference. With this change, all the available frequency channels reflect its improved stability and accuracy. The AN/ARC-21 equipment's frequency-control system was responsible, more than any other feature, for its relatively easy conversion to ssb operation. This one feature resulted in a stability of the AN/ARC-65 which insures a deviation of not more than 22 cycles from nominal at any r-f channel for both transmission and reception.

The highly successful modification of the AN/ARC-21 equipment to the AN/ARC-65 was the result of resourceful and practical engineering.

This teamwork exemplifies at its best the inter-related operation of separate RCA units, whose diverse talents were blended together to do a job much too complex to be done economically by any single group.

AIRBORNE REMOTE CONTROL SYSTEMS

by **R. J. WHITE, H. M. THELEN, and H. A. BRILL**
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IT IS BECOMING increasingly common in electronic equipment to locate operating controls at some distance from the principal portions of the equipment. This trend is nowhere more apparent than in airborne installations, where minimum cockpit space and multiple control stations force the use of remote-control indication and presentation for virtually all electronic equipment.

Remote-control systems consist of three basic portions: 1) the control element (control box); 2) the controlled or positioned element (remote positioner); and 3) the indicator and presentation element (remote indicator). The third element may or may not be combined with the first. In an airplane, lack of control console space often requires that the control element be so located that it is manually but not visually accessible. In other cases, multiple control stations may be required. In either event, it is often necessary to supply at all operating positions an indicator that displays the settings of the functioning control element. In an aircraft, this indicator must be of minimum size because it must occupy a portion of the control console within the visual acceptance angle of the pilot when he also has in view his primary operating and navigation instruments. This space is extremely limited.

The element to be controlled may be almost any type from a simple on-off switch to a complex frequency-synthesis system. Regardless of the function it is to perform, however, the controlled element usually involves one or more remote positioner elements of such accuracy as to meet the requirements of the system. Mechanical devices, for example, may be used to select crystals, position-ganged capacitors, or switch circuitry.

The AN/ARC-62 is an advanced airborne UHF communications set for use in high-performance aircraft in the 1960 era; it has recently been designed by RCA under an Air Force contract. In keeping with design goals to make this set light, compact, and reliable, a remote tuning system has been developed which is significantly improved over past systems and is well suited to the 3-phase, 400-cycle power source in all new aircraft. It has elements useful in other systems and can serve as a design guide.

AN/ARC-62 REMOTE-CONTROL SYSTEM

The AN/ARC-62 must automatically tune in the space of several seconds to any one of 3500 frequencies, spaced 50 kc apart between 225.00 mc and 399.95 mc. Five digits are required to define any channel frequency; for example, 257.30, 329.45, etc. The tuning, which is done at the pilot's control box, must be direct reading in frequency and have the following modes:

1. Manual—frequency digit knobs manually set, providing all 3500 channels.
2. Preset—20 preset channels, selected by a single knob, each of which may be set to any of the 3500 channels by a mechanical memory drum in the control box.
3. Guard—selection, by operation of a single control, of a predesignated emergency frequency.

As may be noted from the frequency range and the channel spacing, the first and last digits involve only two numbers each, whereas the remaining three digits involve any number from 0 to 9. The need for direct-reading frequency setting favors a five-digit decimal system from the control-box viewpoint. A review of the receiver-transmitter remote-positioning requirement has also indicated the need for separate positioning elements for each digit. It was desired to keep the number of positions per digit to a minimum so as to simplify the circuitry and to gain reliability; thus, a five-digit decimal control system was adopted.

The requirements of the control system, from the positioner viewpoint, are the same whether *manual*, *preset*, or *guard* is used. In each case, five frequency digits are involved, and the positioner performs the same operations. The control leads need only be switched in the control box between the manual control element, the memory-drum control element, and the guard element by a five-pole, three-position switch. However, the presentation on the remote indicator must provide for displaying the preset channel number or the guard setting if the 3500-channel manual mode is not used. On manual mode, the five frequency digits are desired; on preset, the letters PRE and the channel numbers 1 through 20 are desired; and on guard, the word GUARD is desired. This necessitates increasing the digit positions* of the electrical control system from ten to twelve in order to provide positions for preset and guard.

As a result, a five-digit system, each digit incorporating a twelve-position capability, was chosen. This does not require increasing the number of positions on any frequency-control knob because the manual-preset-guard control switch adds the necessary positions and presents them only to the indicator.

ELECTRICAL CONTROL SYSTEM

The electrical control system could take several forms. However, one of these three basic types is generally used:

1. Bridge (balance of voltages from two similar dividers)
2. Multiwire (selection of voltage source and path)
3. Function Matching (matching of frequency, phase, or other function)

The bridge and function-matching systems in general offer advantages in switching simplicity and fewer inter-element wires. The bridge system has the disadvantage of requiring a divider at each location, and the function-matching system usually involves complex generator circuitry. Where many digits and many positions per digit are required and more than one remote-controlled element is involved, the bridge system offers the greatest advantage and is most frequently used.

Fig. 1 represents a simple resistive bridge. Two similar resistive divider

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*The number of positions refers to the number of discrete balanced positions which the electrical remote-control system provides for; thus a twelve-position electrical control system may use ten numerals and two letters providing a versatile display of channel frequency, preset channel, or GUARD.

R. J. WHITE, Leader, Airborne Communications Engineering, received his BS in EE from Cornell University in 1949. Prior to that time, his experience included five and a half years in the Signal Corps and Air Force in many technical capacities such as teaching at the Signal Corps Schools, assisting in radar design, Radar Calibration Officer for the 7th Air Force, and technical member of the 10th Army Tactical Air Force general staff. While at Cornell University, he designed such equipment as entomological electroencephalographs and ultra precise temperature controls. Since joining RCA in 1949 he has been responsible for the design of several portions of the AN/ARC-34. He has performed production engineering on the AN/ARC-34 and the AN/ARR-44 Data Link Receiver. Mr. White has particular skills in component design and application especially from the reliability standpoint. Since the outset of the AN/ARC-62 program in early 1957 Mr. White has directed Guard Receiver design.

H. M. THELEN, Airborne Communications Engineering, received his BSEE from Clemson College, in 1953. After graduation, Mr. Thelen joined the RCA specialized training program. Since completion of specialized training program, he has been a member of Airborne Communications, participating first in the AN/ARC-34 and AN/ARC-66 programs, and recently in the AN/ARC-62 program. Mr. Thelen has been working on the design of the control system for the AN/ARC-62.

H. A. BRILL, Airborne Communications Engineering, received his BSME from the University of Pennsylvania in 1945. Upon graduating, he was awarded a *Certificate of Distinction* for work of outstanding quality. He joined the Bausch and Lomb Optical Company where he designed automatic aerial cameras and control devices. In 1946, Mr. Brill formed his own company, where he designed and manufactured electromechanical devices. He joined RCA Airborne Communications Engineering in 1956, where he has worked on the design of several airborne uhf communications sets. He has contributed to analytical investigations leading to a Uniform Design Criteria for airborne electronic equipment for USAF, and has had mechanical design responsibility for the remote control box and the remote indicator for AN/ARC-62 UHF Command Set. Mr. Brill holds two patents. He is a member of ASME, Pi Mu Epsilon, Sigma Tau, and Tau Beta Pi.

elements are powered from the same source, and an error-sensing device is inserted in the center arm of the bridge. When the contacts of the center arm are at equal potential positions, the sensing device removes power from the motor which operates the controlled-element switch. When there is a difference of potential or error of one position or more, the sensing device must activate the motor, which will turn the switch until balance is achieved. The error voltage may be of any magnitude from that corresponding to one step to the full divider potential. Thus, the sensing device must operate reliably over a wide range of error voltage. On the other hand, divider tolerances and unbalanced loadings may cause some error voltages to exist when actually the bridge is in a balanced position. This lack of balance is accentuated by multiple controlled elements and dictates the pull-in to drop-out voltage ratio of the sensor.

Thus, the key design parameters affecting bridge control systems are:

1. Ratio of maximum error voltage to single-position error voltage
2. Ratio of pull-in voltage to drop-out voltage
3. Number of bridge elements
4. Standby power.

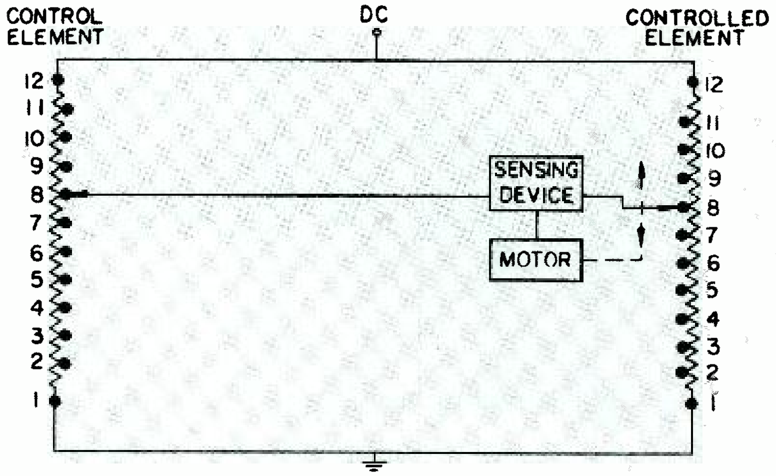
In the simple bridge, the ratio of the maximum error voltage to single-position error voltage is equal to the number of positions minus one, plus a factor representing the total bridge voltage drop for a single position error. The drop may be minimized by reducing the resistance of the bridge arms, but this will increase the standby power requirements. The sensing device, at best, must have a rather small pull-in to drop-out ratio, be very sensitive, and be capable of withstanding very great voltage overloads. It is difficult to supply more than one digit (or two controlled elements) from one control divider resistor with any reasonable degree of reliability.

If autotransformer dividers are substituted for the resistors in Fig. 1, a simple a-c bridge is formed. By its use all design parameters are improved:

1. Because the source impedance of the divider transformers is negligibly small, the ratio of maximum error voltage to single-position error voltage is reduced to number of positions less one.
2. The ratio of pull-in voltage to drop-out voltage also is improved for the same reason.
3. Many digits and controlled elements can be supplied from one low - source - impedance control divider transformer.
4. The standby power is reduced to a negligible level.

The last three parameters are sig-

Fig. 1—Simple resistive bridge.



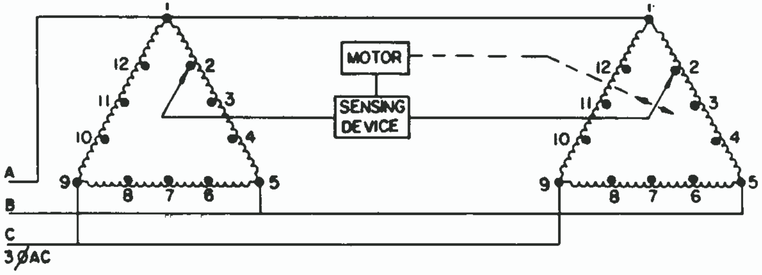


Fig. 2—Three-phase delta bridge, such as used in AN/ARC-62.

nificantly improved, but the maximum-to-minimum error voltage still incurs penalties on the sensing device. In order to reduce this ratio, some parameter other than voltage magnitude must be used. A multiphase bridge permits this.

Fig. 2 illustrates a three-phase delta bridge such as is used in the AN/ARC-62. Each phase winding incorporates three taps, and these, combined with the phase voltages, offer the required twelve positions. As can be seen in the vector diagram, Fig. 3, the ratio of maximum-to-minimum error voltage has been reduced to four rather than the eleven of the single-phase a-c bridge. Fig. 3 shows position 2 as a reference point, but any reference position will give similar results. Each vector in this figure represents a possible unbalance voltage which would be detected by the error-sensing device.

The three-phase system may be used in many forms such as a Y system, a Y-delta combined system, or even a double-Y or six-phase system. Each of these offers advantages for certain applications, usually depending on the number of discrete positions and on the accuracy required. A continuous system is suggested by combining a multitapped delta transformer and a precision potentiometer correspondingly tapped.

An a-c bridge requires the use of an a-c error-sensing device. Where the sensing device is to be a relay, either an a-c relay or d-c relay with rectifiers must be used. The latter choice was made in the AN/ARC-62, and a subminiature, noncritical relay in combination with a four-diode, full-wave bridge rectifier was designed. Thus, a small-size, low-cost, and reliable error-sensing element has been achieved.

The complete AN/ARC-62 control bridge is represented in block form in Fig. 4. Basically, five bridge systems are used, each of which has two controlled elements operating from one control element. The control-element divider transformer supplies ten position potentials to each digit of each of the three frequency-control switches. The manual-preset-guard function switch selects the mode that is to be

Fig. 3—Ratio of maximum-to-minimum error voltage. Each vector represents a possible unbalance voltage which would be detected by the error-sensing device.

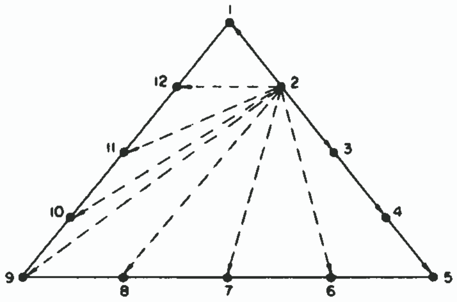
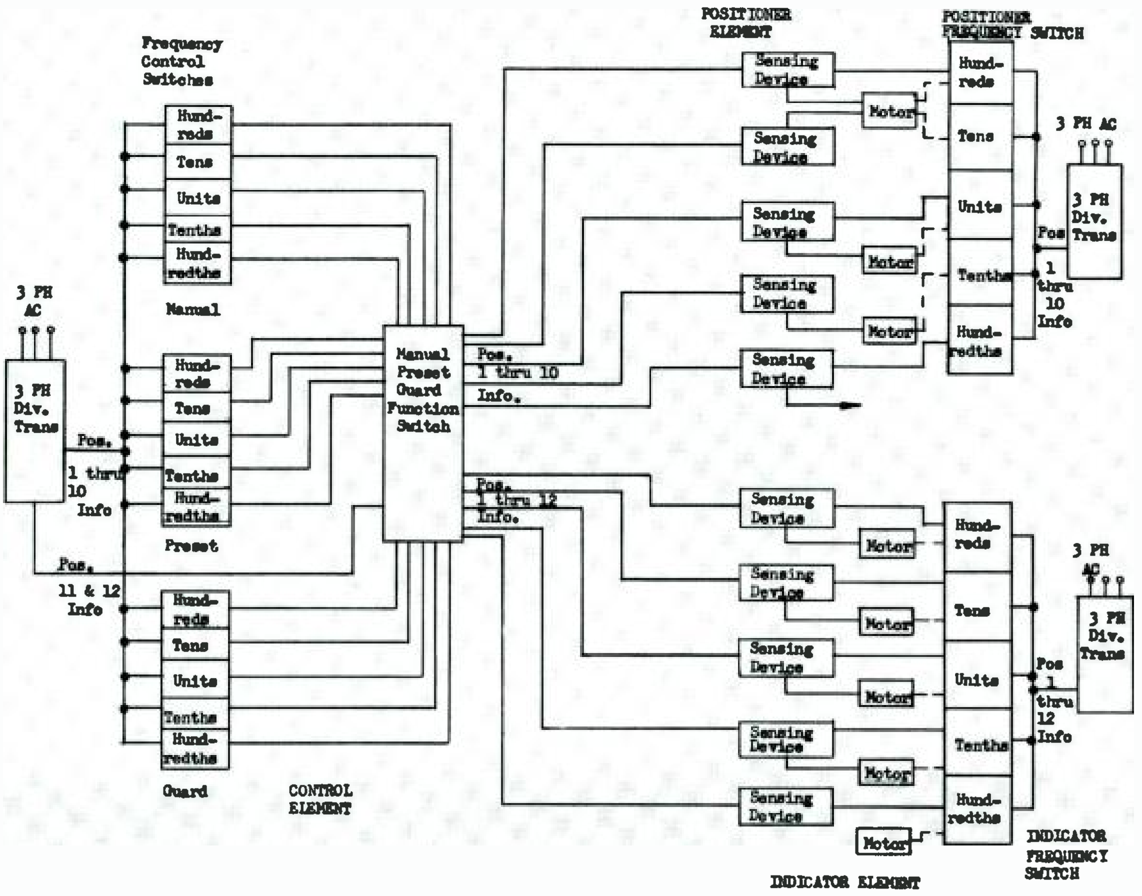


Fig. 4—AN/ARC-62 control bridge.



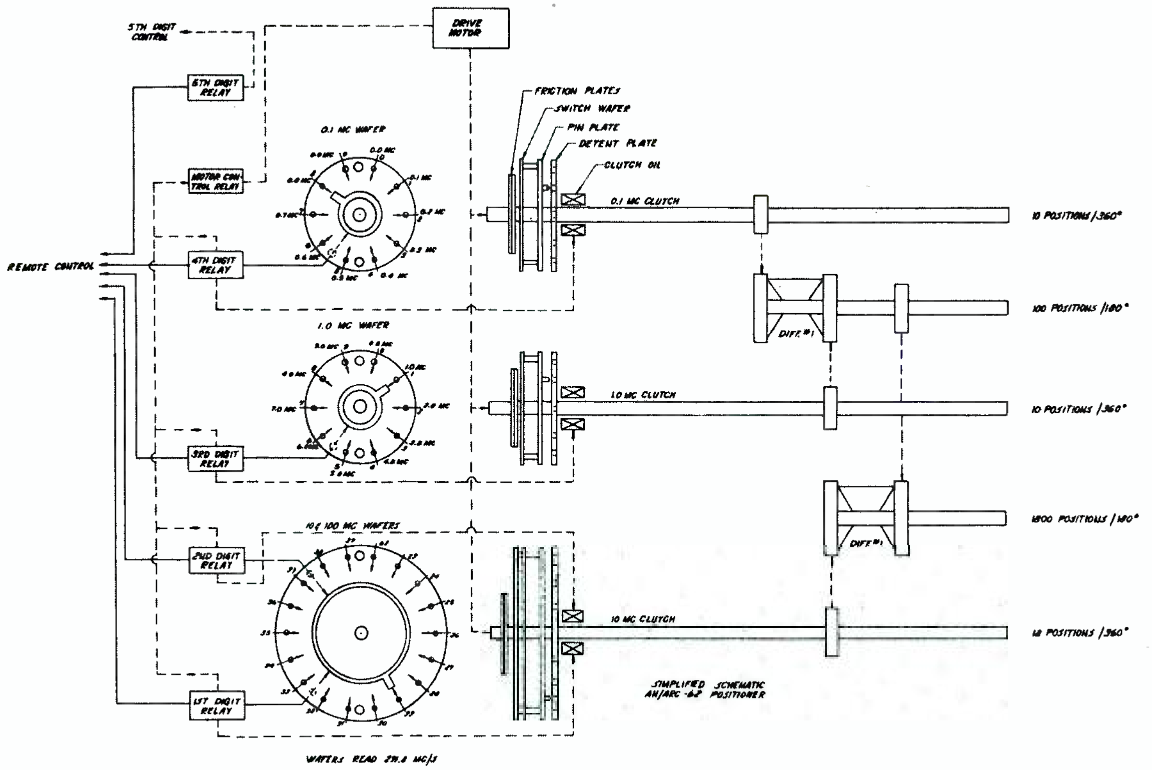


Fig. 5—AN/ARC-62 positioner.

used and in the preset and guard functions substitutes appropriately the eleventh or twelfth position potentials to the indicator lines. The positioner lines carry only the ten position potentials. At the positioner, the hundreds and tens-digit sensing devices combine their output information to control a single motor. The hundreths digit in the positioner is also unusual in that it has no motor. These variations are explained later.

POSITIONER

The AN/ARC-62 positioner forms a part of the bridge control system just discussed and provides the means for accurately positioning the ganged tuning capacitors and the crystal selection switches used for synthesizing the 3500 frequencies of the AN/ARC-62. As shown in Fig. 5, the positioner combines a drive motor and three clutches to control five output shafts with combinations of positioned information from the first four digits. The clutches contain friction plates for engaging or disengaging the output shafts and plates with precisely located slots. Detenting action is accomplished by a pin in a second plate. With the pin in a given detent slot, the output shaft or shafts associated with a particular clutch will be accurately positioned for a given frequency setting of the remote-control unit. Three clutches are provided: one ten-position clutch for each of the units and tenths digits in the frequency band and one eighteen-position clutch which combines control information contained in tens and hundreds digits. The fifth, or hundredths, digit relay selects appropriately one of two i-f filters and two transmitter crystals spaced 50 kc apart. Because of the bandpass characteristics of the r-f and first i-f, no positioner change is required.

Wafer switches are mounted to and rotate with the clutch output shafts. These wafers are connected to the divider transformer in the same manner as those in the remote control unit. The error-sensing relays energize the proper clutches whenever any bridge is unbalanced, and when a balance point is reached, they cause the clutch pin to fall into the proper slot.

The tens and hundreds bridges are combined into a single eighteen-position control by means of two eighteen-position wafers mounted together. The tens wafer contains the 0-9 position voltages repeated as necessary for all the possible values that the ten's control may assume. In like manner the hundreds wafer has two position voltages (either a 2 or a 3) that the hundreds digit may assume giving a combined possibility of those 18 values between 22 and 39 which are required for 225.00-mc to 399.95-mc frequency values. The eighteen-position clutch is controlled by both the tens and the hundreds sensing relays, and therefore, the pin cannot fall into position until the wafers have rotated to a point where both bridges are balanced.

Since the drive motor is controlled by a relay which itself is controlled by any of the sensing relays, the motor will continue to operate until all bridges are balanced.

The positioner provides shaft outputs which, in two cases, are not the outputs obtainable directly from one of the clutches. The r-f tuner of the receiver must tune or be positioned to 1800 discrete frequencies, each spaced 100 kc apart in the band 225.0 to 399.9 mc. These positions are obtained by combining the outputs of the three clutches through two differentials, each of which provides an output shaft that moves in accordance with the algebraic sum of the inputs. The two ten-position clutches are combined in DIFF #1 to provide an output of 10 x 10 = 100 positions. This output and that of the eighteen-position clutch are combined in DIFF #2 to provide 10 x 10 x 18 = 1800 positions. Thus, in the case of the AN/ARC-62 design it is possible to position a capacitor shaft to any one of 1800 discrete positions by means of five conventional detented wafer switches in a remotely located control box. Each of these 1800 discrete positions is set to an accuracy determined by the tolerances of the detent slot and pin. In this design, ±0.3-degree tolerance is permissible without adversely affecting circuit operation; hence, the slot and pin design has been made accordingly.

REMOTE INDICATOR

A number of display devices were considered for the remote display of digit and letter information in the AN/ARC-62 system. These included vacuum-tube displays, projection-type displays, magnetic clutches, impulse counters, and motor-driven wheel indicators. Each of these, except the last, were rejected for one or more of the following reasons: (1) relative size, (2) complexity, (3) unsatisfactory presentation, (4) extensive associated circuitry required, (5) lack of military approval, (6) response time. The design approach adopted employs a self-contained digit wheel with its own d-c drive motor controlled by a positioning switch wafer.

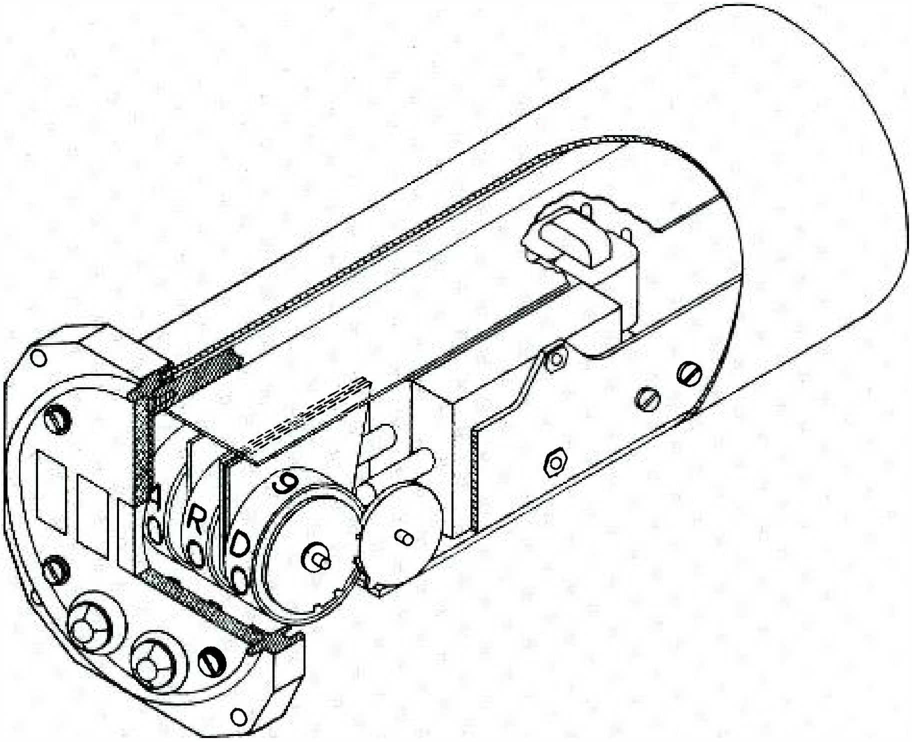
Based on a successful checkout of a breadboard unit operating with the rest of the system, a final system has been designed. Many advantages have been gained with this design, notably the versatility offered by twelve position wheels, which eliminates the need for a mechanical shutter. One of the additional positions is used to spell GUARD across the five wheels. The twelfth position spells PRE across the first three wheels when preset is set. The remaining two wheels show the preset channel number—1 to 20.

MIL-specification, 32-volt, d-c permanent-magnet motors, only ½″ wide, were built to meet RCA requirements and are available from two sources. The motor supply voltage is obtained from a half-wave, 3-phase, 400-cycle rectifier. The narrow motor permits a center-to-center spacing between number wheels of ½″. No purchased indicator, otherwise suitable, permitted this close spacing. The final design, a five-digit remote indicator with ¼″ high figures, is compactly packaged in a case only 3⅛″ in diameter and 6½″ deep. The weight is approximately 3 pounds. The case, designed to MS-33550, is made to mount in a standard instrument panel cut-out. The completed unit is shown in Fig. 6.

In the final design the numerals are illuminated by having the leading edge of the Plexiglas wheels run in grooves in the rear face of the edge-lit front panel. Light from the panel enters the polished edges of the wheels and is reflected from the figures. The number wheels are driven by an intermittent Geneva movement from a worm gear attached to the motor. A closed-circuit, two-pronged contact rotor on each wheel wipes a printed-wiring-board switch stator. One contact sweeps across 12 equally spaced stator contacts corresponding to the 12 displays on the face of the wheel. The 3-phase transformer taps are connected to the stator contacts. The other rotor contact wipes a continuous printed rotor return ring wired to one side of the sensing-relay bridge diodes. This completes the bridge circuit for each digit.

The above remote-control system may be readily modified to present a wide variety of information. It is anticipated that the basic system, including remote indicator, will gain wide favor because of its advantages in size, cost, accuracy, and reliability.

Fig. 6—Five-digit remote indicator.



AIRBORNE TELEVISION

By **A. F. FLACCO**
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MILITARY TELEVISION is a comparatively new endeavor for ASD. Display devices are common in fire-control systems; however, television-type sensors are not as yet widely employed on operational aircraft, although RCA has participated in many study and system-development programs for tactical use of television.

At present, ASD is engaged, under both military contract and internal funds, in these programs:

1) development of a transistorized image-intensifier television camera
2) pilot production of a transistorized vidicon camera for a television sight
3) development of a transistorized infrared-vidicon system
4) a study of high-resolution techniques
5) an infrared-vidicon evaluation
6) production of an image-orthicon, closed-loop television system
7) a slow-scan transistorized vidicon camera.

The transistorized cameras which have been built include video amplifiers, synchronizing generators, deflection circuits, and focus-current regulators. In addition, the orthicon cameras include alignment-coil current and dynode voltage generating circuits. The vidicon cameras weigh approximately 15 pounds, occupy a volume of about 450 cubic inches, and need approximately 30 watts of input power. The outputs are video and drive signals for a monitor. An image orthicon camera which is transistorized weighs approximately 25 pounds, occupies 1,000 cubic inches and needs approximately 75 watts of input power. Its output signals are the same as those from the vidicon camera. In applications where weight and power limitations are not too critical, the image orthicon camera is preferred, since it provides operational capability over a wider range of light levels. The vidicon operates satisfactorily with approximately 1 foot-candle on the photoconductive surface of the tube in the scene highlights. The wide-spaced image orthicon permits satisfactory operation down to 1×10^{-4} foot-candles on the photocathode. Image-intensifier image orthicons provide detection capability more than 100-times greater than the wide-spaced image-orthicon.

APPLICATIONS

Since television systems cannot now provide resolution equal to the human eye or good optical systems, their use is restricted to applications where a human observer does not have ready access to desired visual information. Airborne military applications include navigation aids, terrain clearance, reconnaissance, internal surveillance, tail defense, bombsights, and damage assessment.

The tactical application dictates the pickup tube to be used. The standard vidicon surfaces permit operation under daylight conditions only. The wide-spaced, ruggedized image orthicons add both sensitivity and resolution for an extended period of daylight operation. The image-intensifier image orthicons are sensitive enough to permit operation throughout a 24-hour period, even on cloudy, moonless nights, although it does not penetrate cloud layers. Infrared pickup

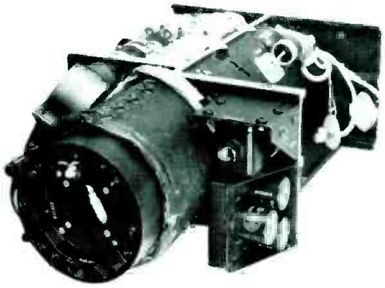

Fig. 1—Camera

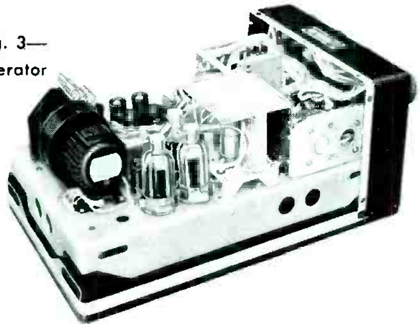

Fig. 3—Sync generator

Fig. 2—Power supply

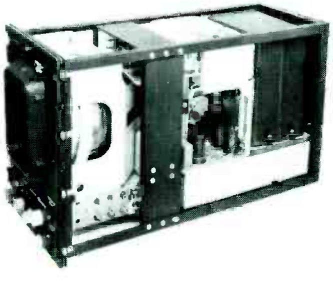

Fig. 4—Monitor

tubes permit operation outside the visible spectrum.

Variations in these tubes to serve specialized applications include reducing pickup-tube size, development of different photosensitive surfaces, and the addition of multiplier sections in vidicons.

ENVIRONMENTAL EFFECTS

Airborne military TV equipment must survive environmental extremes more stringent than those normally encountered. Operation at altitudes up to 60,000 feet is a requisite, and vibration and shock requirements are commensurate with airframe specifications. Shock levels as high as 55 G's could be applied to such equipment, and vibration levels up to 10 G's throughout the frequency range from 5 to 500 cycles must be withstood. Operation above 20,000 to 30,000 feet with high voltages of the order of 10,000 volts can present problems not easily overcome. Insulating surfaces become charged, and corona may occur between terminals spaced five to ten times the safe distance for ground operation. Kinescopes generally require anode voltages between 7,000 and 15,000 volts. The dynode multipliers of the image orthicon and other tubes require end voltages of up to 2,000 volts. It is, therefore, mandatory that precautions be observed in designing such equipment, since arcing or corona could cause explosions. Because of the difficulty of preventing arcing or corona at high altitudes, pressurizing of television equipment is preferred.

USE OF TRANSISTORS

Transistorized television circuits have become particularly common in military applications, since transistors are less susceptible to vibration and shock effects, require less power than vacuum tubes, and operate well at low temperatures. They lend themselves to lightweight, compact equipment design. In the past, doubts had existed as to whether video amplifiers could be built which would not affect the signal-to-noise ratio and would provide the high-level, wide-bandwidth signals required for output circuits. It was suspected that the linearity requirements of military television could not be met with the circuit limitations of transistors. Recently developed military transistors have permitted the use of transistors whose characteristics can be guaranteed within certain required limits to assure interchangeability. Until quite recently, it was necessary to use entertainment-type transistors whose characteristics could not be guaranteed from unit to unit. This difficulty has been overcome to such an extent that transistorized military television systems can be considered as standard military equipment.

Video amplifiers have been tailored to the needs of the particular pickup tube involved. The type of signal usually encountered from the image intensifier, the image orthicon at low light levels, and the infrared vidicon are compatible with transistor characteristics. The transistors used for video-amplifiers have noise characteristics which are "white" throughout most of the frequency spectrum. When using transistors in slow-scan applications, however, the high noise level that most transistors generate at the extremely low frequencies can cause difficulty when only low-frequency information is being processed.

IMAGE-INTENSIFIER ORTHICON CAMERA

ASD is developing a transistorized image-intensifier orthicon camera to operate at extremely low light levels. The camera has a volume of approximately 1600 cubic inches, weighs 20 pounds and will use 75 watts input power. It includes a video preamplifier, amplifier, sync generator, horizontal and vertical deflection, focus current circuits and the auxiliary circuits required for control.

The pickup tube used contains an intensifier section cascaded with the image section that is usually a part of an image orthicon. The amplification thus realized permits operation at light levels below those at which the dark-adapted human eye can obtain useful information.

AIRBORNE CLOSED-LOOP TV LINK

RCA has designed and is now producing a closed-loop TV link for an airborne application to meet Air Force specifications. Tubes are JAN or military types. All components are ruggedized and adapted to military use. The system is capable of operating with one or two cameras. The units required for operation as a single camera system are the camera, synchronizer, monitor, and power supply (see Figs. 1 through 4). For dual-camera operation, a second camera and an auxiliary unit are required.

DESCRIPTION

The system operates with approximately 25 feet of cable between the cameras and the synchronizer and 170 feet of cable from the synchronizer to the monitor. To meet operational requirements, the yokes in the cameras and monitors were rotated 90° to obtain a raster scanning from left to right in the field (slow) scan and bottom to top during line (fast) scan.

The power provided for the system is 400-cycle, 120-volt, 3-phase a-c from the aircraft supply. Normal power consumption when heating is not required is approximately 1800 watts. Operation is required at temperature extremes from +160°F to –76°F, altitudes above 50,000 feet, impact shocks up to 10 G's for 20 milliseconds, and under vibrations from 5 to 500 cycles. In addition, no components are permitted to operate at a temperature that might ignite fuel used by the plane, and no corona or arcing is permissible. Vibration effects are not permissible in the picture presented on the monitor.

CAMERA

The tube used is the wide-spaced image orthicon, designated thus because it has a 150-mil spacing between the glass target and mesh as compared to a 3-mil spacing in the image orthicon commonly used for commercial studio work. By increasing mesh-to-target spacing, target capacitance is reduced. This improves vibration characteristics, reduces time lag, and most important, achieves better signal-to-noise ratios at very-low light levels.

The wide-spaced tube is capable of producing useful signal information at 1 × 10^{-5} foot-candles on the photocathode. At 1 × 10^{-3} foot-lamberts of scene brightness, the wide-spaced image orthicon can reproduce *more information* than can be discerned by the dark-adapted human eye.

The image-orthicon camera contains a preamplifier, a voltage-regulator plate supply for the preamplifier, and dynode voltage dividers. It also contains the heating and cooling system, a series of resistive heating elements in an internal forced-air system that maintains the image-orthicon temperature within operating limits. In addition, the air stream is by-passed or recirculated in response to changes in the outside ambient temperature. At higher altitudes, a barometric switch reduces the power in the convection heaters, and heating is accomplished primarily by conduction through the camera housing. This system allows the camera to be brought to operating temperature within 20 minutes at any altitude from sea level to over 50,000 feet.

The power-supply unit provides all the d-c power needed to operate the system and includes some control circuits necessary to operate the camera. Six volts d-c is provided for the filament of the image orthicon in one camera. Three regulated d-c supplies (+250, +150, –150 volts d-c) are provided. A relay used in common with all three supplies causes them to go into operation after a time delay. This allows sufficient filament warm-up time to protect all tubes for approximately 54 seconds before the plate supplies become available. The system also has a *standby* switch and an *emergency override* switch that by-passes the time delay and makes the plate supply voltages available immediately.

The power supply also contains a regulated focus-current supply for one camera. A number of the necessary controls—alignment, multifocus, image-orthicon gain, field size, and horizontal centering—are included in this unit. A coaxial relay actuated from the control panel switches video from either camera to the monitor.

MONITOR

The monitor contains a kinescope and associated circuitry such as monitor line-rate deflection, monitor and camera field-rate deflection, kinescope ultor-voltage, and a video amplifier.

Field-rate deflection is obtained by taking field-rate drive pulses from the synchronizer and using them to trigger a field-rate deflection circuit. The circuit consists of a sawtooth generator, sawtooth amplifiers, and a power-output tube which drives the field-rate yoke through the output transformer. Thermistors in series with the field-rate yoke compensate for temperature changes that would change the field-rate scanning.

Line-rate deflection is obtained with a reaction scan circuit from which an ultor voltage of 10 kv is obtained. A conventional damper diode prevents ringing in the line-rate sweep. The high-voltage supply is regulated by a corona-regulator tube.

The video signal obtained from the camera preamplifier is amplified in two stages; then, d-c is restored with a driven clamp. External-mixed blanking obtained from the synchronizer is added to the video signal.

SYNCHRONIZER

The synchronizer generates the sync signals for the system. The field rate is 50 cycles, with 2:1 interlace. The line rate is 625 lines/sec. The basic oscillator frequency is 31,250 cycles/sec, which when counted down in a 5:5:5:5 sequence yields the 50 cycles for the field rate. A divide-by-two stage provides 15,625 cycles for the line-rate drive and blanking signals. The synchronizer includes most of the auxiliary circuits for one camera.

AUXILIARY UNIT

The units described comprise the equipment required for single-camera operation. When using both cameras, an auxiliary unit is required. This unit contains the field-rate deflection circuits and most of the auxiliary circuits for the second camera. Line-rate deflection is obtained, as noted above, from the synchronizer. During dual-camera operation, the line-rate deflection yokes of both cameras are in parallel.

SUMMARY

The military services have been attempting to evaluate television type sensors for tactical use since the beginning of World War II. The most-useful applications at present appear to be airborne or missile applications. Improvement of resolution capability and the development of secure transmission systems will lead to more widespread use of these devices.

During the past three years, ASD has expanded its facilities and technical ability to develop and produce military television systems. The projects under development at present involve several different types of sensors, with scanning systems being adapted to particular tactical needs.

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FUNDAMENTAL CONCEPTS OF OPTICAL PROCESSING

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A RATHER SIMPLE experiment illustrates most aptly the purpose of this article: If one looks at a small, distant light source between slightly separated fingers held close to the eye, a set of fringes appear with the fringe separation increasing as the separation of the fingers decreases. The single-slit diffraction pattern as observed in this fashion is familiar; if mathematical expression is given the observed pattern, it is expressed in the equally familiar sin x/x form. More-sophisticated experiments further illustrate that an optical system can form the spectrum of a function: the *single slit* may be replaced by a *grating of slits*, where the diffraction pattern takes on the mathematical form of the spectrum of a pulse train. The grating may be made two-dimensional, i.e., take the form of a screen, causing the spectrum to also become two-dimensional, a case which is familiar to the mathematician but seldom to the electrical engineer.

The close analogy between the behavior of an optical system of stops and lenses and an electrical communication channel has received new impetus in the last eight or ten years. The basic idea underlying the analysis herein is more or less fundamental to the physics of the situation, but beyond this there comes a point of view which largely determines what is done with the results of an analysis. The purpose of this paper is to outline the mathematical bases of a coherent optical system and, in some cases, to point out the electrical analog.

SYSTEM FUNDAMENTALS

Consider the image-forming properties of the well-corrected lens system illustrated in Fig. 1. For the present, the object can be considered as made up of point radiators of monochromatic light. The first lens is located so that the divergent spherical wave fronts become plane between the lenses. The second lens converts the plane wave fronts to convergent spheres. Ideally, there exists a one-one correspondence between the radiators in the object plane and the illuminated points in the image plane. In the spectral plane (designated by the coordinates μ-ν) there exists a superposition of plane waves from every point of the object.

The problems of this simplest lens system can be given a reasonable description, which can then be superimposed on more complicated systems. Of interest here are those of limited aperture and source coherence. Since in any optical system the aperture represented by the μ-v plane is finite, the optical aperture acts as a low-pass filter producing not a point image of a point source but a diffraction-pattern image of a point source. To this extent, the object-image relation fails to be one-one. The magnitude of the pattern is inversely proportional to the size of the aperture and determines the smallest reproducible image, just as the finite band-pass of a filter limits the detail in a communication channel.

The coherence of the object radiation determines the manner in which the various waves combine to form the object spectrum and the image. There are two limiting cases of interest, and any practical illumination falls somewhere between the two. *Complete incoherence* demands that any phase relation between the various points of the object be completely random, most nearly approximated when the object is the primary source of radiation—a lamp or an arc. As the result of the random-phase relation, the light intensities (power) are additive in the succeeding planes. *Complete coherence* implies that it is possible to write a point relation relating the phase to the position of the point. It is possible under this condition to add the amplitudes in the succeeding planes. The remainder of this paper is confined to giving mathematical expression to the *coherent* case.

MATHEMATICS OF COHERENT SYSTEMS

An optical imaging system of a special type is illustrated in Fig. 1. Ideally, there exists a one-to-one correspondence between points of the object and image planes. For simplicity of expression, unit magnification is assumed. The description of the excitation in the object plane can be given in terms of a complex point function where the phase is represented by the argument and the amplitude by the modulus:

$$1) \quad \hat{A}(x,y) = A(x,y)\,exp[j\,a(x,y)]$$

That it is possible to write such a description implies phase coherence over the object plane. It is not a complete description as it does not contain any reference to the polarization, and the assumption of monochromatic excitation is made.

In the spectral plane is displayed the *spectrum* or the *Fraunhofer diffraction pattern* of the object. This can be quite accurately described by the double Fourier transform, where the two orthogonal directions are independent of each other:

$$2) \quad \hat{G}(\mu,\nu) = \Gamma_{\mu,\nu}[\hat{A}(x,y)]$$

The inverse operation performed by the second lens forms the image, and a description of the two-step process involves the Fourier integral description of the image:

$$3) \quad \hat{A}(x',y') = \Gamma^{-1}{}_{x',y'}\{\Gamma_{\mu,\nu}[\hat{A}(x,y)]\}$$

The observed image as seen by the retina or a photographic emulsion is given by the intensity distribution:

$$4) \quad I(x',y') = \hat{A}\cdot\hat{A}^{=}$$

(For the sake of simplicity and to further point out the electrical-optical analog, in most of what follows, the two-dimensional property of the optical system will be ignored.)

The transformations indicated in the orthogonal directions can be performed independently of each other. It is even possible to use a cylindrical lens to perform a one-dimensional transformation instead of the two-dimensional transformation of the spherical lens. When equations (3) and (4) are rewritten accordingly the uses of the operational scheme becomes apparent.

$$5) \quad \hat{G}(\mu) = \Gamma\cdot[\hat{A}(x)]$$

$$6) \quad \hat{A}(x') = \Gamma^{-1}[\hat{G}(\mu)]$$

Let $\hat{A}(x)$, for example, be a real function which can be expanded as a sum of three terms:

$$7) \quad \hat{A}(x) = A_0 + A_1\cos\omega_1 x + A_2\cos\omega_2 x$$

This might be a transmission grating containing two frequencies. The spectrum of such a function is given by equation (6).

$$8) \quad G(\mu) = A_0\delta(\mu) + \frac{A_1}{2}\delta(\mu\pm\omega_1) + \frac{A_2}{2}\delta(\mu\pm\omega_2)$$

$$9) \quad \delta(\mu\pm\omega_n) = \Gamma[\cos\,\omega_n x]$$

The equation defined by (9) is a finite-integral approximation to the usual delta function. It is of sin x/x form and its location is given by the zeros of its argument. The reason for writing it in this form is to point out the physical possibility of filtering. Since the spectrum is physically displayed by the first lens, it is possible to examine it and even to remove a component or components by the use of obstructions in the spectral plane—hence the action of a filter. The sharpness of the filter response is limited only by the sharpness of the spectral display, i.e. the dimensions of the transforming aperture and the quality of lens used. A description of the filtered image is given by:

10) $\hat{A}_F(x) = \Gamma^{-1}[g(\mu)G(\mu)]$

where $g(\mu)$ is the filter function.

The reason for writing the functions as complex (as indicated by the cap) is not immediately apparent until it is recognized that it is, at times, desirable to treat complex functions as objects and to even have filters with phase functions. An optical function which produces only phase variations can be constructed from any transparent material by which the optical path length may be varied. The pure amplitude variations may be produced by slits, wires, semi-transparent films, gratings, etc. It becomes immediately apparent from equation (1) that an optical comb filter is of relatively simple construction. By means of such a filter, it is possible to either pass or filter a given frequency with all of its harmonics. The advantages of the comb filter are well known in terms of its noise suppression.

The correlation of one signal with another or with some previously known information about the signal is possible by a repeated use of the filtering property. From practical considerations, it is necessary to write a signal about a bias. In order to produce a usable correlation, the bias term which corresponds in the diffraction plane to the central image must be removed by a high-pass filter. The product of the two functions without the bias is produced by imaging one through the filter on to the other. A second low-pass filter in the spectral plane of the product function removes all but the correlation term.

The effect of the multiplication of two harmonic signals is for the two to be beating together and the component which is filtered out is the d-c component of the product. It is not necessary to filter the bias from but one of the factors in order to remove both biases from the final filter.

A system as illustrated in Fig. 2 can be constructed so that it is possible to display and correlate signals which vary relatively slowly with elevation, the primary requirement being that the information pass through the filters. It is also necessary that the elevation information, taken as the direction into the paper, be imaged on the final filter. Hence, the final lens must be a combination of cylinders with short focal length in the imaging meridian and long focal length in the spectral-forming or correlation meridian.

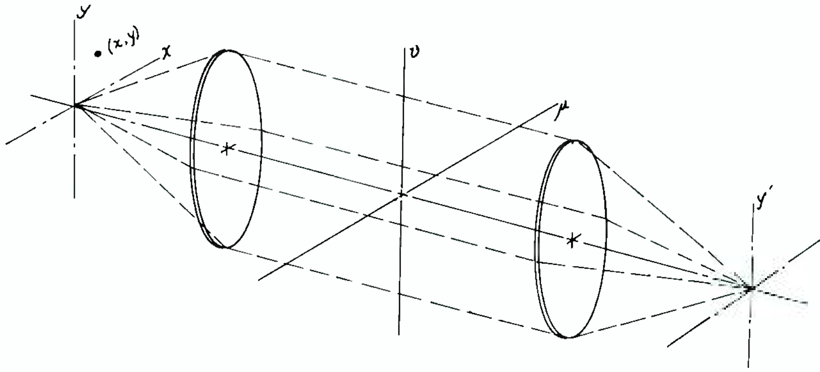

Fig. 1—Well-corrected lens system.

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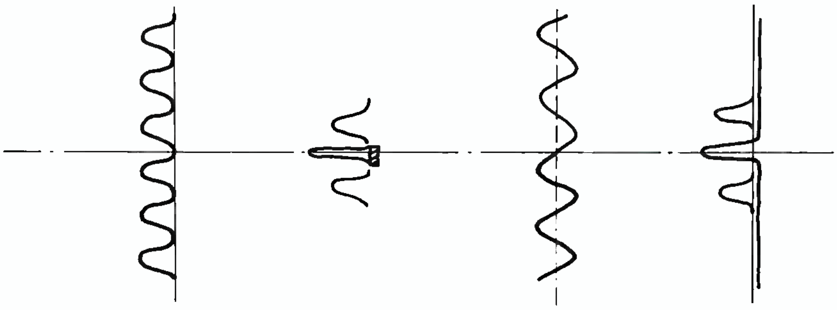
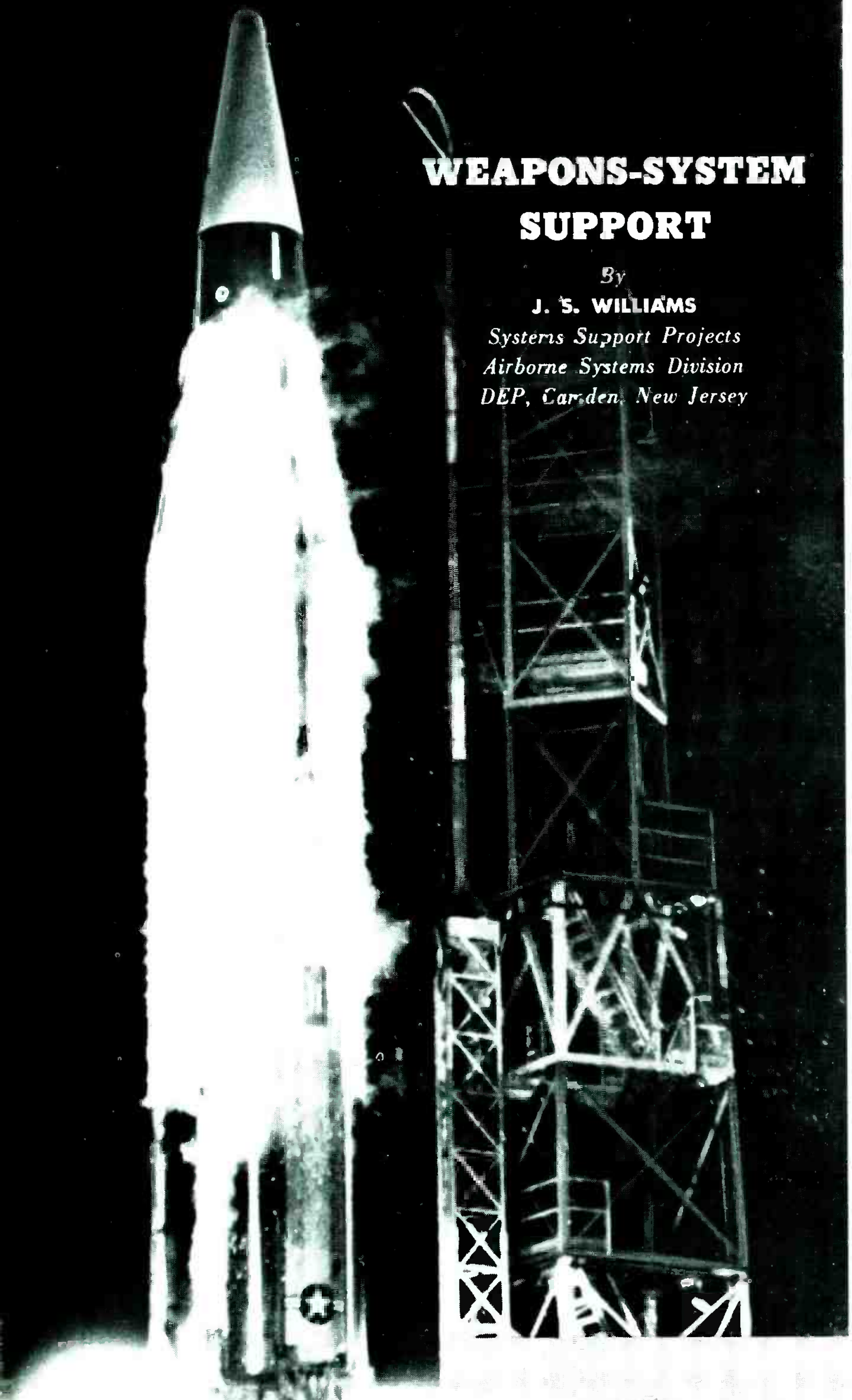


Fig. 2—System to display and correlate signals varying relatively slowly with elevation.



WEAPONS-SYSTEM SUPPORT

By
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Weapons systems support has become a big business. For every dollar the Armed Services spend on hardware, they spend two dollars per year to support that hardware. To develop this attractive market further for RCA, ASD created its Systems Support Marketing Organization. Soon after, a Systems Support Projects and a Support Equipment Design Organization were established in engineering to round-out the ASD Systems Support Organization.

This did not mark the beginning of ASD support activities; but, the new ingredient is the extension of the *integrated weapons system* concept to maintenance and support programs. The prime objectives of the integrated support concept are:

improved in-mission reliability of equipment, by performance checking with quantitative go, no-go automatic checkout equipment prior to and during the mission.

minimum out-of-service time, by use of automatic fault-isolation checkout equipment and modularized construction to facilitate component replacement.

fewer highly skilled maintenance personnel, by use of automatic checkout equipment.

reduced logistic problems, by limiting first-line corrective maintenance to the replacement of black boxes, modules, or major subassemblies and performing all repairs to these units in maintenance shops.

increased effectiveness of maintenance shops, by use of automatic checkout consoles.

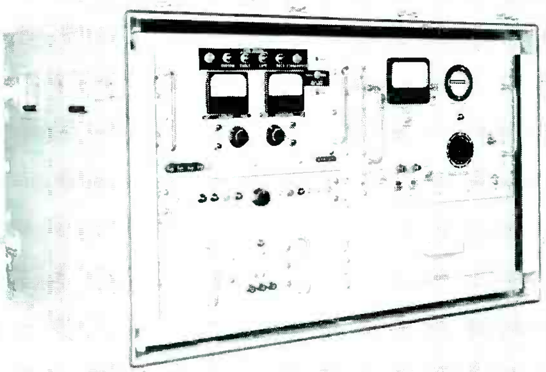


Fig. 1—Dynamic Accuracy Test System (DATS), a fully integrated test and checkout unit that evaluates the dynamic performance of a weapons system.

Fig. 2—Magnetron and Lobster Test Set, which performs a complete operational check in the field, reactivating the magnetron as well as testing it.

PREVIOUS SUPPORT PROGRAMS

This systems-support concept is the evolutionary product of previous ASD support programs. One of these was the preparation of a comprehensive maintenance philosophy that fitted the peculiar needs of the *Astra* Weapons System for the RCAF's CF-105 interceptor. The philosophy was implemented by a program that included the design of checkout and support equipment; the specifications of a maintenance and overhaul program; the provisioning of spare parts; the selection of training courses and their content as well as the setting up of the courses and training aids; and the outlines of plans for field service manuals.

On another program, RCA developed and is now delivering a *Dynamic Accuracy Test System* (DATS) designed to exploit the ASD maintenance concept for the fire control systems used in the F-101 and F-102. DATS (Fig. 1) is a fully integrated test and checkout tool that employs dynamic, straight-through checkout procedures to evaluate the dynamic performance of a weapons system by:

accepting the transmitted pulse from the weapons system, processing it, and then feeding it back into the system as a dynamic target in bearing and range.

allowing the weapons system to lock-on to this simulated target and compute steering information and the time to fire.

automatically analyzing the system's outputs and presenting a readout of the system's actual performance.

In the communications area, RCA is producing *Data Link* support equipment for installation at interceptor bases that is interrogated prior to flight by the aircraft on the flight line. In answer, this radiating test facility broadcasts a message that produces a standard test display on the pilot's scope. If the standard display is not produced, diagnostic messages can be transmitted to locate the malfunctioning assembly. These radiating test units are excellent examples of the application of digital information-handling techniques to checkout equipment for weapons systems.

The RCA modularized automatic-checkout consoles have two complementary features that give them utmost flexibility—modularization and automatic programming. Through this flexibility, integrated, automatically programmed trouble-shooting procedures can be extended or modified rapidly. Through changes in programming, most changes in test requirements can be accommodated at little cost. By adding or replacing subassemblies, modules, or plug-in stages, major changes in the functional capabilities of the test console can be made rapidly and economically. This flexibility is so basic that test consoles designed to automatically test one equipment can be modified to automatically test other equipments.

Another example of integrated RCA support equipment is the *Hawk Checkout Equipment*. The Hawk Program includes the development of selected third- and fourth-echelon electronic test equipment.

Again in the missile support area, Systems Support Projects is participating in the engineering effort on the *Atlas Launch Control and Checkout Equipment*. This equipment includes the low-voltage, transistorized power supplies, the time and events recorder, the relay control units, the *Firex* system, the closed-loop TV system, the autopilot ground-control units, the line amplifiers, and the propellant and pressurization system units.

Some of the support equipment is shown in Figs. 2 through 6.

SEPARATE PROJECT GROUP

In the development of integrated test equipments, the desirability of a separate project group for the support program of a weapons system became apparent. The Astra Program, as a result, had a project group responsible for all aspects of support equipment.

The Astra experience proved that such a separate support group has many advantages. It allows the overall project management and design teams to concentrate on the development of the weapons system itself. Further, it can assure that experienced engineers will give prime consideration to making the system easily and effectively maintainable. The support group, through an analysis and integration effort, can significantly reduce the amount of checkout and support equipment required, eliminate redundant equipment, and

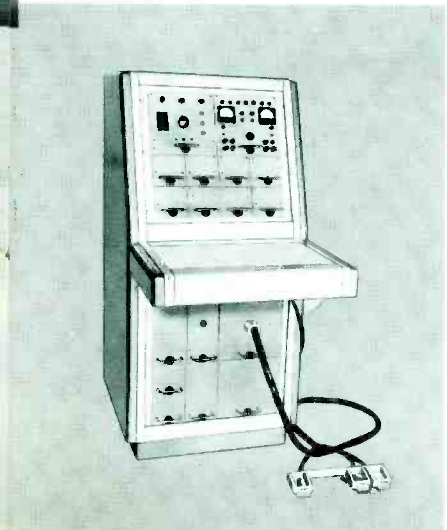


Fig. 3—Lacrosse Missile Test Console utilizing RCA's modular, automatically programmed approach for weapons systems test equipment.

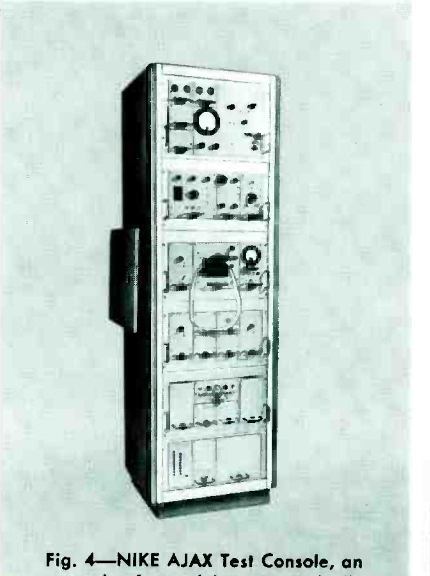


Fig. 4—NIKE AJAX Test Console, an example of a modular, automatically programmed test equipment.

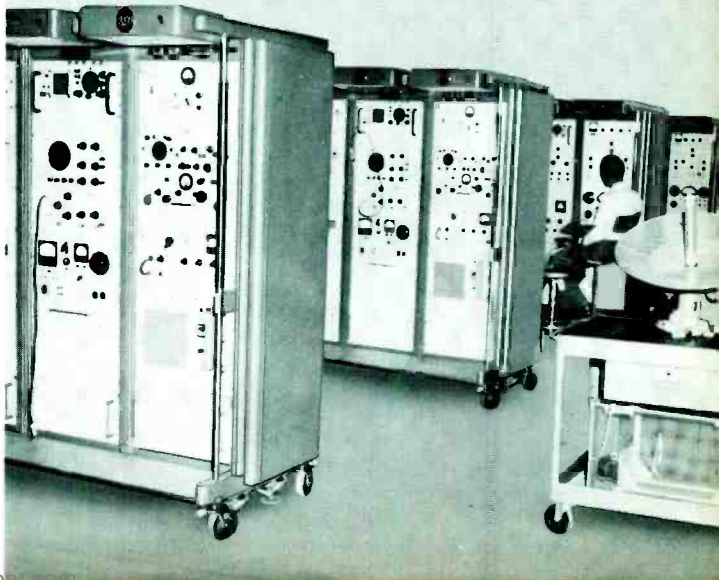


Fig. 5—Depot Equipment for MA-7 Fire Control System designed and installed by Weapons Systems Support Engineering personnel.

provide for more effective use of the checkout and support equipment. Also, the group can make certain that such equipment and other support elements are available when needed.

PROGRAM PHASES

The specific approach Systems Support Projects takes for a weapons system is determined by the particular requirements of the system. But, in general, the aprpoach is divided into two phases. The *first phase* begins with an analysis program to provide detailed recommendations for the complete implementation of the support program. The *second phase* is the execution of the program in all areas, including procurement of equipment, of documentation, and of personnel; and the setting up of the logistics and training programs.

Analysis

In the analysis phase, the mission of the weapons system is determined; the methods and equipment needed for checking integrated system performances are defined; and the requirements for shop checkout equipment are established.

The analysis of the weapons system mission goes into all operational requirements. This analysis leads to an optimum maintenance plan that is a specific and detailed application of the general RCA support philosophy. Throughout the analysis, Systems Support Projects works closely with the system design group and the subcontractors so that the maintenance program will fit the system equipment in all respects.

In defining the best methods and equipment for checking integrated system performance, System Support engineers often use analog computers to simulate system parameters. This simulation also is used in determining what portions of the system must be accurately checked to be sure that the entire system is operating properly within performance specifications. In other words, major decisions concerning the first-line checkout equipment and methods, and the configuration of the checkout equipment for a specific system are based on the simulation results.

In establishing the requirements for the shop checkout equipment, Systems Support engineers reviews all the functional packages and circuitry in the electronic system. The object is to determine and summarize the individual test requirements of the packages. In this way, duplication of equipment can be avoided and the number and types of specialized automatic or semi-automatic test consoles as well as standard test equipment can be kept to a minimum.

After the analyses are completed, Systems Support Projects can prepare the specifications, outlines, plans, and schedules on all items related to the maintenance and support of the electronic systems of the weapons system. This includes the development of the maintenance philosophy best fitted to the specific equipment; the functional specifications for specialized support equipment; the requirements for general purpose test equipment; outlines and plans for handbooks, manuals, and other training requirements; and the schedules and specifications for a logistics support program.

Execution

In the second phase, work is started on the procurement of personnel, materials, and equipment needed to execute the support plan.

A major step is the preparation of detailed specifications that provide maximum standardization and uniformity in all specialized checkout and support equipment. At the same time, an effort is made to include any special requirements related to weapons system integration. Emphasis is placed on integrating the first-line checkout equipment into a single configuration that will best provide a straight-through dynamic test of the complete electronic system. Effort is devoted to coordinating the design efforts of the subcontractors for subsystem test equipment with the design work on the automatic or semi-automatic test consoles for shop and depot facilities. Moreover, engineering follow-up is provided to the system design group during the initial stages of physical integration and application of the electronic support equipment to the weapons system.

Another aspect of the support program is recommending the establishment of depots if they are necessary. Along with this goes the suggestion of what depot equipment and facilities are needed as well as the number and level of personnel required. Outlines of special training courses for these personnel are specified, and, if necessary, such training can be provided.

In addition to its planning and coordination work, Systems Support Projects is concerned with the implementation of planned training programs. The group directs the preparation of design specifications for training equipment and syllabi for training courses. In addition, ASD Engineering personnel help in conducting training courses for subcontractor and service personnel.

FUTURE SUPPORT PROGRAMS

Systems Support Projects is now developing sophisticated maintenance techniques for space-vehicle electronics. Undoubtedly, these new techniques and space vehicle electronics will lead to many changes in support and maintenance equipment and programs. These changes, however, are not expected to alter the basic support concept of integrated test equipment and programs, but rather to strengthen it. As weapons systems become more complex and advanced, the need for the Systems approach to Support problems will increase, and the prime objectives of the ASD maintenance concept will reflect these growing needs.

JAMES S. WILLIAMS received a BS in Physics from Bethany College in 1949. After graduation, he worked for Radio Station WEIR as a transmitter engineer and was an instructor at Tri-State Technical Institute. Mr. Williams joined DEP in 1951. His earlier work included the design of special microwave and mobile communication systems. In 1954, Mr. Williams joined Airborne Fire Control Engineering as a unit engineer on Radar Antennas and Fire Control Computers. Early in 1955, he became senior engineer of a group responsible for the product improvement of the computer section of a large fire control system. In 1956, Mr. Williams was appointed leader of a group having project responsibility for maintenance engineering on major airborne weapons systems. The group he heads became part of Weapons Systems Support Projects earlier this year when the Airborne Systems Division created its Weapons Systems Support Organization.

SEMINAR HELD FOR SYSTEMS ENGINEERS

Editor's Note: Our thanks are due C. A. Gunther, Chief Defense Engineer, DEP, and P. C. Farbro, Manager, Professional Personnel Programs, RCA Staff, for the information reported here. The seminar was organized and administrated by Messrs. Gunther and Farbro, along with N. I. Korman and L. E. Mertens of DEP Engineering, and R. F. Maddocks, Administrator of Training, RCA Staff, who was assisted by Miss Shank of RCA Staff Personnel.

Engineers and managers representing RCA's systems capabilities attended a series of "Advanced Systems Engineering Seminars" during August, at the Berkeley-Carteret Hotel, Asbury Park, N. J. To assure realistic, meaningful discussions, representatives were selected from marketing, design, development, and project organizations in addition to systems engineering and management. The groups attending represented DEP, IEP, AEP, and the RCA Laboratories.

Those attending were divided into four convenient-size groups: each then attended an identical week-long session. The basis of the sessions was that personal abilities in systems engineering can be increased through the study, contemplation, and discussion of systems problems.

The seminars used the case method, augmented by a minimum of formal lectures (four during the week-long seminar). Emphasis was placed upon detailed discussions of nine cases based primarily on RCA systems experience. The case method was particularly effective, since it depends upon a searching analysis to define problems and then solve them. Each case was studied by conference members prior to class sessions. The facts of the case were then appraised in group discussion. Individual participants suggested courses of action and defended their recommendations when other members of their conference group had different ideas. Although the discussion of many cases led to a decision accepted by a majority, the discussion was not necessarily expected to culminate in any one approved solution. The case method was demanding. No ready-made general themes were presented. There were no answers to memorize. There was no unimpeachable authority to hand out academic security in the form of approved solutions. In these case discussions, the participants told *each other* a great deal that was useful. All gradually realized that they were in fact absorbing a large amount of experience.

The series of lectures was on the subjects, "Systems Analysis and Synthesis", "New Technique Developments", "Military Weapon Systems" and "The Role of Systems Engineering in RCA". The outstanding lecturers, chosen from educators and industry at large, as well as RCA, were:

D. R. Brown, Head
Component Development Department
MITRE Corporation
Dr. E. W. Engstrom,
Senior Executive Vice President, RCA
Dr. R. M. Fano, Professor
Electrical Communications, MIT
Lt. Col. G. T. Galt
Air Defense Systems Integration Division, USAF
Dr. D. Green, Asst. Director
Plans. Operations & Management Research Directorate
Systems Development Corporation
C. A. Gunther
Chief Defense Engineer, DEP, RCA
C. W. Halligan, President
MITRE Corporation
A. P. Hill, Asst. to the President
MITRE Corporation
Lt. Col. Kenneth B. Huff,
Air Defense Systems Integration Division, USAF
Captain E. B. Jarman
Bureau of Ordnance, USN
Dr. C. B. Jolliffe
Vice President and Technical Director, RCA
Dr. N. K. Korman, Director
Advanced Military Systems, DEP, RCA
Dr. Benjamin Lax, Head
Solid State Division, MIT
H. W. Leverenz, Director, Research
RCA Laboratories
J. P. May
MITRE Corporation
Major P. J. Melucas
Air Defense Systems Integration Division, USAF
Dr. R. W. Peter, Director
Physical & Chemical Laboratory
RCA Laboratories
Dr. Wallace E. Vander Velde,
Assistant Professor,
Aeronautics & Astronautics, MIT
Lamar Washington, Jr.
Industrial Liaison Officer, MIT

A typical systems-seminar discussion group working on one of the cases which were based upon RCA systems-engineering experiences. (Unfortunately, space limitations prevent including photographs or a list of all those who attended.)

RCA AT CAPE CANAVERAL
PART III—OPTICAL INSTRUMENTATION

By

A. L. CONRAD, Vice Pres.

Government Service Dept.
RCA Service Co.
Cherry Hill, N. J.

THE TWO DISTINCT types of missiles tested at Cape Canaveral can be classed as *aerodynamic* or *ballistic*. Each has its special operational characteristics, but for testing purposes they have one aspect in common: *every* phase of *any* flight is important, and it is essential that *all possible data* be gathered.

Aerodynamic missiles are launched almost horizontally and then cruise, reacting much like a manned aircraft. For testing, they are often flown along the range and either destroyed at the preselected impact point or flown back to be recovered. In either instance, it is extremely important to obtain accurate metric position data and initial-trajectory data.

Ballistic-missile flight can be compared to that of an artillery projectile, with the powered and guided phase being somewhat analogous to a gun barrel that guides an artillery projectile. Accurate metric position data is highly necessary, especially during the powered portion of the flight, when the missile is being guided into an accurate ballistic trajectory.

CINE THEODOLITE TRACKING

One of the important instrumentation systems engineered and operated by the RCA Service Company at Cape Canaveral to obtain metric data is the Cine Theodolite Tracking System. Effectively, the Cine Theodolites used for metric-position data are complex versions of the common surveyor's theodolite. Both are used to measure azimuth (angle from true north) and elevation (angle from the horizontal plane). The Cine Theodolites record these measurements, simultaneously with a time code, on 35-mm photographic film. Since the operators cannot always keep the image of a moving target centered in the film frame, as a surveyor does on a stationary mark, the film also records the vernier error between the centerline of the theodolite and the true position of the missile.

Theodolites are pulse-operated cameras, with the pulses synchronized throughout the theodolite network. When two or more theodolites photograph a missile at the same time, with both recording the time code, the geographical position of the missile at a specific time can be computed. A series of these matched frames can then define a missile's trajectory to a high degree of accuracy.

Theodolites are extremely accurate instruments, consisting of two tracking telescopes and a 35-mm camera mechanism located on a precision base common to all components. The base is housed in a rotating astrodome to provide climatic protection. The theodolite requires two operators, one performing the azimuth positioning of the instrument and the second the elevation positioning. The camera mechanism is

Fig. 1—Two operators train a Cine Theodolite on a moving target.

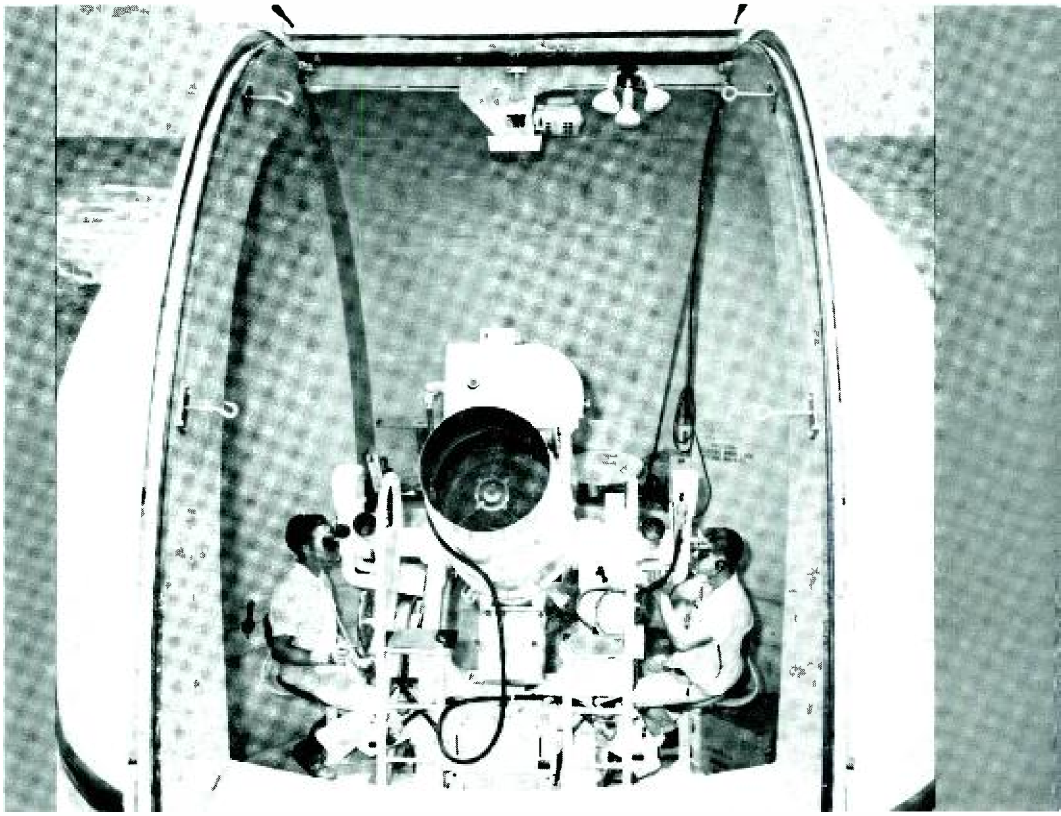


Fig. 2—IGOR camera site.

mounted between the two, with the tracking telescopes collimated so that the precise scope center is in line with the object being photographed (Fig. 1).

The Canaveral theodolites have lenses of 60-cm focal length and automatically photograph one, two, or four frames per second, depending on the pulse rate triggering the camera. The camera magazines contain 100 feet of film on which photographs are recorded at eight frames per foot. Theodolites can accurately track and photograph a ballistic missile in the early stages of flight.

THEODOLITE FILM READER

When composing documentary reports, film is of great value, at times alone providing sufficient information. However, to get data in a usable form for the missile designer, the film must be read and reduced to allow computer tabulation.

For Anthony L. Conrad's biography, see Vol. 4, No. 3, page 50.

The Theodolite Film Reader is designed to assess and record all data from the 35-mm Theodolite film containing azimuth and elevation of an object relative to the instrument's reference axes in conjunction with time. It can project the image on a screen, measure distances, and automatically record data on punched tape (in computer format) and in typewritten tabular form.

The instrument is designed to avoid the laborious task of reading and manually recording all numeric data. Such data is recorded on punched paper tape, so that it may be read directly into either FLAC (Florida Automatic Computer) or IBM-709. Computer outputs are in a format and language that can be accepted by other data-processing equipment. This *common-language* concept is applied to the entire data acquisition and processing activity.

The film reader is housed in a single cabinet with its major functional components. These include an optical system that projects an image of the magnified record onto ground glass screens with cross-wire reading systems; a bank of electronic counters for recording the position of the cross wires; and selector switches for recording data from each frame of film. Indicator lamp banks with identifying glass overlays provide a visual indication of the numbers standing in the accumulators. The images of the vernier dials are projected onto separate screens displaced from the main screen, in order to eliminate interference of the cross-wire system and to provide easier operation for the measurer. Projected images of the film are shown on the viewing screens in the front panel of the reader, which is inclined 28° from vertical at eye level for a seated operator.

ENGINEERING SEQUENTIAL CAMERAS

The recording of images to permit subsequent measurement of *space position* versus *time* is a reasonably obvious application of cameras and film. Less apparent is the application of the family of optical instruments identified as Engineering Sequential Cameras. These are used to record *events* versus *time*. The object is to obtain images of both scheduled as well as unanticipated events throughout the powered phase of ballistic-missile flights and during the critical intervals encountered in aerodynamic-missile flights. For the former, examples might be lift-off, staging, or separation; for the latter, examples include dropping of RATO bottles, ignition of ram-jets, or deployment of drag parachutes during recovery.

Because such events are scheduled, the general area and time of occurrence are known in advance. Engineering Sequential Camera locations, cameras, lenses, and film and frame rates are selected several days prior to an actual test.

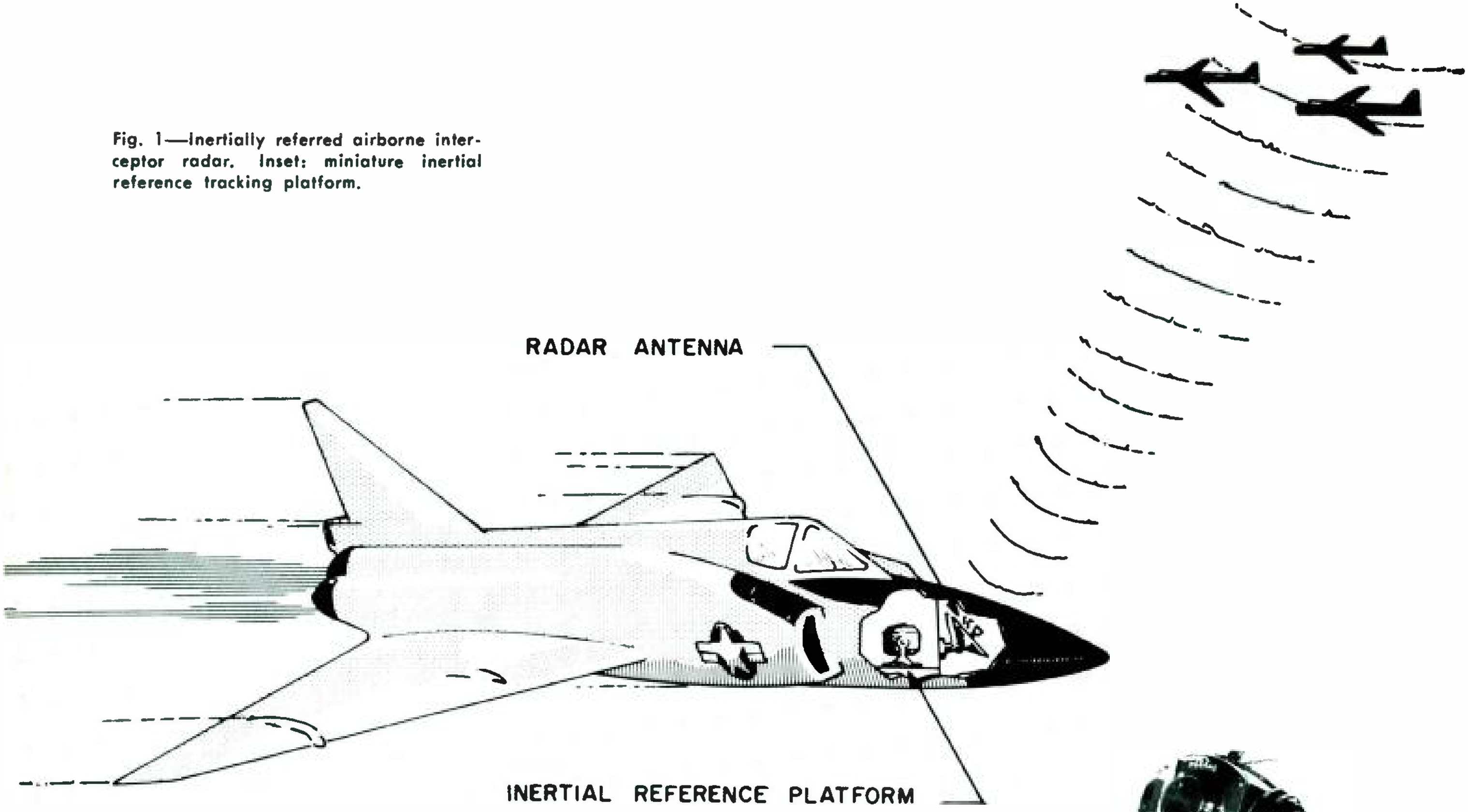
In testing research vehicles, spectacular departures from the plan of flight sometimes occur. Images recorded by Engineering Sequential Cameras often provide important clues to the source of trouble. This is especially true when photographs can be correlated with the functioning of internal components of the missile as reported and recorded on the ground by means of the telemetry system. Suppose, for instance, that telemetry data from a particular test indicate that an aerodynamic missile's propulsion system developed full thrust, but that air speed and rate of climb dropped abruptly after 100 seconds of flight. If subsequent examination of the film records reveals that a hatch cover aboard the missile flew open at plus-100 seconds, much fruitless analysis and investigation may be avoided. Range timing signals are recorded on Engineering Sequential films so that correlations of this nature may be made easily and accurately.

To acquire usable images of events such as staging and separation is difficult. Consider a hypothetical, but not improbable, ballistic missile programmed to drop its booster at a 60-mile altitude and 70-mile range from the launching point. This results in a slant range of about 92 miles from the launch pad to the point in space at which booster separation is expected to occur. In practice, long-focal-length lens systems such as ROTI and IGOR are located 15 or more miles from the launching site and are thus at even-greater slant ranges from the separation point. This arrangement is necessary to obtain a more-favorable aspect angle. Photographs taken in essentially the same plane as the trajectory would contribute little useful information regarding separation. Tracking-telescope sites normal to the plane of the trajectory are unfortunately ruled out by geographical, economic, or technical considerations.

Assuming an approximate slant range of 100 nautical miles and an object one foot long, the ROTI telescope produces an image of about 4 x 10^{-4} inch on the 70-mm film used in the associated motion-picture camera. An enlargement of 100 times in the printing process still yields an image of only 0.04 inch in length. Obviously, all facets of photographic art must be optimized to obtain usable results under these conditions. Long-focal-length systems such as the IGOR (Fig. 2) and ROTI instruments are currently producing good results.

The equipment and problems discussed herein are representative of the optical instrumentation being utilized at Cape Canaveral. Other, complementary optical gear (e.g., the ballistic plate-camera system) is utilized to complete RCA's data-gathering and -processing capabilities.

Fig. 1—Inertially referred airborne interceptor radar. Inset: miniature inertial reference tracking platform.



INERTIAL NAVIGATION
PART III–INERTIAL STABILIZATION

By
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Missile Electronics and Controls Dept.
Defense Electronic Products
Burlington, Mass.

INERTIAL STABILIZATION IS the key to effectiveness in many present-day weapon systems. Stabilization deals with the use of sensor elements and power drives to orient moving bodies in a prescribed manner despite the presence of random disturbances. Typical examples of subsystems frequently requiring inertial stabilization are radar antennas, photographic cameras, television pickups, and infrared telescopes.

Inertial stabilization can be defined as the art of maintaining a body nonrotating or rotating in a prescribed fashion, with respect to inertial space. A stabilization system must first establish a reference vector to which the geometry of the stabilized body can be related through appropriate coordinate transformations. The reference vector and its derivatives must remain unchanged regardless of the coordinate transformations performed. Secondly, the stabilization system must include a mechanization of inertial sensors, computing elements, amplification devices, and controls to produce the desired system behavior.

STABILIZATION OF AN INTERCEPTOR RADAR

Fig. 1 gives one example of an airborne stabilization system employing an inertial reference. In this system an airborne interceptor radar is stabilized with respect to an inertial reference platform. A miniature three-gimbal inertial reference platform is also shown in Fig. 1. The following is a simplified analysis of an inertially referred interceptor radar.

Fig. 2 represents a set of coordinate transformations which might be used for a two-gimbal slaved system and a two-gimbal reference system mounted on a common airborne base. In the example chosen, the order in which the reference system is gimballed is different from the gimballing order of the slaved system. This is shown by the order of rotation noted on Fig. 2. It is desired to position the Z_S axis of the slaved system parallel to v_R, the Z_R axis of the reference system R.

The components of v_R in the systems R and S are defined by the following column matrices:

$$[R]_{v_R} = \begin{bmatrix} O \\ O \\ v_R \end{bmatrix} \qquad (1)$$

$$[S]_{v_R} = \begin{bmatrix} X_S \\ Y_S \\ Z_S \end{bmatrix} v_R \qquad (2)$$

Equation (3) expresses the fact that the components of v_R transformed from the reference system R into the aircraft system A are equal to the components of v_R transformed from the slaved system S into the aircraft coordinate system A.

$$[\theta_R]\,[\phi_R]\,[R]v_R = [\psi_S]\,[\theta_S]\,[S]v_R \qquad (3)$$

Both a trigonometric and a unit vector analysis of this stabilization problem will be outlined.

TRIGONOMETRIC APPROACH

The transformation matrices $[\theta_R]$, $[\phi_R]$, $[\psi_S]$, and $[\theta_S]$ can be expressed as follows:

$$[\theta_R] = \begin{bmatrix} \cos\theta_R & 0 & -\sin\theta_R \\ 0 & 1 & 0 \\ \sin\theta_R & 0 & \cos\theta_R \end{bmatrix} \quad (4)$$

$$[\phi_R] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi_R & \sin\phi_R \\ 0 & -\sin\phi_R & \cos\phi_R \end{bmatrix} \quad (5)$$

$$[\psi_S] = \begin{bmatrix} \cos\psi_S & \sin\psi_S & 0 \\ -\sin\psi_S & \cos\psi_S & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (6)$$

$$[\theta_S] = \begin{bmatrix} \cos\theta_S & 0 & -\sin\theta_S \\ 0 & 1 & 0 \\ \sin\theta_S & 0 & \cos\theta_S \end{bmatrix} \quad (7)$$

Substituting equations (1), (2), (4), (5), (6), and (7) into equation (3) and simplifying, the following important design relationships are obtained:

$$\cos\psi_S \sin\theta_S = \sin\theta_R \cos\phi_R \quad (8)$$

$$\sin\psi_S \sin\theta_S = \sin\phi_R \quad (9)$$

$$\cos\theta_S = \cos\theta_R \cos\phi_R \quad (10)$$

Further simplification can be accomplished by dividing equation (9) by equation (8), and equation (9) by equation (10) to yield:

$$\tan\psi_S = \frac{\sin\phi_R}{\sin\theta_R \cos\phi_R} \quad (11)$$

$$\tan\theta_S = \frac{\sin\phi_R}{\cos\theta_R \cos\phi_R \sin\psi_S} \quad (12)$$

Fig. 3 presents a brute force mechanization of a stabilization system based on equations (11) and (12). A unit voltage is fed into the reference system roll resolver *R* #1 from which are obtained $-\sin\phi_R$ and $\cos\phi_R$. The $\cos\phi_R$ component is next fed to the reference system pitch resolver *R* #2. The yaw resolvers (*S* #3, *S* #4, *S* #5) and the pitch resolvers (*S* #6, *S* #7) of the slaved system modify these trigonometric components and develop error null signals ϵ (ψ_S) and ϵ (θ_S) which are fed to the appropriate gimbal servo drives $M\psi_S$ and $M\theta_S$. In this system the slaved yaw gimbal mounts three resolvers and the slaved pitch gimbal mounts two resolvers.

COORDINATE ROTATION OR UNIT VECTOR APPROACH

Since there are only four coordinate transformations involved in relating the reference vector v_R to the slaved system, it should be possible to mechanize the complete set of transformations with four resolvers. The coordinate rotation or "unit vector" approach yields a simple mechanization directly by making use of the following requirement. For two axes to be parallel in space, the projection of a unit vector along either axis onto a third orthogonal coordinate system must produce equal components along the axes of the third coordinate system (in this case, the aircraft coordinate system *A*).

In the reference system, the vector v_R lies along the Z_R axis and does not project components along X_R and Y_R. This is stated in equation (1). Since the

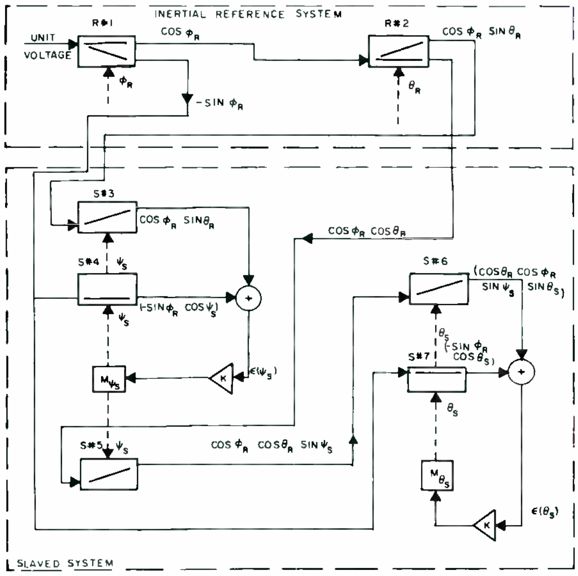

Fig. 3—Mechanization of radar antenna stabilization; trigonometric approach.

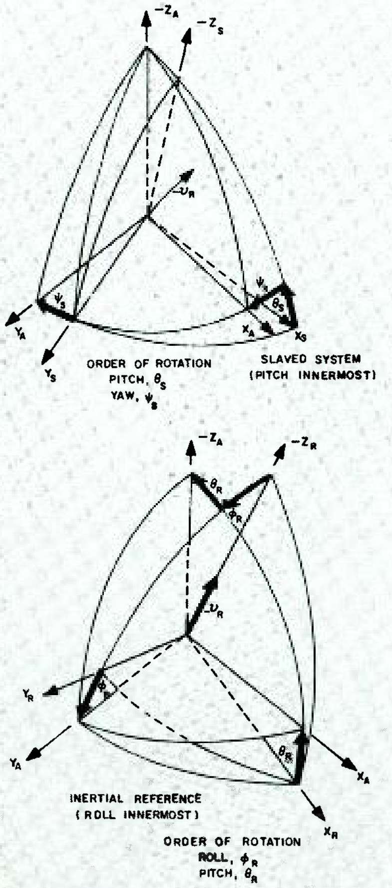

Fig. 2—Geometry of an inertially referred interceptor radar.

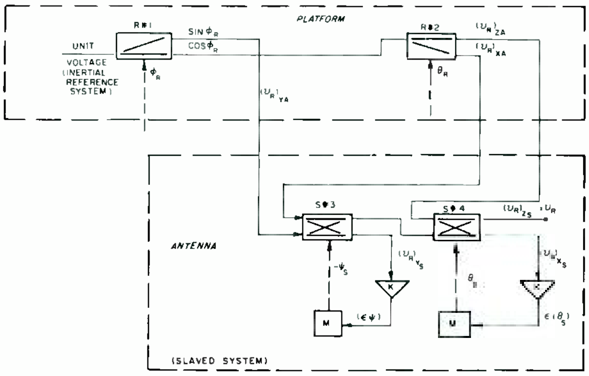

Fig. 4—Mechanization of radar antenna stabilization based on coordinate rotation.

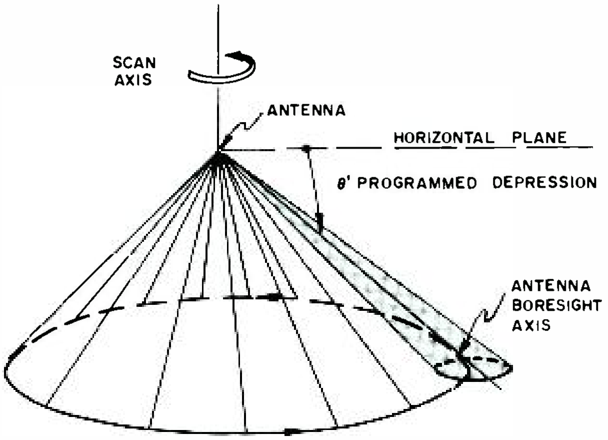

Fig. 5—Programmed ground-mapping radar.

slaved Z_S axis must be parallel to the reference Z_R axis, it cannot have X_S and Y_S components of the v_R vector. Thus, the slaved servo error signals can be derived directly from the X_S and Y_S components of v_R, as shown in Fig. 4.

It should be noted that the mechanizations shown in Figs. 3 and 4 are equivalent. Apparent differences in the two block diagrams are the phasing in the resolvers R #1 and R #2 on the reference system gimbal package and the sign of ψ_S and θ_S. By rewriting equation (3) as equation (13) to define the $[S]$ matrix in terms of the inverse $[\psi_S]$ and $[\theta_S]$ transformations and by noting that the inverse of a coordinate matrix is equivalent to a reversal of rotation of the coordinate system, the reasons for the changes in sign of ψ_S and θ_S in Fig. 3 become evident.

$$[S] = [\theta_S]^{-1}\,[\psi_S]^{-1}\,[\theta_R]\,[\phi_R]\,[R] \qquad (13)$$

Fig. 4 shows the progressive transformation of the v_R vector through the aircraft coordinate system A to the slave system S, whereas Fig. 3 is based on equating the slave system and the reference system components of v_R in the aircraft coordinate system A. A further difference should be noted. The resolvers in Fig. 4 are used as coordinate transformers, whereas those in Fig. 3 are used as trigonometric multipliers.

A STABILIZED GROUND MAPPING RADAR

In a number of gimballed system applications it is desirable to use a reference system for stabilization only and to slave a second system to a program of control signals relative to the stable reference coordinate system. An example of this type of stabilization is a gimballed search radar antenna system required to scan about a prescribed axis. Fig. 5 shows an airborne radar antenna constrained to a programmed depression angle θ' as it scans about a vertical reference axis. In a two-gimbal radar antenna system, neither gimbal axis is vertical at all times, although it is desired to scan about a vertical axis. Since only two degrees of freedom are available in the antenna gimbals, only the boresight axis can be slaved to the programmed θ'. (Cross-roll effects from this arrangement must be compensated if not negligible.)

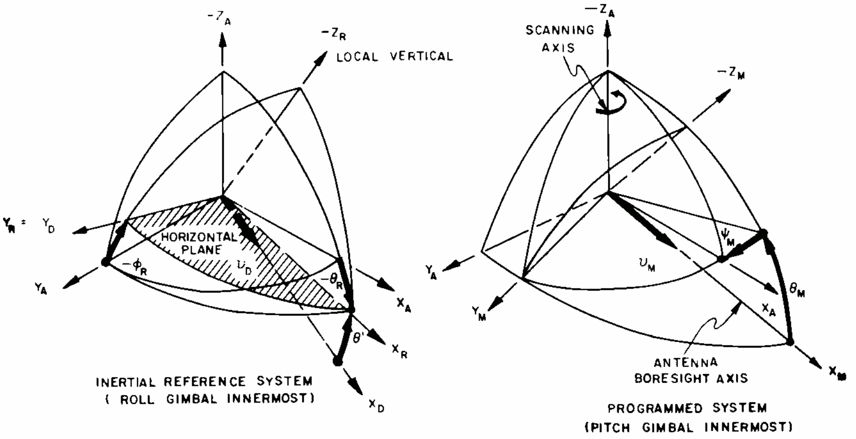

Fig. 6—Geometry of inertially referred gound-mapping radar.

Fig. 6 shows the geometry of the reference system, and the two-gimbal scanning system mounted in a common airplane reference system. The Z_R axis now represents the indicated direction of the local gravity vector and the plane containing X_R, Y_R is the horizontal reference plane. The unit vector v_D represents a vector which is programmed at a depression angle θ' from the horizontal and lies in the vertical X_R-Z_R plane. The unit vector v_M lies along the antenna boresight axis and is directed at the depression angle θ' below the horizontal. The unit vector v_M is equal in magnitude to the v_D vector, but lies parallel to the v_D vector only at the scan angle which occurs when the boresight axis parallels the vertical X_R-Z_R plane.

The projection of the v_D vector into the reference system R can be expressed by:

$$[R]\,v_D = [\theta'] \begin{bmatrix} v_D \\ 0 \\ 0 \end{bmatrix} \qquad (14)$$

Similarly, the projection of the v_M vector into the reference system can be expressed in the inverse form by:

$$[R]v_M = [\phi_R]^{-1}\,[\theta_R]^{-1}\,[\psi]\,[\theta_M] \begin{bmatrix} v_M \\ 0 \\ 0 \end{bmatrix} \qquad (15)$$

Again the transformation matrices can be written:

$$[\phi_R]^{-1} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi_R & -\sin\phi_R \\ 0 & \sin\phi_R & \cos\phi_R \end{bmatrix} \qquad (16)$$

$$[\theta_R]^{-1} = \begin{bmatrix} \cos\theta_R & 0 & \sin\theta_R \\ 0 & 1 & 0 \\ -\sin\theta_R & 0 & \cos\theta_R \end{bmatrix} \qquad (17)$$

$$[\psi] = \begin{bmatrix} \cos\psi & \sin\psi & 0 \\ -\sin\psi & \cos\psi & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad (18)$$

$$[\theta_M] = \begin{bmatrix} \cos\theta_M & 0 & -\sin\theta_M \\ 0 & 1 & 0 \\ \sin\theta_M & 0 & \cos\theta_M \end{bmatrix} \qquad (19)$$

$$[\theta'] = \begin{bmatrix} \cos\theta' & 0 & -\sin\theta' \\ 0 & 1 & 0 \\ \sin\theta' & 0 & \cos\theta' \end{bmatrix} \qquad (20)$$

Noting that the projection of v_M into the reference system R must be driven to equal the projection of v_D in the reference system, i.e., equation (14) and equation (15) are equivalent, and that v_M will be controlled through the gimbal

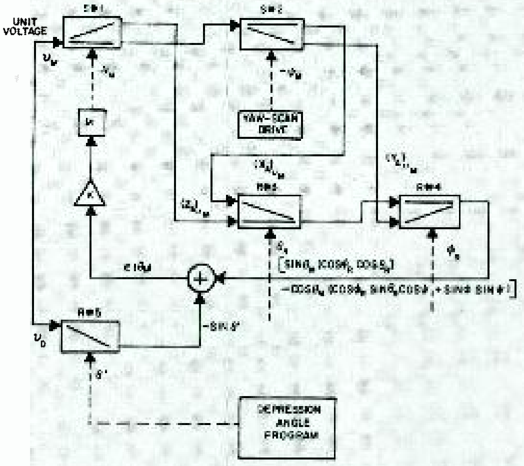

Fig. 7—Mechanization for stabilization of ground-mapping radar.

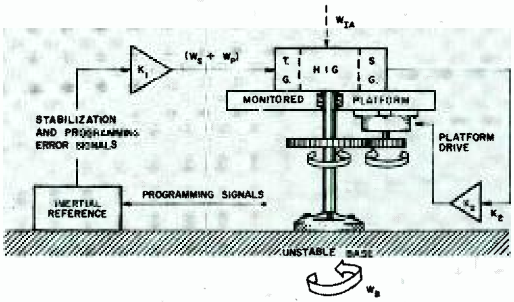

Fig. 8—The Gyro as a means of providing isolation from base motion.

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angles ψ_M and θ_M lead to the following simplification of the resulting matrix expansion:

$$\sin\theta_M\ (\cos\phi_R \cos\theta_R) - \cos\theta_M\ (\cos\phi_R \sin\theta_R \cos\psi_M + \sin\phi_R \sin\psi_M = \sin\theta' \qquad (21)$$

Equation (21) could be mechanized as it stands. However, more than the minimum five resolvers, dictated by the number of coordinate transformations, would be required. As in the mechanization of equations (11) and (12), the coordinate rotation or unit vector approach can be used to reduce the number of resolvers required. Fig. 7 is a functional diagram of a mechanization which uses the minimum five resolvers and which can be shown to be equivalent to equation (21).

(The various techniques for simplifying the mechanization of trigonometric transformations is a separate subject involving the appropriate selection of alternate feedback loops, resolver characteristics, and servo drives.)

STABILIZATION AND ISOLATION

Frequently, a gimballed system programmed by an inertial reference system is required to provide its own isolation from base perturbations and vehicle maneuvers. Consider for instance, an airborne gimballed radar system, such as the previous example, which must scan a ground sector at a high scanning rate with a narrow beam. For low-frequency perturbations and aircraft maneuvers, an inertial reference system, such as a vertical gyro to which a scanning program is added, may be adequate. As aircraft maneuvers become more violent and air turbulence induces higher-frequency perturbations, a form of base motion isolation must be incorporated to assure faithful following of the scanning program. An obvious device for isolation is the gyroscope. By virtue of its high sensitivity to angular motion, it senses angular base-motion disturbances. (See "Instrumentation of Inertial Systems," Vol. 4, No. 1, *RCA Engineer*, June-July 1958.)

Let us consider the role of the gyro in stabilization *and* isolation functions. Fig. 8 shows the control loop for stabilization about one antenna gimbal axis.

Let the output of an inertial reference system be a composite stabilization and scanning program signal $(\omega_S + \omega_p)$ for the gimballed airborne radar system mentioned above. After amplification at K_1 the signal is fed as a torque command to a hermetic integrating gyro (HIG) mounted on the radar antenna. The commanded torque and a torque equivalent to a random disturbance, ω_B, of the radar antenna about the gyro input axis are summed by the gyro. This produces a signal which is subsequently amplified at K_2 and used to drive the antenna with respect to its base mounted on the aircraft. In this situation the gyro acts to filter perturbations on the command signal $(\omega_S + \omega_p)$.

As the frequency ω_B of the aircraft base motion increases, the lags associated with the inertial reference, gyro, antenna mount, and drive loop become significant. Without the gyro in this loop, the positioning error would increase. In this case the gyro also senses the disturbance rotation directly and produces a signal which is fed to the antenna drive to null the uncompensated disturbance. The gyro is therefore used in two different functions; namely, as a filter for low-frequency signals and as a detector of high-frequency perturbations, providing isolation from base motion.

SPACE EXPERIMENTS AND AUTOMATIC DATA ANALYSIS

by **M. S. COHEN**
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TODAY, A GLANCE AT almost any newspaper reminds us of the powerful new techniques that will enable man to explore the universe to an extent at best only dreamt of by our earthbound ancestors. These are techniques that will produce great volumes of data eagerly awaited by scientists in all fields. But the very speed with which this new space technology is progressing, when coupled with man's inherent impatience and the all-too-imposing military potentialities of space, creates an attendant problem: how to efficiently convert this wealth of basic *data* into ordered knowledge of our space environment. It is here that the comparably new research tool of automatic data analysis can be applied to bring scientific rewards out of a potential data chaos.

INFORMATION FROM FACTS

Scientific research is often described in terms of two interdependent phases—the *experimental* and the *theoretical.* Both are dedicated to closing the gap between what *is* presently known and understood and what *can be* known and understood about the universe. The experimental phase is concerned with the observation and measurement of physical phenomena, while the theoretical phase is concerned with the development of conceptual models, and the theories and interpretation of experimental data. The real test of scientific progress is not just in the gathering of masses of facts; rather, it is in the analysis and interpretation of these facts.

Let us assume, for the moment, that the many practical problems associated with the construction and instrumentation of space vehicles have been solved; the first series of exploratory vehicles have been launched and are in their desired satellite or space trajectories. The problem remaining, then, is to assess what must be done before man can claim that he has mastered the mysteries of space.

An exploratory space fleet can be expected to provide a tremendous volume of information per day—on the order of millions of pieces of data. The real value of this volume of data cannot be realized until the following are learned:

1) the accuracy and adequacy of existing knowledge and theory by comparing space observations with predictions obtained from theory,
2) the existence of heretofore-unknown space phenomena and empirical relationships,
3) new basic theories that explain the newly detected phenomena and relationships, and
4) the adequacy of the data as to type, quantity, and quality so that subsequent space probes can be designed to supply specific data for the various scientific research groups.

THE THEORETICIAN'S TOOLS

Obviously, data analysis is part of the theoretical phase of research mentioned above. Unfortunately, the theoretician's prime tool, the human mind, has received little improvement or modification since the days of Newton, when it was far from new.

The inductive and deductive reasoning capability of the human mind is the basis of scientific analysis, but the analytic process is inherently slow, tedious work, undertaken with confidence in success but with difficulty in knowing how long it will take to be successful.

Of course, technology has provided the theoretician with some time-saving devices. Improvements in transportation, communications, and publication have made easier the exchange of ideas and data among scientists with a common interest. The remarkable development of the "electronic brain," or digital computer, has proven of value, but in limited areas only. It can be used to advantage once the scientist has arrived at a theory and wishes to use it in the prediction of certain physical quantities under specified conditions. In the present rather crude state, it is usually necessary for the theoretician to describe his problem to a computer programmer who then transforms the problem into the highly specialized language required by the computer. Thus, the theoretician usually must wait for days or even months while the programmer and computer are solving the problem even though the computer may dispatch the problem in only a few minutes once the problem has been properly expressed in computer language.

Despite the lack of modernization in the techniques of performing analysis, the theoretician is saddled with the responsibility of exploiting the huge volume of data made available by the efforts of thousands of "experimentalists" and the expenditure of millions of dollars. Society, be-

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cause of the technology race in which it is engaged, is, and will continue to be impatient for results. This is particularly true of space exploration.

It is certainly timely to find techniques to aid the theoretician. The prospect of developing a device within the next few years that will do all of the theoretician's thinking for him is out of the question. A more-promising approach seems to be:

1) acceptance of man's brain as the most powerful device for inductive and complex deductive reasoning that will be available in the immediate future,
2) recognition that present methods of research do not make efficient use of this device.

The second item is better understood when one realizes that often the theoretician is forced to spend the majority of his time in:

1) filtering useful data and ideas from the huge volume of reports that cross his desk each week,
2) maintenance of his files, recording, updating, filing, reordering, retiring data,
3) searching his research files for data pertaining to the problem at hand,
4) sampling, arranging, ordering, and listing data in an appropriate form for inspection.

At present, the researcher devotes a great deal of his time to these necessary tasks that make use only of his physical and very elementary logic capabilities. For these tasks, machines and devices that are presently available (or can be made available in the near future) are far superior to man.

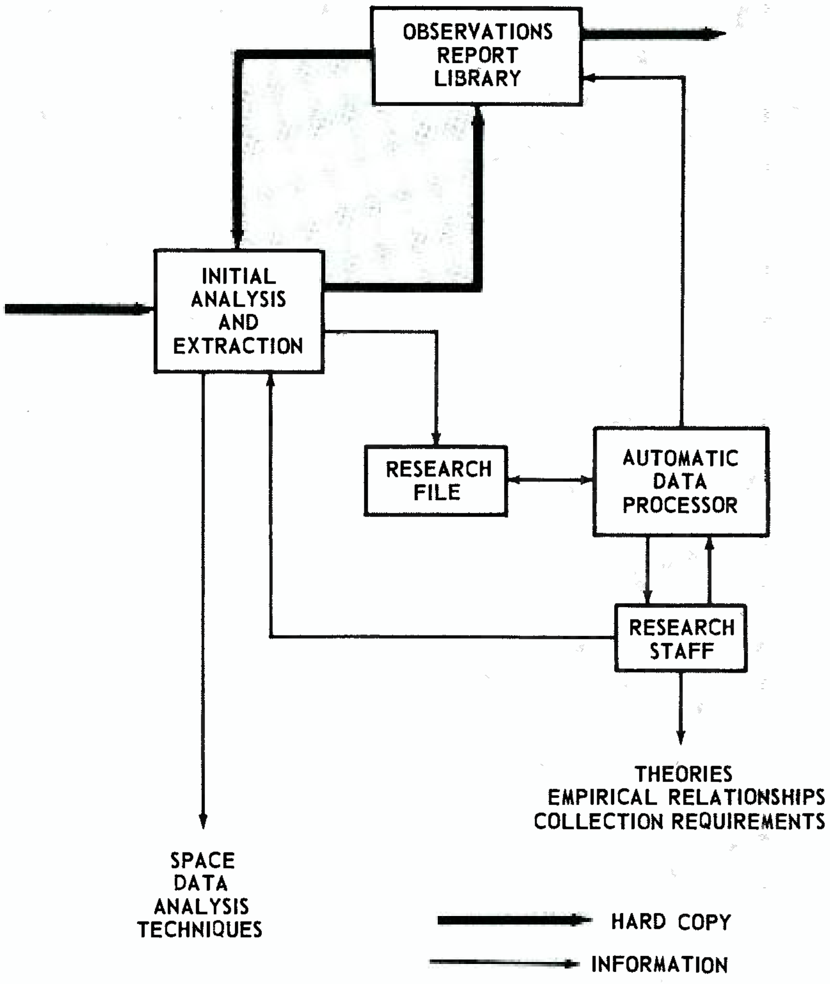

Fig. 1—Space data research system.

MEN AND MACHINES

A system consisting of men and machines shows great promise of exploiting, within minimum time, the expected volume of space-exploration data. To be efficient, the system would have to be designed around the scientists, giving them full control of the data they require, the processing they wish accomplished to test their ideas, etc. This control over the machines in the system can most easily be accomplished by broad instructions expressed in a free language, rather than the lengthy detailed instructions expressed in the computer language presently used by programmers. The design of such a system must also provide for:

1) simultaneous operation by several scientists, each performing independent research upon the same data,
2) presentation of data in a form preferred by each analyst. (Thus, there may be many alternative forms for presenting the same data),
3) methods that permit the scientist to override any machine decision arrived at using previously prescribed rules of logic and even to change at will the rules of logic and processing that the machines will follow in the future.

A DATA-ANALYSIS SYSTEM

A simple functional diagram of a man-machine system is shown in Fig. 1. Data from various sources such as satellites, space vehicles, or ground observation points is presented to the system in various forms, graphs, charts, tables, oscillographs, records, photographs, magnetic tapes. This data must be carefully screened to insure that reports and observations having no bearing on the particular research problem do not enter the system. Material passing this test is next evaluated to see if it contains significant and worthwhile data. For example, automatic recording devices in space vehicles and satellites can be expected to yield a significant quantity of recordings that contain no valuable data because of vehicle position or orientation, instrument error or insensitivity, noise conditions, meteor or similar obstructions, etc. On the basis of previously assigned rules, extracts and summaries are now made of the space observations. In this process, it may be necessary to analyze reports from several sources that have observed the same event.

These various steps are taken in the block marked *Initial Analysis and Extraction* in Figure 1. Both men and machines will be required to accomplish these steps. The arts of automatic semantic and syntactical analysis, photographic interpretation, etc. have not advanced sufficiently to permit mechanization of this entire block. Machines, however, can be of great aid to the analysts at this point in the system.

At this point in the flow, it is necessary to clearly distinguish between *hard-copy material* such as reports, photographs, oscilloscope records, etc., and the *significant information* that is contained and has been extracted from the hard-copy material. The hard-copy material up to a point serves as a convenient courier of and storehouse for information.

Research, however, is performed on *information*, not on documents or photographs. Thus, in even the simplest research system, such as a man and a single document, the document takes one path (for example, to a file drawer, book-shelf, or library) until it is needed again, while the information extracted takes a different path to the human memory (or machine memory) for further processing with other stored information.

This separation of physical, or hard-copy, material and information occurs during the initial analysis. The physical materials, after assignment of the necessary library accession numbers and identifiers to permit efficient recall, are sent to an *Observation Reports Library*. The extracted information is entered into a machine memory here termed the *Research File*. The contents of this file will constantly be searched, rearranged, and displayed and undergo various logical and arithmetical operations by the logic components of electronic data-processing machinery upon the instructions of the research staff.

The scientists, during the course of developing and testing theories, can be expected to place various demands and requirements upon the machine and system. During the development phase, they will require the display in various forms of selected pieces and groups of data. The data-processing equipment will have to possess a series of stored programs for searching, rearranging, and printing-out the contents of the *Research File* in anticipation of this requirement. A review by the scientists of the displayed data might result in the conclusion that insufficient or incorrect data was initially extracted. In that case, the machine will be required to: 1) obtain the accession numbers of the appropriate physical materials in the *Observation Report Library* so that they can be submitted for further analysis and information extraction, and 2) accept the new extracted information and incorporate it into the research file.

Both prior to the formulation, and during the testing of hypotheses, the scientists will require the accumulation of various correlations and statistics of all information in the research file relevant to the hypothesis. As before, the data-processing equipment must have stored detailed machine programs for the required logic and arithmetic operations in anticipation of this type of demand.

The usual problems will be faced in the design of the *Observation Report Library*. A large volume of hard-copy material of different forms must be housed here. In deciding how to store the material so it can be efficiently retrieved, answers must be found for such questions as: Should the material be grouped in some manner such as observation reports from various sources dealing with a single event? If so, what procedure should be followed when one report pertains to several events?

DATA DISSEMINATION

Because of the world-wide interest in space research projects, the system may be required to have a considerable capability for reproducing and disseminating raw and processed data to research activities throughout the country or world. Such a system should greatly reduce the physical and tedious labors often experienced in performing research involving a large volume of recorded data. Allowing the research staff to concentrate their intuitive powers on selected data and providing them with the means to test quickly their hypotheses should decrease, by an order of magnitude, the time and effort required to get fruitful results from such a research task.

The outputs of such a space data-research system would be:

1) tested theories and empirical relations concerning space phenomena,
2) collection requirements regarding quantity, quality, and type of observation needed for additional research,

   (These will, of course, serve as design criteria for future space vehicles and collection systems.)
3) techniques for efficiently extracting and analyzing the data obtained from space vehicles.

EQUIPPING THE SYSTEM

Existing data-processing equipment and techniques must be improved before such a system as discussed here can work efficiently. At present, difficulties are encountered in man-machine communications even though man serves as an off-line element in the processing system. This problem will become more acute in a space data research system which requires that the scientist become an on-line element. Certain functions for which solutions must be found are:

1) the ability to perform simultaneous and rapid complex searches for data in a large file where the search criteria are automatically modified in accordance with the data previously retrieved,
2) the ability to rapidly add, modify, delete, and rearrange data in a small segment of the file without rewriting a large portion of the file,
3) the ability to rapidly modify machine programs and subroutines,
4) the ability to handle several problems at one time in order to accommodate several scientists who are on-line at the same time.

Important work is now in progress on these and other problems of automatic data handling and analysis. The successful solution of these problems and the ability to construct data analysis systems of the type discussed above will represent an extremely valuable tool in solving the problems of space.

Fig. 1—Photograph of Package-Tube Assembly.

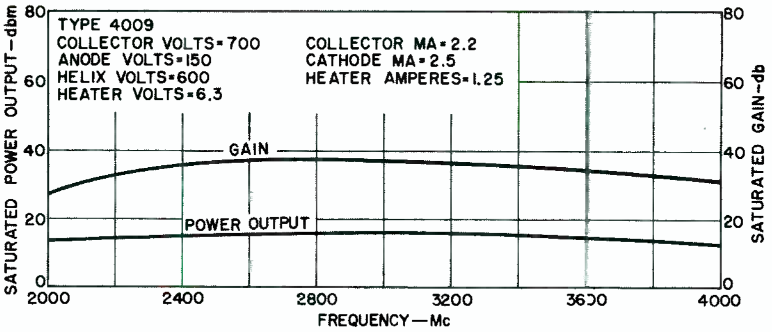

Fig. 3—Curves of RF Performance for RCA-4009.

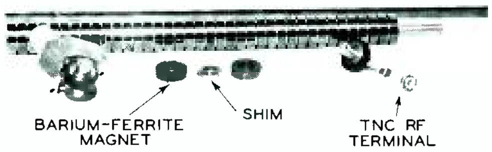

Fig. 2—Miniaturized Periodic-Magnet Focusing System.

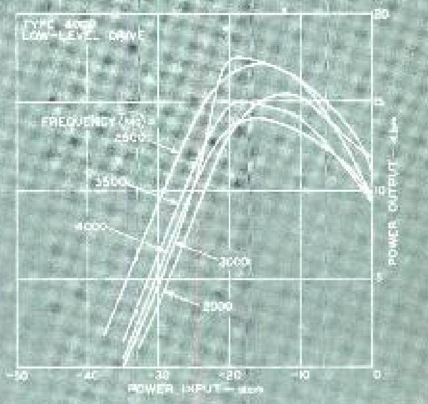

Fig. 4—Power Output as a Function of Power Input for RCA-4009

TRAVELING-WAVE-TUBE AMPLIFIER CHAIN—AN AID TO RELIABLE AIRCRAFT COMMUNICATIONS

by

H. WOLKSTEIN

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THE TRAVELING-WAVE TUBE, although it possesses exceedingly wide bandwidth and high power-gain characteristics, was formerly relegated to the role of a land-based laboratory curiosity because of the size, weight, and power requirements of the solenoid structure used for beam focusing and because of the fragile construction of the tube. Several major breakthroughs have recently been made, however, which eliminate the need for the heavy solenoid structure and which make possible the design of rugged tube structure.

This article describes an amplifier chain consisting of two small, lightweight traveling-wave tubes designed specifically to meet environmental demands peculiar to military aircraft equipment. The first tube in the chain, the RCA-4009, is a low-level 10-milliwatt tube; the second, the RCA-4010, is an intermediate one-watt driver tube. Operating in tandem as an S-Band amplifier chain, these tubes provide saturated gain in excess of 60 db. This level of gain assures a minimum power output of one watt for an input drive of approximately 1 microwatt across the 2000-to-4000-megacycle band.

A complete packaged-tube assembly is shown in Fig. 1. The package assemblies for both tube types have the same external dimensions. Each package comprises a traveling-wave tube, small integral periodic-focusing magnets, tnc male coaxial connectors, and an air-cooled radiator. Flying leads are provided as power-supply connections for adequate high-altitude airborne service. The complete package weighs approximately two pounds, and is 15¼ inches long and 1½ inches in diameter. For a major portion of its length, the package has a diameter of approximately one inch.

FOCUSING SYSTEM

The small size and light weight of these traveling-wave tubes are obtained through the adaptation of a miniaturized periodic focusing system, shown in Fig. 2. The use of this periodic-magnet structure is made possible by the small diameter of the helical slow-wave circuit and the external rf helical transducers.

The periodic-magnet stack is considerably smaller (0.8-inch diameter) and lighter than either a solenoid or uniform permanent magnet with the same effective focusing field. Temperature-stabilized focusing magnets permit operation of the tube over a wide range of temperature. The required focusing field utilized for both tube types can be maintained at operational temperatures as high as 75°C with a minimum tolerable storage temperature of −50°C. In addition, because the polarity of alternate magnets in the stack is reversed, stray magnetic leakage fields are greatly reduced. Thus, tubes used in tandem operation can be arranged in very close proximity. Tests have indicated that less than one inch clearance between adjacent tubes will not affect the stability of the focusing field. Besides reduced size and weight and stray magnetic fields, the use of periodic-permanent-magnet focusing rather than solenoid focusing provides a considerable reduction in power requirements. This amplifier chain requires less than 25 watts, exclusive of heater power, with a maximum potential

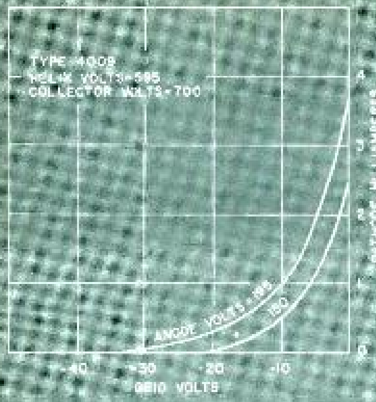


Fig. 5—Grid Transfer Characteristics of RCA-4009.

H. WOLKSTEIN received the BS degree in Electrical Engineering in 1953 at Newark College of Engineering and is presently working toward an MS degree in the same field. In 1945 and 1946 he served with the Air Force as a radar operator (technical) with Army Airways Communications System. In 1948 he became a member of the Research Laboratories of National Union Electric Corporation, where he worked as project engineer on the design of special-purpose beam-deflection and computer tubes. He joined RCA Microwave Engineering in 1955 where he has since been engaged in the development of traveling-wave tubes and is now Engineering Leader, TWT Section. In this area he has made outstanding contributions on electron-beam-focusing periodic magnets, and the design of slow-wave structures. He has been awarded several patents in the electron tube field and other patents are pending. In addition, he is the author of a number of articles which have been published and presented at technical conferences. Mr. Wolkstein is an Associate Member of the Institute of Radio Engineers.

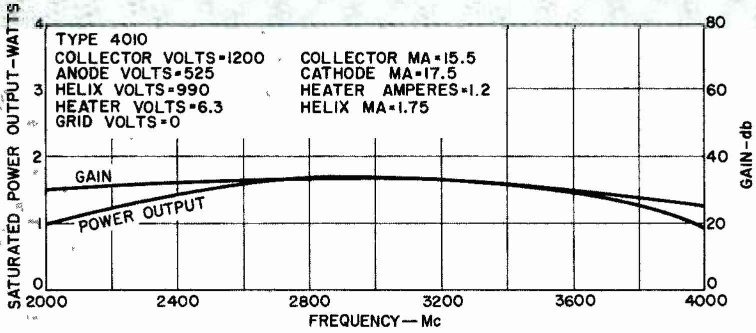


Fig. 6—RF Output Characteristics of RCA-4010.

of 1100 volts. A system employing conventional traveling-wave tubes requiring solenoids would dissipate perhaps ten times this power solely for focusing requirements.

R-F TRANSDUCERS

As shown in Fig. 2, helical coupled transducers, are used as the r-f input and output terminals. The use of helical coupled transducers permits the transfer of r-f energy without interrupting the periodicity of the focusing field created by the periodic magnets. Adequate matching to 50 ohm tnc male connectors is attained to provide a voltage standing-wave ratio of less than 1.5 across the 2000-to-4000-megacycle band.

Sufficient isolation of the input and output signals is obtained through the use of external bifilar lossy helical attenuators. This method of r-f decoupling is utilized for both tube types, and provides a minimum insertion loss of over 50 db and insures stable operation of the tube.

PERFORMANCE CHARACTERISTICS: 10-MILLIWATT

Curves showing the average r-f performance characteristics of the low-power traveling-wave tube are given in Fig. 3. As indicated, a saturated gain of approximately 30 db and a minimum power output of 10 milliwatts are obtained across the band. A single setting of the helix synchronous potential provides satisfactory interaction between the r-f wave and electron beam over the octave band width of the tube. As stated previously, the low-level tube is to be used in tandem operation to supply the drive power for a one-watt amplifier. This tube, therefore, must provide high gain within a limited power output range so that excessive overdrive of the final stage does not occur. This necessitates the use of several multiple-segmented attenuators properly positioned to maintain an output of less than 40 milliwatts across the band. As shown in Fig. 4, the decoupling characteristics of multiple attenuators are such that the rate of power fall-off is considerably reduced as the power input is increased. For this tube, a 30-db variation in input power provides an output which is well above 2 milliwatts, adequate input drive for the one-watt tube across the entire band.

The 10-milliwatt tube is capable of constant-wave and pulsed performance, using simple convection cooling over the normal range of operating temperatures. A control grid having an amplification cutoff factor of approximately five is incorporated in the tube for pulsed service. Fig. 5 shows the grid transfer characteristics of this tube. As shown, cutoff is realized at less than —50 volts, with an accelerating potential of the order of 200 volts. The grid input capacitance is less than 15 micromicrofarads.

PERFORMANCE CHARACTERISTICS: 1-WATT

The external dimensions of the intermediate-power traveling-wave-tube amplifier used in this tandem chain are identical to those of the low-power tube. The r-f output characteristics of this tube, RCA-4010, are shown in Fig. 6. This one-watt amplifier provides a saturated gain at midband of approximately 35 db. The minimum saturated gain is greater than 30 db across the entire band. For wide-band operation, the sychronous helix potential (approximately 1000 volts) is adjusted to yield maximum small-signal gain at the high end of the band.

For constant-wave operation, this tube requires forced-air cooling of approximately 0.1 pound per minute at a pressure of 2 inches of water. Natural convection cooling can be utilized at duty cycles less than 10 percent.

Dynamic grid control performance with a cutoff amplification factor of approximately five is shown in Fig. 7. The grid configuration employed, the same for both tube types, provides maximum power output when the grid is driven

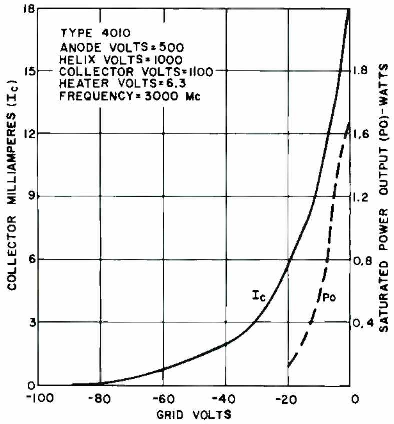


Fig. 7—Grid-Control Characteristics of RCA-4010.

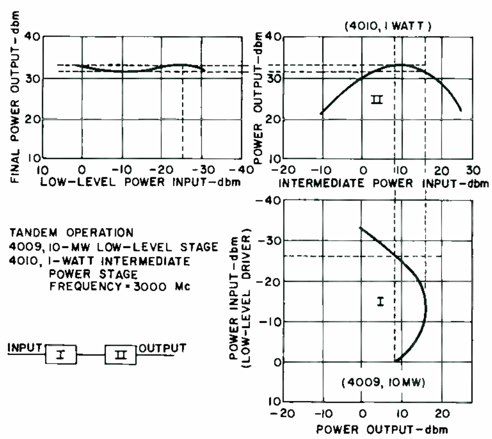


Fig. 8—Typical Power Transfer Curves for Tandem Operation.

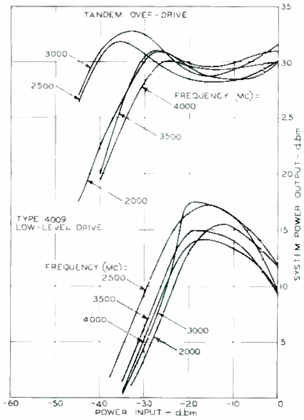


Fig. 9—Over-Drive Characteristics of Tandem System.

from cutoff to cathode potential. This mode of operation assures a relatively high grid-input impedance and no grid-dissipation problem. A grid input capacitance of less than 15 micromicrofarads, including the stray capacitance of the flying leads, requires a low level of input drive power. As shown in Fig. 7, full output power of more than one watt is obtained at midband with a beam current of 12 milliamperes. The r-f cutoff characteristics of the tube are comparatively sharp because of the fast reduction in circuit interaction as beam-current cutoff is approached.

TANDEM OPERATION

Because of their power characteristics, these tubes are admirably suited for tandem operation. The output drive power of the low-level tube provides adequate over-drive for the one-watt amplifier so that saturation is readily attained. This over-drive must be restricted, however, to a limited range to insure that the power output of the system does not drop below one watt. Saturation of the one-watt tube, therefore, must be closely followed by saturation of the low-level tube. Typical power transfer curves for the system at midband, which are shown in Fig. 8, indicate the complementary characteristics of these tubes in tandem operation. With a low-level input drive over a 30-db range, this system can provide a power output of one watt at 3000 megacycles. The curve for the system is derived from a simple cross-plot of input and output power characteristics for both tube types (curve I and curve II). It is obvious that a large range of input drive capabilities requires a final saturated output power well in excess of one watt. At both ends of the frequency band where little excessive output power beyond one watt is available, however, the usable input drive range narrows considerably.

Over-drive characteristics of individual tubes in the system for various frequencies are shown in Fig. 9. The curves show a concurrence between the dip in the system output curve and the maximum power output for the low-level tube which suggests excessive over-drive power. This characteristic can be minimized by the use of adequate isolating pads which will slightly reduce the gain between tubes. Average operating characteristics, obtained for a number of tubes utilized in tandem operation, are shown in Table I.

Table I—Average Operating Characteristics of RCA-4009 and 4010 in 2000-to-4000-megacycle, One-Watt Tandem Chain.

Characteristics	4009	4010	
Minimum Power Output	0.01	1	watt
Minimum Saturated Gain	30	30	db
Maximum Cathode Current	4	25	ma
Helix Voltage	600	1100	volts
Collector Voltage	700	1150	volts
Grid Voltage for rf gain 50 db below gain with full beam current	-50	-100	volts
Anode Voltage	250	625	volts
Grid Input Capacitance	15	15	μμf
Grid Drive Voltage	50	100	volts

RUGGEDIZATION

Fig. 10 is a cross-sectional view of a packaged tube. The modified Pierce electron gun, which is of the shielded convergent-flow type, is encapsulated in an epoxy resin after pre-focusing. The gun stem and flying-lead terminals are encased in a suitable silicon rubber potting compound. Teflon plugs are employed at both ends of the capsule; at the gun end to provide stem and tip-off protection and at the collector end to provide centering control. The fluted-glass tubing which supports the helix is supported at the center of the tube (not shown) as well as at the ends to prevent whipping under excessive vibration. The periodic magnets are held firmly in place at both ends of the assembly by suitable retaining elements.

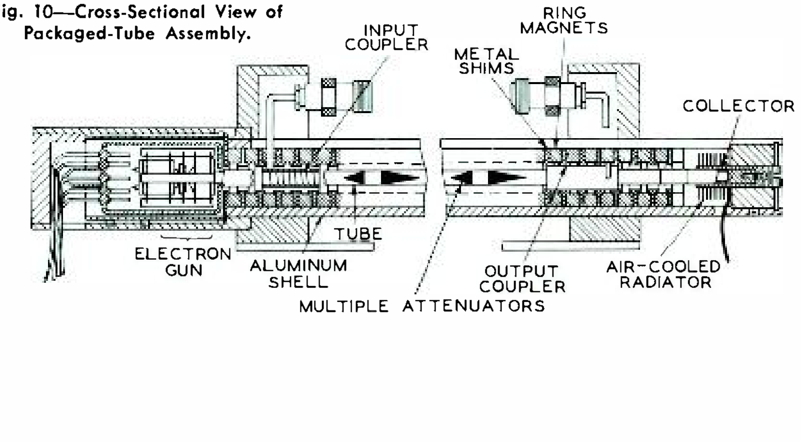
The encapsulated package is capable of withstanding vibration of up to 500 cycles per minute at a displacement which ranges beyond 1/10 of an inch. Tests have been successfully made for an impact shock of up to 15 g's applied for 15 milliseconds.

ADDITIONAL TUBES

Other tubes which employ periodic magnets are in development and can be used to complement and extend the power range of this chain. A 100-watt, S-Band traveling-wave tube having a duty cycle of 10 percent and weighing 12½ pounds and a 1000-watt tube of similar design are now being developed. The 1000-watt tube, which also utilizes a periodic-magnet focusing structure, weighs about 15 pounds and has a duty factor of 1.0%.

The author acknowledges the guidance of C. L. Cuccia, and the assistance of R. Pekarowitz, E. Diamond, R. Bridge, H. Bothner, and many others in pursuing the details of the work described.

Fig. 10—Cross-Sectional View of Packaged-Tube Assembly.



INTEGRAL-PACKAGED TUBES FOR AIRBORNE APPLICATIONS

by

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Electron Tube Division
Harrison, N. J.

For more than a decade following World War II. the traveling-wave tube was the object of intensive development. As a result. it became the unique microwave amplifier—a tube capable of amplification over bandwidths of more than an octave and having substantial power gains at power levels from the milliwatt to the kilowatt range.

Basically. the traveling wave tube consists of the structure of Figure 2. comprising a slow wave structure. such as a helix. along which the wave to be amplified travels. and an electron beam projected through the helix at the velocity of the traveling wave. One of the most important parameters of the traveling-wave tube is the means used to focus the electron beam from the electron gun through the helix. a distance of at least several inches. During early development. the focusing was accomplished with solenoids. and the resulting structure was heavy and cumbersome. Early laboratory solenoids for focusing traveling-wave tubes weighed in excess of 100 pounds and consumed up to 1 kilowatt of d-c power. In the middle 1950's. solenoid design was refined along with tube structure. and in 1956. the first commercial traveling-wave tube. the 6861. was offered for sale as a capsule device including tube and couplers. It could be focused in the commercial RCA solenoid. the MW4900. which weighed 40 pounds and consumed 150 watts of focusing power. During 1959. the traveling-wave tube package consisted of an electron tube, r-f circuits. and a separate solenoid. The resulting package. even though very modern when compared to tubes and solenoids of the 1950 vintage was still very heavy and bulky, and unsuitable for consideration in airborne systems.

Fig. 1—The author with typical traveling-wave tubes.

In 1956, Siekanowicz and Sterzer of RCA disclosed a new type of traveling-wave tube[1] which has had far-reaching influence on the traveling-wave-tube art. This tube used a periodic permanent-magnet focus structure based on classical theoretical and design principles described by K. K. N. Chang[2,3,4] and was the first integral-package traveling-wave tube—i.e.. a sealed capsule containing not only the electron tube and r-f couplers. but also the focusing structure. The tube provided 100 watts of r-f output at a gain of 20 db across the frequency band from 2000 to 4000 megacycles, required no focusing power, and weighed less than 15 pounds.[5]

By the end of 1958, RCA's traveling-wave-tube development activity had provided designers of electronic-countermeasures equipment with an extensive family of integral-package traveling-wave tubes using periodic permanent-magnet focusing.

Concurrent with its development of a family of periodic-permanent-magnet-focused tubes, RCA was developing other approaches to focus-structure modernization. Blattner and Vaccaro[6,7], following a pioneer tube development having electrostatic focusing (by Chang[8]), developed a traveling-wave tube using entirely electrostatic means of focusing enclosed within the electron-tube envelope. Cuccia and Wolkstein, recognizing the need for light-weight wide-band low-noise traveling-wave tubes, also produced a minaturized integral-package traveling-wave tube using a low-power solenoid included within the package. Traveling-wave-tube development for airborne systems in the RCA Microwave Operations is now concentrated on the development of new very-lightweight integral-package tubes using three different focus systems: periodic permanent magnet. periodic electrostatic. and miniaturized solenoid.

BASIC TUBE COMPONENTS

As the emphasis in traveling-wave-tube development was placed on light weight and integral packaging. certain electron-tube structures and r-f–coupling structures were found by tube fabrication and test to have the most merit.

Electron Guns

Two types of electron guns are used, the low-noise gun and the convergent-flow gun.

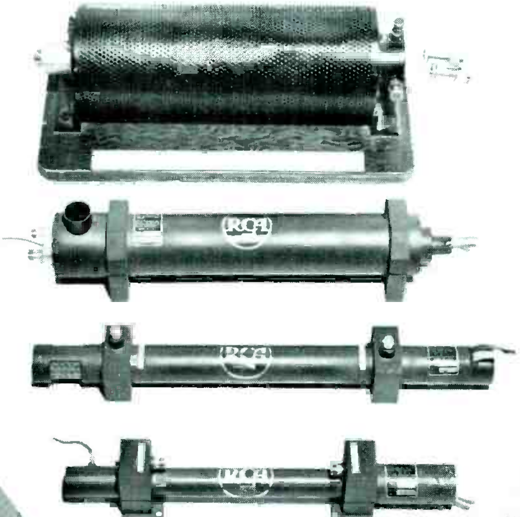
Fig. 3a shows the construction of a typical low-noise electron gun based on a design by Dr. R. Peter[9] of the RCA Laboratories. The gun uses a small, flat, space-charge-limited cathode immersed in an axial magnetic field to produce a parallel-flow electron beam. The beam passes through a series of apertures positioned and operated at potentials which produce a substantially exponential rise in voltage and minimize the shot-noise components in the electron beam at the entrance to the helix.

The convergent-flow gun, proposed originally by J. R. Pierce. is a means of obtaining a convergent flow of space-charge electrons without the use of a magnetic field. and is used in traveling-wave tubes when low-noise operation is not required. A typical modern convergent-flow gun is shown in Fig. 3(b). The electrons emitted by a large concave cathode are converged into a narrow beam before they enter the drift tube by electrodes of appropriate design.

Couplers

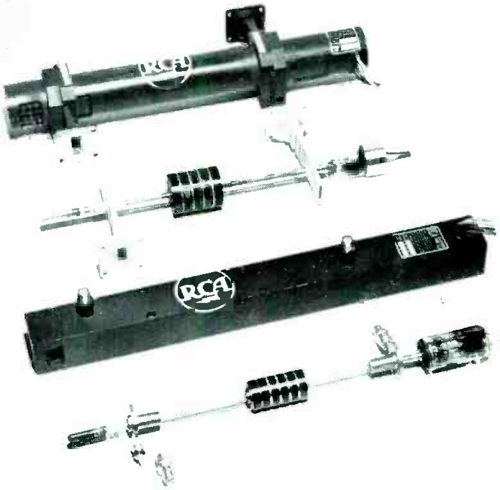
RCA's new integral-package tubes use helical couplers for frequencies up to 7500 megacycles and waveguide couplers for frequencies above 7500 megacycles. Both types of couplers can provide good impedance match to a helix structure over very-wide frequency ranges and have the advantage that they are external to and mechanically separate from the tube envelope. Their small

Top to bottom, the RCA-6861 low-noise traveling-wave tube installed in the older-style, heavy-weight MW4900 solenoid, and the three new types of S-band integral-package traveling-wave tubes: the solenoid-focused RCA Dev. No. A-1119, the RCA-4010 using periodic permanent-magnet focusing, and the electro-statically focused RCA Dev. No. A-1097.

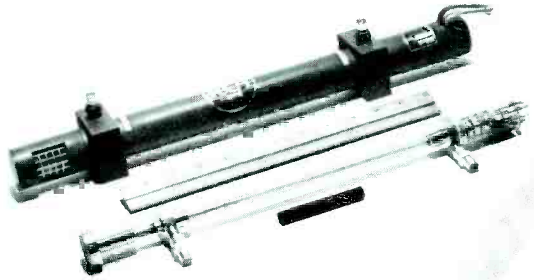


The solenoid-focused RCA Dev. No. A-1119 integral - package low-noise tube and its component parts.

The integral packages and the tube couplers and focusing components of the 1-watt X-band RCA Dev. No. A-1133 (bottom) and the 1-watt L-band RCA Dev. No. A-1124 (top).

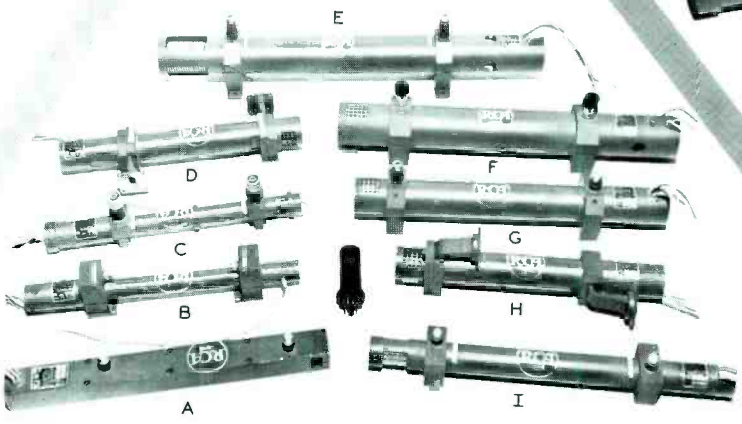


THE NEW LOOK IN TRAVELING-WAVE TUBES



The final package and component parts of the RCA Dev. No. A-1097 Estiatron. The electron tube and input and output couplers, shown separately, are all that are required for tube focus and r-f operation.

Three integral-package low-noise periodic permanent-magnet focused tubes, RCA Dev. Nos. A-1171, A-1173, and A-1174 (top to bottom), for providing amplification from L-band through C-band. A 6L6 receiving tube is shown for comparison.



A group of integral-package traveling-wove tubes using periodic-permanent-magnet focus structures: (A) 1-watt L-band A-1178; (B) 1-watt S-band 4010; (C) 1-watt C-band A-1129; (D) 1-watt X-band A-1133; (E) 1-kilowatt S-band A-1134; (F) 100-watt S-band A-1101; (G) 50-watt C-band A-1136; (H) 50-watt X-band A-1120; (I) 10-watt S-band A-1063. A 6L6 tube is shown for comparison.

size also makes them particularly suitable for use in integral-package tubes.

A typical external-helix coupler is shown in Fig. 4(a). The helix is wound in a threaded Teflon sleeve, and is connected by a short coaxial line to an external connector. The external helix is electromagnetically coupled to the internal helix through the tube envelope, and may be positioned for optimum coupling.

The waveguide coupling arrangement is shown in Fig. 4(b). The waveguide coupler couples through the tube envelope to an antenna at one end of the helix. This type of coupler is ideal for use in integral-package traveling-wave tubes operating at X-band and higher frequencies because of the small sizes and low losses of waveguides at these frequencies.

Helix Support Structures

One of the most important considerations in the design of a traveling-wave tube is the method used to support the slow-wave helix. Three methods of helix support used in RCA's integral-package tubes are shown in Fig. 5.

The fluted-glass envelope shown in Fig. 5(a) is an ideal helix-support structure because the point-type contacts between the flutes and the helix produce minimum dielectric loading and, therefore, cause very little loss of gain.

The "embedded-helix" structure shown in Fig. 5(b) is used in tubes specially designed to withstand vibration and shock. In this type of construction, the fluted-glass envelope containing the precision-wound helix is heated until the glass softens, and the glass flutes are then pressed into the helix.

The ceramic-rod supports shown in Fig. 5(c) are used with helixes which have an antenna at each end. This type of helix support is ideal for X-band tubes because it provides effective support of the small-diameter helixes characteristic of tubes designed for such high frequencies.

Attenuators

A traveling-wave tube used as an amplifier must be equipped with an attenuator which will provide r-f isolation between the input and output circuits of the tube and prevent reflected waves from producing oscillations.

All RCA integral-package traveling-wave tubes using fluted-glass envelopes for helix support use external helix-type attenuators which provide insertion loss by inductive coupling through the tube envelope to the slow-wave helix. These attenuators may be helixes of lossy wire supported by tape, or loss-less helixes wound in a lossy material such as Aquadag or carbonized ceramic.

Traveling-wave tubes using rod-supported helixes are provided with internal attenuators consisting of Aquadag or carbon coatings on portions of the support rods in contact with the helixes.

PERIODIC-PERMANENT-MAGNET FOCUSING

Fig. 6 shows a portion of a structure of ring magnets and steel shims designed to produce a periodic magnetic field. Each ring magnet is magnetized so that north and south poles are produced on its side faces. The ring magnets are then stacked between steel shims with their similarly polarized faces together. Thus, the facing south poles of adjacent ring magnets produce a south pole in the steel shim between them, and the facing north poles of adjacent ring magnets produce a north pole in their common steel shim. The strength of the magnetic field along the axis of the structure thus varies periodically, being zero in a plane through the center of each steel shim and maximum in a plane through the center of each ring magnet.

An electron beam passing along the beam axis and provided with sufficient accelerating voltage is constrained most in regions where the force exerted by the field is directed from the steel shim toward the central axis, and constrained least in regions where this force is directed from the central axis to the steel shim.

The convergent-flow electron gun shown in Fig. 3(b) is designed to operate in a field-free region, while the low-noise parallel-flow electron gun shown in Fig. 3(a) is designed to operate in a uniform magnetic field.

The field-free region for the convergent-flow gun is obtained by the use of a steel magnetic shield at one end of the permanent-magnet focus structure, as shown in Fig. 7(a). The resulting magnetic-field distribution along the axis of the tube is shown in Fig. 7(b).

The uniform-field region specified by Chang^4 for use with a low-noise gun is provided by a permanent magnet installed at the gun end of the periodic permanent-magnet structure, as shown in Fig. 8(a). A specially designed ring magnet and shim between the uniform-field magnet and periodic structure provide a transducer magnetic field which matches the gun field to the periodic field. The resulting field configurations are shown in Fig. 8(b).

ELECTROSTATIC FOCUSING

The heart of the electrostatically focused traveling-wave tube (or "Estia-

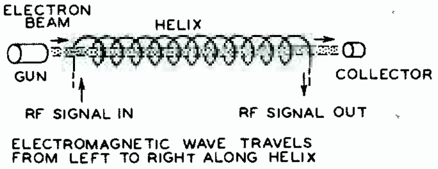


Fig. 2—Basic traveling-wave-tube structure.

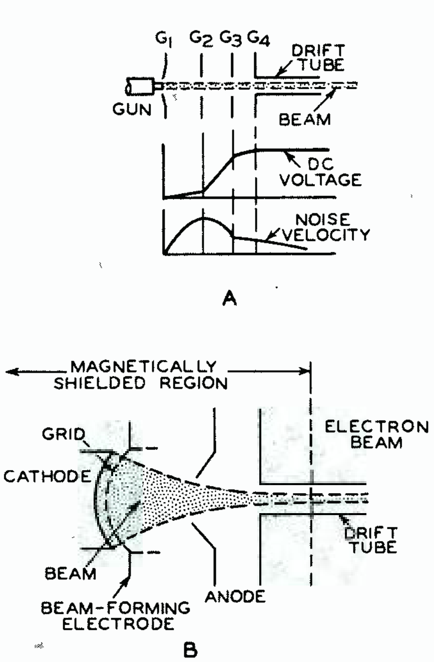


Fig. 3—(a) Low-noise gun and characteristic voltages and noise velocities; (b) grid-controlled convergent-flow gun.

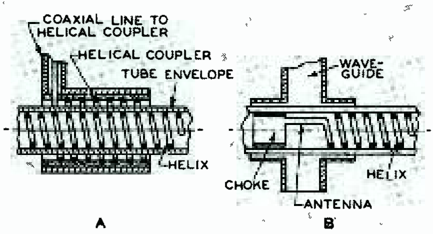


Fig. 4 (a) A helical coupler and main helix structure; (b) a waveguide coupler and helix structure.

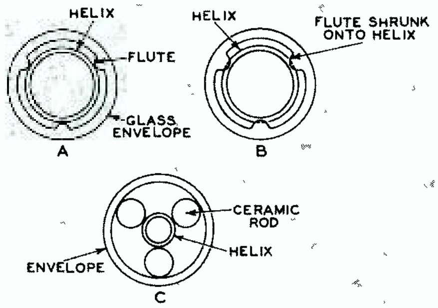


Fig. 5. (a) Helix supported by flutes on the inner surface of a glass envelope; (b) helix supported by fluted glass tubing with flutes embedded into the helix; (c) ceramic-rod-supported helix.

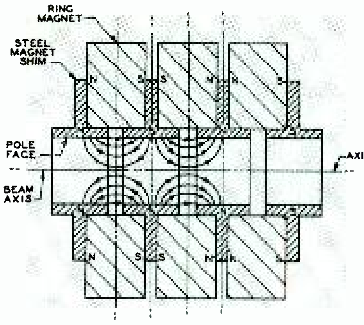


Fig. 6—Cross section of a periodic permanent-magnet focus structure.

tron") is the bifilar-helix structure[7] shown in Fig. 9(a). This structure consists of a pair of interleaved helixes having the same diameter and turns-per-inch ratio. When the two helixes are operated at different potentials, they produce the same effect as a series of iterated lenses spaced at very small intervals. The forces exerted on an electron and the resulting electron trajectory are shown in Fig. 9(b).

INTEGRAL-PACKAGE TUBES

Solenoid Focused

RCA has developed solenoid-focused low-noise tubes in an integral package, using a specially designed light-weight air-cooled solenoid weighing only six pounds, e.g., the RCA Dev. No. A-1119.

The solenoid portion of the A-1119 employs an air-cooled sectionalized winding of aluminum foil designed to operate at 90 volts and 2.3 amperes, and provides an axial magnetic field of approximately 450 gausses. This miniaturized electron tube uses helical couplers and operates at a synchronous helix voltage of 425 volts. The electron tube, helical couplers, and an external lossy-helix attenuator are protected by a brass-rod and fiber-plug cage; the assembly is potted in an aluminum cylinder only ¾ inch in diameter.

The A-1119 provides a power output up to 3 milliwatts with gains in excess of 20 db over the 2000-to-4000-megacycle frequency band, and has a noise figure in the range of 8.5 to 10.5 db.

An L-band tube, RCA Dev. No. A-1139, is designed to provide 25-db gain with noise figures of 9 to 11 db from 1000 to 2000 megacycles.

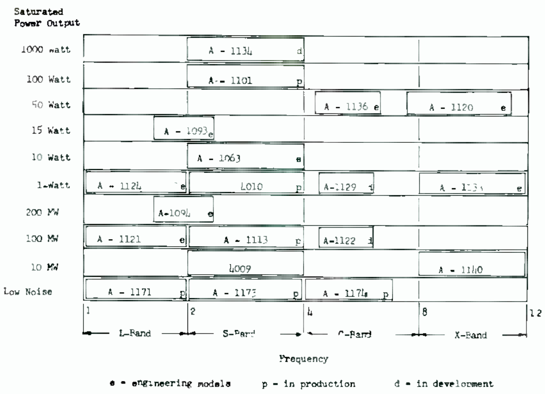
Electrostatically Focused

RCA has developed and made available to system designers a developmental 5-watt electrostatically-focused traveling-wave tube, RCA Dev. No. A-1097, which operates in the frequency band from 1800 to 3800 megacycles. This tube uses a convergent-flow gun which projects an electron beam down a self-focusing bifilar helix.

Successful fabrication of the A-1097 Estiatron required the development and refinement of a new technique — the technique of positioning and bonding the bifilar helix in the glass envelope so that the turns are held in precision alignment. In this technique, the component tungsten helixes are wound on a mandrel with separators between the adjacent turns of the two windings. A "glass-shrinking" process is then employed to bond the two helixes to flutes in the tube envelope. The separators are then removed, leaving the bifilar helixes firmly bonded to and supported by the flutes.

TABLE I

FREQUENCY AND POWER COVERAGE OF RCA TRAVELING-WAVE TUBES



Periodic-Permanent-Magnet-Focused

By 1957, G. Novak had successfully completed the development of a grid-controlled 100-watt S-band tube RCA Dev. No. A-1101 based on the earlier tube of Siekanowicz and Sterzer, E. Bliss had completed the development of a 10-watt S-band tube RCA Dev. No. A-1063[10], and H. Wolkstein had developed a miniaturized periodic-permanent-magnet-focused tube RCA Dev. No. A-1094 for microwave relay service. These three tubes were used as prototypes for new high-, medium-, and low-power tubes, and by the latter part of 1958 a new product line of RCA traveling-wave tubes had been established.

Table I shows the power levels and frequency ranges of the different tubes in this family of periodic-permanent-magnet-focused tubes. These tubes cover octave frequency ranges in all bands from L-band through X-band, and output-power levels from 10 milliwatts to 1 kilowatt.

The ring magnets, shims, couplers, and gun shield are assembled and installed as a unit in an aluminum capsule. The electron tube is inserted in this structure and moved about to obtain optimum focusing and electrical characteristics. It is then firmly bonded into the structure by means of new thermoplastic potting compounds, end disks are installed, and the capsule is painted and labeled. The resulting integral package is extremely rugged, laboratory adjusted for optimum operation, and cannot be disassembled or damaged by normal handling.

Table II gives the electrical and mechanical features of some S-band tubes using periodic permanent-magnet focus.

TUBE RUGGEDIZATION

Ruggedization of integral-package tubes using periodic permanent-magnet focusing is more than a problem in advanced mechanical design. It involves two major considerations: (1) ruggedized support of the helix in the envelope; and (2) maintenance of the peak value of

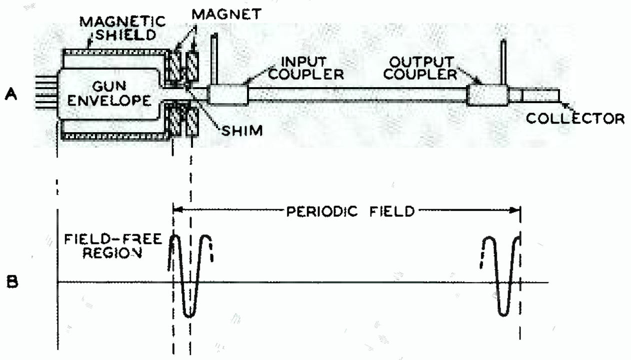


Fig. 7—(a) Periodic permanent-magnet focus structure including a steel magnetic shield at one end which magnetically shields a convergent-flow gun installed in the shield; (b) magnetic field configuration for structure shown in (a).

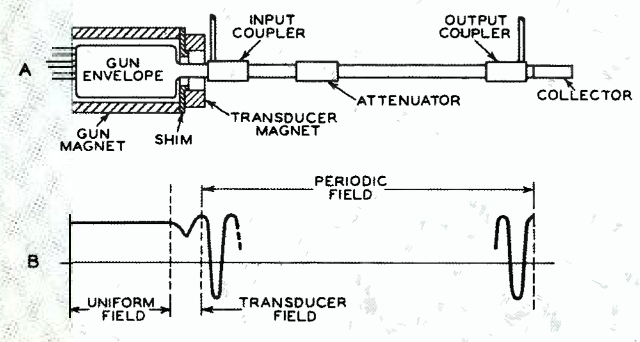


Fig. 8—(a) Periodic permanent-magnet focus structure using a permanent magnet at one end to provide a uniform field for the low-noise type of electron gun; (b) magnetic field configuration for structure of (a).

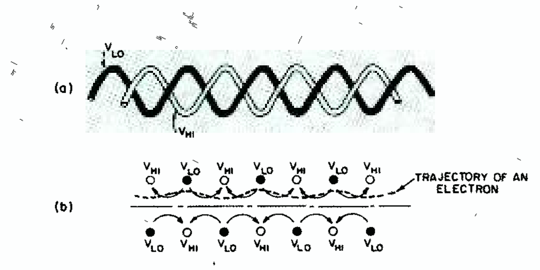


Fig. 9—(a) Cross-section of a bifilar-helix type of electrostatic focus structure; (b) forces exerted on an electron passing through an electrostatic focus structure, and the resulting electron trajectory.

the periodic magnetic field during wide excursions of ambient temperature and other environmental factors.

Ruggedized support for the slow-wave helix is achieved by shrinking the fluted-glass envelope onto the helix. The effectiveness of these techniques is shown by the fact that a tube not having an embedded helix showed amplitude modulation of 2 db during axial vibration at approximately 2 g, whereas a similar tube having an embedded helix showed amplitude modulation of only 0.25 db under the same conditions. The addition of intermediate support for the helix envelope reduced this amplitude modulation to 0.1 db.

The RCA 10-milliwatt, S-band 4009 and 1-watt, S-band 4010, using the above imbedded-helix technique, now withstand vibrations of 50 to 500 cps up to 5g with less than 1 db change in output power.

A novel approach to the temperature compensation of periodic permanent-magnet structures was used by E. Bliss[11] in his development of a ruggedized version of the 10-watt S-band tube, RCA Dev. No. A-1063. The magnetic properties of the ferrite ring magnets used in the periodic focusing structure change by as much as 0.2 percent per degree centigrade. At this rate of change, the peak strength of the magnetic field of an uncompensated magnet structure will experience as much as 50-percent change over the temperature ranges required by military equipment.

Bliss's approach was to wrap the magnet stack with a special-alloy steel having a permeability which increases with decreasing temperature (see Fig. 10). Because the remanence of the ferrite ring magnets increased with decreasing temperature, the magnetic shunt provided by the alloy-steel wrapping maintained the peak magnetic-field strength of the structure substantially constant over a wide temperature range.

A double-shunt system in which one shunt compensated for temperature variations at low intermediate temperatures, and the other for variations at very-high temperatures was used in a ruggedized version of the A-1063. With the double-shunt system, the peak magnetic-field strength of the focus structure varied only 26 gausses in 480 gausses between the temperatures of −65° and +135° centigrade, whereas that of the uncompensated structure changed 160 gausses over the same temperature range. This ruggedized tube is now the A-1166.

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TABLE II—ELECTRICAL AND MECHANICAL FEATURES OF SOME S-BAND TRAVELING-WAVE TUBES USING PERIODIC PERMANENT-MAGNET FOCUS

RCA Tube Type	Saturated Power Output watts	Gain db	Beam Current ma	Helix Volts	Length inches	Diameter inches	Weight lbs
4009	0.01	35	3	600	15-3/16	1-1/16	2-3/4
A1113	0.1	35	4	600	14-3/16	1-1/16	2-1/4
4010	1	33	19	1100	15-3/16	1-1/16	2-3/4
A1166	10	25	60	2100	18-1/2	1-1/2	4
A1101	100	30	250	3700	19-5/8	2-1/2	12-1/2
A1134	1000	30	1500	7800	21	2-1/2	15

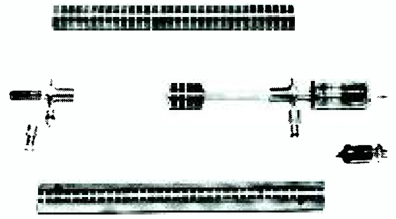

Fig. 10. A periodic permanent-magnet focus structure and tube, and the temperature-compensated version of the focus structure using a sheath of alloy steel having a permeability which varies with temperature as a magnetic shunt.

C. LOUIS CUCCIA (see Fig. 1) received the B.S. degree in E.E. in 1941 and the M.S. degree in 1942, both from the University of Michigan. From 1941 to 1942 he was also employed as a Research Engineer for the Fisher Body Division of General Motors to investigate the high-frequency welding of aluminum. He joined the technical staff of the RCA Laboratories in 1942 and worked on microwave-tube research and development until 1954. His work included the first 2J41 magnetron, new frequency-modulated magnetrons, injection-locked grid-controlled magnetrons, and the development of high-power transverse-field traveling-wave tubes known as "electron couplers." From 1954 to 1957, he was assigned to the color-television activity of the Laboratories, specializing in evaluation of new ideas, patenting of new developments, and liaison between the various activities involved in the color-television-receiver production. Early in 1957, he joined the Microwave Design activity of the Electron Tube Division as Engineering Leader in charge of traveling-wave-tube and backward-wave-oscillator design and development. Since January 1959, he has been engaged in planning and analyzing advanced systems utilizing microwave products.

A PICTURE IN SECONDS

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STIMULATED BY THE widespread impact of television broadcasting, a whole new era of electronic communication has been evolving during the past decade. It is communicating by *electronic pictorial* means information that in the past was sent verbally or pictorially by *electromechanical* means.

The development of techniques necessary to implement such a system has been progressing in industry for a number of years. In RCA, the work has variously been called *Slow-Speed* or *Narrow-Band Television, Study of Army Television Problems,* or more recently, *Telesimile* and *Telebriefing.* At the present time a rather sophisticated system is under construction capable of providing *a picture in seconds* many miles from point of origin over relatively common transmission facilities such as telephone lines.

SYSTEMS CONSIDERATIONS

Commercial television is well suited for its primary role of providing entertainment. However, its efficiency is low when one considers the tremendous amount of information that must be provided to produce a continuous motion background. Large quantities of data per unit of time, however redundant, require large bandwidths and expensive transmission facilities.

Economic

In commercial television, large investment in plant and spectrum is offset by millions of inexpensive viewers. The system is economically balanced, but where the exchange of graphic data involves only a relatively few viewers, as in business or military applications, the fiscal situation can be quite different. Such users generally cannot afford the cost of a wideband circuit nor do they need the instantaneous changes that such a link can provide. To satisfy the quest for a quality picture without a high repetition rate, *slow-speed television* has been developed.

In the development of any television system employing a *uniform* raster scan, the fundamental information-theory relationship between time, bandwidth, and resolution must hold. Since the economies of the situation have set limits on bandwidths, the remaining variables are time and resolution. But, since the user will usually set requirements on resolution, the other variable, time, appears to be established by the first two.

In practice, there is often a range of transmission facility costs from which the user can select and still have an economical system. Included in these facilities are the new data terminal equipments available on lease from the telephone company, which can be used over common talk circuits or on special leased lines. The data rate, of course, varies with the quality (and cost) of the circuit actually chosen. More often, the circuit selection will be influenced by *availability* of wire in the areas to be connected, rather than by the highest-quality, lowest-cost line. Within an acceptable dollar range, there are data circuits capable of 1600 bits per second or program circuits of up to 15 kilocycles.

Technical

To illustrate what can be expected of a slow-scan television system employing uniform raster scan, Table I shows the relationship between the time of one frame (T_v), the bandwidth required (BW), and the resolution possible (N_L). These numbers are approximate and assume a square raster with equal horizontal and vertical resolution.

Table I reveals a hard fact about slow-speed television: the uniform-raster method of conveying picture information is not very efficient. If resolution is desired, the price of time must be paid if the cost per hour per loop mile of the circuit is important, and it usually is in most practical installations. On the other hand, sophisticated systems employing variable scanning speed and digital encoding offer an improvement in the time-bandwidth-resolution relationship up to a factor of three or four, depending on the type of pictorial material scanned. Such systems are currently under development in DEP.

SYSTEM IMPLEMENTATION

The attractiveness of the electronic method in providing a *picture in seconds* lies in its ability to produce the high-speed variations in scanning velocity necessary to practical bandwidth-conservation schemes. From an equipment point of view, a slow-speed graphic communicator resembles a conventional television system, but with a different set of performance-limiting factors.

Transducers

Transducers, i.e., the pick-up and display devices, present special problems in a slow-scan television system. Usually, this is the point in the system where resolution is limited. But, because of the length of time required for the slow transmission of the pictorial material, the storage period of the transducer becomes limiting long before the loss of resolution due to aperture effects is noticable. Table II summarizes the devices that have been found useful as transducers in slow-scan television systems. The specific system application will dictate which of the several devices will best serve the purpose intended. Quite a range of transmission times have been encountered in different system implementations that have often limited the transducer choice to one or two of those listed. Most of the methods shown are purely electronic in nature; a few are electromechanical.

A salient advantage that slow-speed television possesses over the conventional method of wire picture transmission is the applicability of television-like pickup and display transducers. Usual camera techniques can be employed with the attendant flexibility in copy size permitted by choice of lens. Practically any size copy can be accommodated ranging from an ID card to a full-sized wall chart.

Scan Converters

Table II suggests that for a given application, where storage time is fixed by resolution and bandwidth considera-

TABLE I — BANDWIDTH RELATIONS

For Constant Resolution: 500 Lines, 500 Elements a line	T_v, sec.	1	25	62.5	125
	BW, kc	125	5	2	1
For Constant Bandwidth: 5 kc	T_v, sec.	25	10	1	—
	N_L, TV lines	500	317	100	—
For Constant Bandwidth: 1 kc	T_v, sec.	125	60	30	10
	N_L, TV lines	500	347	245	141

L. M. SEEBERGER received his BS in EE in 1943 from the University of California, Berkeley. He served with the Signal Corps during World War II as a radar officer and, in 1946, joined the Engineering Products Division of RCA, where he contributed to the development of the Teleran System of air navigation. In EPD Advanced Development, he was engaged for the next several years in the application of storage devices to radar and television problems with emphasis on the bright display of radar data. Equipment was produced to adapt video storage principles to GGA, VG, VK, and a developmental high-resolution-television plotter for Navy shipboard use. Since 1951, Mr. Seeberger has directed a group of development engineers active in the area of electro-visual data handling. In 1952 he was an industry member on the TEOTA panel ("The Eyes of the Army"). He had project responsibility for "A Study of Army Television Problems," a comprehensive military television program for the Signal Corps which began in 1953. He is presently Manager of Visual Data Handling, West Coast Missile and Surface Radar Division, and is engaged in the development and design of information display for combat operations centers, applications of electroluminescent materials to display problems, and digitalized television for graphic communications. He is a Senior Member of the IRE.

TABLE II — TRANSDUCER CAPABILITY

Pickup		*Display*	
Type	*Max. Usable T_v*	*Type*	*Max. Usable T_v*
Flying Spot Scanner	Hours	Long Persistance Kinescope	Up to 20 sec.
Image Orthicon	0.1 Seconds	Storage Kinescope	Up to 5 Min.
Standard Vidicon	5.0 Seconds	Intermediate Film	Hours
Slow Scan Vidicon	180 Seconds	Electrofax	Hours
Dissector	Hours	Magnetic tape or drum	Hours

tions, the choice of transducer is very often limited. To alleviate this problem and to make possible the application of standard commercial cameras and monitors, the *scan converter* has been developed. With scan conversion, the storage required in a slow-scan system is provided in a separate device such as an electrostatic storage tube or a magnetic-tape loop. If standard-rate pick-up and display equipment is to be used, two converters must be employed.

The first takes a single frame from the 30 frames per second produced by the camera, stores it, and delivers it to the transmission line at the rate the bandwidth will permit. The other converter accepts the transmission rate, stores the video, and reads it out at a 30-frame-per-second rate for display on regular television monitors. Of course, the displayed picture will contain no motion; it will appear as a series of still pictures being changed at a rate determined by the transmission time. Equipment is currently available capable of conversion ratios up to 2000 to 1 with no appreciable loss in resolution. A summary of currently available scan-conversion means is shown in Table III.

Recent developments in magnetic recording heads have made the tape-loop converter practical. Present machines use head-to-tape contact, and the storage time of 8 to 10 hours is set by tape wear. The magnetic-drum scan converter uses a multi-head assembly and computer logic to essentially load the drum tracks in *parallel* at a high rate and unload the tracks into the transmission medium in *series* at a low rate.

Transmission Equipment

It is well known by communications engineers that the transmission of pictorial data requires a much tighter tolerance on amplitude and phase response than that required for voice. Since most slow-speed television channels make use of voice circuits, the usable channel bandwidth is generally somewhat less than that available for voice. Often as little as 50 percent of the bandwidth can be used for picture transmission.

The advent of data-transmission facilities developed by the Bell System has defined the data rate acceptable by the connecting medium. It remains then to adapt the slow-speed television output to the data system, in order to make maximum use of what is certain to become a standard transmission media.

Digital Television

Such an adaptation is currently under development in DEP for Graphic Communication. Visual data coding is employed wherein the distance between picture transitions is encoded, rather than the absolute position of the picture elements. For low-duty-cycle pictorial material, such as briefing charts and some maps, the resulting bit rate is lower than would be obtained if no coding were employed at all. Complete freedom from transmission vagaries is possible with a signal compatible with the standards for data transmission.

LOOKING AHEAD

The implementation of slow-speed television systems can involve a wide variety of components, each with performance limitations as discussed above. To cite specific performance figures, therefore, would be somewhat misleading, since individual system requirements can cover such a great range. Continued refinement of transducer and rate-conversion devices, however, will increase the number of applications where resolution performance is the controlling factor.

The desire for *a picture in seconds* has created steadily increasing interest among those who need pictorial means of communicating to get the job done most effectively. Means for producing equipment to provide such facilities have been successfully developed and promise to open new partnerships in the man-machine relationship. It will not be too many years before written instructions can be directly inserted into data-processing systems. The elements of such capability are present in the digital, or encoded, form of slow-speed television technology.

TABLE III — SCAN CONVERSION SUMMARY

Type	*Storage Time*	*Maximum Conversion Ratio*
Kinescope/Pick-up Tube	1-2 seconds	30:1
Storage Tubes	10 minutes	2000:1
Tape Loop	8-10 hours	30:1
Magnetic Drum	Indefinite	300:1

SLOW-SCAN TV: MILITARY APPLICATIONS AND COMMERCIAL POTENTIAL

By **R. A. DAVIDSON**

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IN 1953, RCA was awarded an extensive Signal Corps research and development contract to perform *A Study of Army Television Problems.* The Army was aware of the potential utility of television to battlefield surveillance, communications, data processing, and other modern military problems, but that television equipment developed solely for the industrial and entertainment market was not necessarily suitable.

The work encompassed analytic studies of aperture theory and high image definition techniques, evaluation of opto-electric transducers (camera and display devices such as the vidicon, image orthicon, kinescopes, and storage tubes), investigation of unusual scanning rates and geometrys, and circuit techniques. A few of the concepts resulting are *Air "Drone" TV Surveillance System*, *Missile TV Terminal guidance*, and *Narrow Band Graphic Communications*. In addition, several equipments were developed, such as the *TV Observation Post (TVOP)*, *Color TV Camouflage Detection*, and *TV Camera Stabilizer.*

The most potentially useful of all these, in terms of military (and commercial) utility, appear to be those systems which embody slow-scan, narrow-band operating principles.

Slow-scan television has already found initially unforeseen uses in surveillance satellites, high-altitude solar telescopes, lunar and planetary probes, and several proposed graphic communications systems. In fact, slow-scan television shows promise of opening a large new field of business in military and commercial visual communications.

Costs of wide-band television transmission facilities need not and, in many cases, cannot be borne in military applications. (See Seeburger, *A Picture in Seconds*, this issue.)

Equipment simplicity can be achieved through miniaturization, new devices, and careful design oriented to the specific use. Major savings can be made in transmission facilities by reducing the frame rate, while maintaining high resolution.

Pictures appearing at rates much lower than 30 frames per second can provide considerable information, even though the illusion of motion is lost.

SLOW-SCAN RESPONSE OF PICK-UP TUBES

Preliminary to the development of equipment, or even the conception of a system utilizing slow-scan principles, it is necessary to investigate the feasibility of operating pick-up tubes with long scanning periods. An evaluation program was conducted on the image-orthicon and vidicon camera tubes which revealed that under certain operating conditions, these devices would provide not only storage but also increased sensitivity and resolution. In the case of the vidicon, the primary source of electrical noise is contributed by the first amplifier stage. A reduction in scan rate, with its attendant bandwidth reduction, allows operation of the vidicon at lower light levels for a given signal-to-noise ratio, since the noise of the amplifier is reduced by the square root of the bandwidth reduction. The increased resolution is essentially due to the smaller aperture or scanning-beam cross-section resulting from the lower beam current needed at slow scanning rates. The results for the image orthicon, taking into account the differences in tube operating principles, were similar. (Detailed analysis is presented by Shelton and Stewart in *Television Pickup Tube Performance With Slow Scanning Rates*, SMPTE Journal, V. 67, pp 441-451, July 1958.)

Fig. 1—TVOP camera, monitor, auxiliary lens and automatic exposure controls, and a line repeater.

TVOP

One outgrowth of the aforementioned studies was the conception of a System which could, by virtue of slow-scan operation, transmit pictures from a camera to a monitor over two miles of ordinary field telephone wire. The purpose was to provide a forward observer of battlefield areas or situations. The Television Observation Post (TVOP), which resulted, is shown in Figs. 1, 2, and 3.

Slow-scan is acceptable for a diversity of relatively static tactical situations. WD-1/TT Army telephone wire provided an existing, inexpensive medium which would support the transmission of a video signal at one frame per second with a resolution three times that of the average home TV set. However, some activity does occur in battle areas which should not be lost completely. At one frame per second, image smear due to object motion is great enough so that all but the slowest-moving objects (less than 2 mph in the field of view) are undetectable. Additionally, eye fatigue is considerably higher when viewing the strobe line of a one-frame-per-second television raster presented on a long-persistence kinescope. For these reasons, a higher frame rate, four per second, was finally chosen. Thus some resolution was sacrificed to obtain a better balance between image smear (dynamic resolution), strobing, and static resolution.

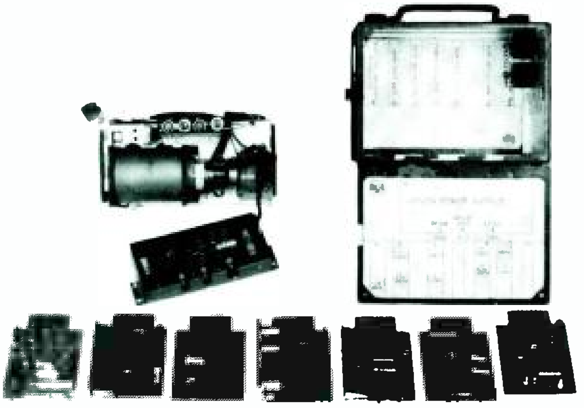

Fig. 2—Disassembled TVOP camera, showing vidicon mount and printed-circuits boards.

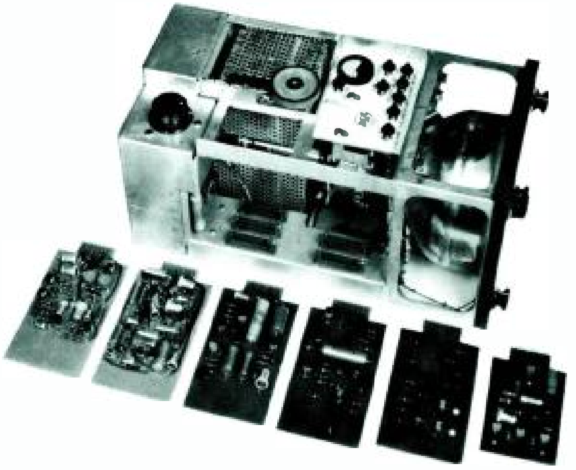

Fig. 3—Disassembled TVOP monitor, showing kinescope, high-voltage supply, and printed-circuits.

The one-inch vidicon was selected as the pick-up device, primarily because its small size and simplicity of operation would permit a relatively small camera.

Since the camera might be located in areas inaccessible to personnel after its initial placement, camera power is supplied from the monitor over the same pair of wires used for video signal return. Transistor-regulating and signal-isolating circuits separate the direct-current power from video. Power dissipation in the field wire was held to a minimum by "swapping" voltage for current. This was effected, for example, by supplying the vidicon filament in series with the camera regulator. The camera was designed to accommodate a tube such as the new RCA7263 vidicon which has a filament rating of 180 milliamperes.

Although the equipment was developmental and a full production design was not imposed, circuits were designed for long-term stability so that controls could be preset before camera installation without requiring further adjustment.

To operate at minimum light levels, it is necessary to set the camera lens at maximum iris opening, but at high light levels the iris must be closed to obtain best resolution from the vidicon as well as to obviate the necessity for adjusting the scanning-beam current. The light-sensitive target of the vidicon is a photoconductor, each elemental area of which can be considered as a small capacitor and resistor in parallel. The resistance varies inversely proportional to the light intensity, discharging the capacitor; the scanning electron beam recharges the capacitor. The higher the light intensity, the more the capacitor is discharged and so the more the beam current necessary for recharging.

An automatic exposure control was designed which allows fully automatic operation of the camera. Lens interchange in the field must of necessity be simple so each of three lenses (10°, 30°, and 60° field of view) is equipped with identical automatic exposure controls and packaged as a unit for plug-in optical indexing and power connection. Power cosumption of this unit is negligibly small, especially since the exposure control is not continuous.

Except for a subminiature video preamplifier tube, all of the camera circuits utilize transistors as the active elements. Circuits include: video amplifier and clamps, horizontal and vertical scan generators and deflection dirvers, vidicon high-voltage converter, blanking, power regulator, etc. They are mounted on eight plug-in printed wiring boards.

The entire camera consumes 9 watts of power and is approximately 5 inches wide, 6 inches high and 11 inches long with the lens-exposure unit attached.

The commercial television camera and its associated equipment may occupy an entire studio or motor van, while the monitor is relatively small, e.g., the home television receiver. While small (somewhat the size of a portable home TV receiver), the TVOP monitor is approximately four times the size of its counterpart "studio"—the camera. The emphasis here is to make the "studio" small, inexpensive, perhaps expendable, while the monitor may take on added complexity.

The TVOP monitor was designed around a 7-inch kinescope with a long-decay phosphor. At 4 frames per second, a P12 phosphor has sufficiently long persistence to store for the entire frame time. Overhang (storage of a previous image into the next frame presentation) is at a low enough level so that negligible smear of moving images is encountered from this source. The line on the kinescope faceplate which is being scanned is much brighter than the rest of the picture, producing an effect much like a window shade being pulled down. This might be somewhat distracting for entertainment purposes, but, as in the case of the bright sweep trace of radar indicators, trained observers soon grow accustomed to the display, hardly noticing the strobe line.

The monitor houses a primary power converter which draws power from the standard generator-battery system found on military vehicles (nominally 24 volts) or from any of the newer class of more compact wet cells if portable shorter term operation is desired. This affords considerable powering flexibility. A variable voltage is applied to the line for the camera.

The monitor also utilizes transistor circuitry (mounted on plug-in printed wiring boards) for low power drain in its video amplifiers, horizontal and vertical oscillators, deflection stages, high-voltage and power converter, etc.

In operation, the camera and monitor controls are preset before the camera is carried into the field. Field wire is laid out from the observer location to the camera site. The two field wires are connected to the camera and personnel may then leave the area.

The operator at the monitor site turns the primary power on, thereby turning on the monitor. Observing a line-current meter, line voltage is increased until camera operating current is reached. As soon as the camera pick-up tube filament has reached temperature, video is transmitted and a display of the scene is obtained on the monitor. The monitor consumes about 60 watts of power and is approximately 8 inches wide. 8 inches high and 19 inches long overall. The field wire is balanced to ground for cancellation of induced noise by external sources. When operated with two miles of field wire, 25 watts of power are dissipated in the wire and system power consumption is then approximately 100 watts.

NARROW-BAND GRAPHIC COMMUNICATIONS

The rapid pace of modern warfare requires ever more rapid and accurate information handling. Briefing sessions held by telephone or in meetings of the participants involves possible misinterpretation of data and time-consuming travel. Often, a military commander must be briefed from several widely scattered points at once. Wideband television can provide high-speed data rates but is extremely expensive of transmission. Slow-scan, narrow-band television is the means by which remote briefing, or *telebriefing*, can be accomplished rapidly and inexpensively with all of the sensory perceptions necessary for evaluation.

The type of material to be visually communicated (usually charts, map overlays, etc.) is static and lends itself well to slow-scan television pick-up and narrow-band transmission. Generally. the bandwidths are those of common leased telephone line for which picture scan periods on the order of a minute or so are required. In many instances, the data terminals already have commercial camera and monitoring equipment which can be used to pick up and display the graphic material. The high-rate video can be *written* into a storage device and subsequently *read out* more slowly for transmission over the narrow-band link.

The Universal Scan-Rate Converter was developed for a broad range of applications. Utilizing an electrostatic, non-viewing, storage cathode-ray tube, it will accept video at a broad range of rates up to the 30 frames per second of standard television. It can store one frame or picture and subsequently scan the latent charge image on its dielectric storage mesh at any selected rate from one frame per second to one frame in several minutes. The resultant slow video signal may then be processed and transmitted over the telephone line. It is also designed to convert information from one scan mode to another; for example, radial-time-base radar video may be stored and read out in TV fashion at slow rates, if desired.

After a slow video signal has been transmitted, it may be desirable to step up its rate again for bright, flicker-free viewing. The converter is designed to operate as either a step-down or step-up device. The equipment includes wide- and narrow-band video amplifiers, deflection amplifiers capable of generating a wide range of sweep rates, and a small transistorized "computer" which controls the sequence and timing of the signal processing.

One graphic communications system currently under consideration utilizes a small transistorized slow-scan camera similar to TVOP and an electrostatic storage tube scan converter like the converter for further step-down of video data rate to narrow-band transmission. At the receiving end, to minimize the degradation of resolution attendant with cascading scanning aperture processes, the picture is recorded at the slow line rate directly onto a rapid dry film-processing machine and then projected. In this system, slow-scan television is used in the camera to obtain high resolution and at the input of the scan converter to narrow-band the signal.

An experimental magnetic-drum scan converter has also been built to accept a frame of slow-scan television (at two frames per second) and convert this to telephone line rates. The magnetic drum's advantage lies in the fact that no equivalent optical aperture as such is involved; hence, there is no inherent limit on the number of bits of information which the device can store and read-out assuming, of course, that the size and form factor of magnetic drums are not fixed. The drum rotates on bearings of compressed air, giving long and silent operation. The video information from the slow-scan camera is quantized and multiplexed onto the 84 drum tracks by transistor computer circuits. Similar circuitry unloads the information at 1,256 bits per second for transmission over digital telephone facilities.

Many configurations of equipment and techniques may be applied to graphic communications. With the development of new camera pick-up and display tubes which store the picture for long periods. intermediate scan conversion may not be necessary in some applications. Where commercial terminal equipment is used for local distribution and viewing of pictures. high-resolution scan conversion is necessary to narrow-band transmission for remote briefing.

R. A. DAVIDSON received the degree of BEE from New York University in 1949 and the MSEE from Syracuse University in 1954. From 1949 to mid 1950 he was employed by Amperex Electronics Corporation, Brooklyn, N. Y. working on high-power, high frequency oscillators, special testing of transmitter and industrial type tubes, and quality control; from 1950 to 1951, as an electronics engineer at the Columbia University, Nevis Cyclotron Laboratories, Irving-on-Hudson, N. Y., he worked on instrumentation for experiments in nuclear physics; and from 1951 to 1954, as a Research Associate at the Syracuse University Research Institute he investigated radar PPI magnetic deflection performance and worked on novel radar indicator circuitry. Since joining RCA, Mr. Davidson has been engaged in the study and development of military television systems and semiconductor circuits. He has been Project Engineer in charge of the development of a transistorized, high resolution, slow scan television system for the Signal Corps; a transistor airborne television camera; experimental study of the effects of nuclear radiation on the vidicon camera tube and development of Scan Converter equipments. Mr. Davidson is presently an Engineering Leader in the Visual Data Handling activity of the Missile and Surface Radar Division. He is a member of the Eta Kappa Nu Association, Tau Beta Pi and the Society of Sigma Xi.

The philosophy and many of the actual circuits of TVOP are being used in the design of television systems which will radio back close-up pictures of the moon from lunar probes. These are also being adapted for *Stratoscope*, a slow-scan television-telescope-equipped balloon which will transmit pictures of the sun from fifteen miles above the earth.

Industrial and commercial use for graphic communications is obvious when one considers the low cost. Transmission of a picture of, perhaps, a bank check. an inventory list, an airline's reservation chart, weather fronts, etc., may ultimately cost no more than ordinary long-distance telephone calls.

ACKNOWLEDGEMENTS

While the author has been an active participant on most of the projects described, the initial and most comprehensive efforts in Slow-Scan Television at RCA must be credited to L. M. Seeberger. C. T. Shelton. E. A. Boyd, and the many other engineers of DEP Advanced Development Engineering.

ELECTROFORMING BATHS—CONTROL VIA AUTOMATIC ADDITIONS

By
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THE RECORDING OF an artist's performance and its subsequent reproduction in quantity as phonograph records is a process requiring extreme care and tolerances. Most obvious, perhaps, are the critical accoustic and electronic techniques involved in the initial step of performance-to-master transcription. Less known, but equally critical, are the various techniques involved in reproducing that transcription. To mold records in quantity, a metal negative of the master transcription (the lacquer disk) is required. The only process at present suitable is electroforming, since tolerances of *less than a millionth of an inch* are essential.

To achieve such tolerances, extreme control must be exercised over the chemical nature of the plating baths used in the electroforming process. Even minute variations in these baths can adversely affect the necessary microinch tolerances, and it is here that automatic techniques in their chemical preparation and control — *automatic additions* — play a vital role in ensuring that the artist's work is faithfully reproduced.

ELECTROFORMING IN RECORD MANUFACTURE

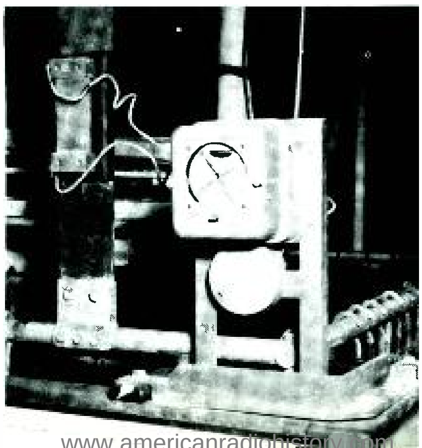
The method generally used for phonograph-record manufacture involves four steps, once the artist's work has been transcribed on the lacquer disk. The first step is to produce a master, or negative, copy of the lacquer disk. A silver film is precipitated on the surface by a modification of the process used to silver mirrors, giving an electrically conductive surface from 3 to 5 microinches in thickness. This is the starting point for the electroforming process. It is then built up in thickness by plating with nickel and then copper, thus forming a laminated metallic master which, after separation from the lacquer disk can be used for further duplication.

The nickel plate is approximately 0.8 to 1.0 mils thick. This is electroformed over the silver deposit, which is the base metal. Very-close control of the nickel bath must be maintained at this point because the silver is loosely held onto the lacquer surface. The current density is maintained at 20 amperes for 45 minutes. An acid dip and water rinse are used just before placing this part into a high-speed acid copper tank. Electroforming takes place at approximately 250 amperes per square foot. The desired thickness is 25 mils.

This electroformed laminated plate is now separated from the lacquer disk. This laminated plate is now called a *master* and could be placed in a hydraulic press and used to mold a phonograph record. However, because of the large quantity of records required, many presses must be in operation simultaneously. In order to do this, metal positives sometimes called *mothers* (or molds) are made from the negative masters by electroforming. The second step in the process is, therefore, the production of these *mothers* and essentially is the same as the process for producing the negative masters. It consists of treating the surface of the master in order to control adhesion and then nickel plating and copper plating. The *mothers* can be played and tested for audio defects because they are similar in profile to the original lacquer disk.

In Europe, the term *father* and *mother* are used frequently to denote the master and mold, respectively. The term *mother* is used because the part can be duplicated again and again for electroforming the next generation, called stampers. Stampers, then, are the third step in the process. The final and fourth step is using these stampers as master dies for molding the final product—the phonograph record.

Fig. 1—Ampere-hour meter controlling additions to a 2000-gallon nickel tank.



ELECTROFORMING PROBLEMS

In duplicating these negatives and positives by electroforming, little or no adhesion must be maintained. If adhesion is too great, the parts cannot be separated and are scrapped; if adhesion is insufficient, the internal stresses of the deposit will cause the parts to separate prematurely. Because there is little or no adhesion, a variation in the internal stresses of the deposit will cause parts to be defective.

The Watts nickel-plating bath is ordinarily considered a stable solution; however, when this is reviewed from the standpoint of record electroforming, it can be quite temperamental. When a nickel plate is deposited to 10 mils or thicker over a flat area of 200 square inches having practically no adhesion to the starting surface, problems unknown in the decorative-plating field develop. The newly formed plate must not be too adherent to the part being duplicated because it must be separated and the original put through the duplicating process several times without deterioration of the surface.

Small quantities of impurities in the bath can cause changes in the internal stress of the electroformed plate. With an increase in stress, the electroformed deposit pulls away from the part being duplicated, resulting in deformation of the surface. (Stress limits are shown in Table I.) Some of these deformations are described as *slipped nickel, blisters, double nickel* and a few other terms peculiar to the record industry. Some impurities tend to lower the stress, causing a peculiar deformation called *crows feet* or *spider web*. Actually, these defects are localized buckling. Therefore, it is extremely important to keep impurities in the solution at a constant minimum level.

Continuous electrolytic purification of the nickel baths has long been used to maintain the metallic impurities at a low level. Commercial nickel plating salts are relatively impure. Quite often, the manual addition of these impure nickel salts raised the level of the total impurities to such an extent that the electrolytic removal rate was exceeded. As a result,

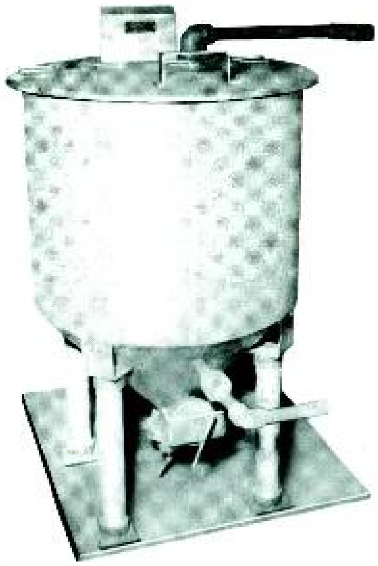


Fig. 2—Chemical salts tank containing nickel sulphate, nickel chloride and sulphuric acid. The pump is below and behind the tank.

TABLE I—ALLOWABLE STRESS LIMITS IN ELECTROFORMED DEPOSITS

Plating Step	*Type of Plating Bath*	*Current Density*	*Stress Limits, psi*
Master	Nickel, Copper	20 asf 110 asf	4000– 8000
Mother	Nickel, Copper	20 asf 110 asf	1000– 4000
Stamper	Nickel	75	12000–15000

All internal stress measurements are positive (tensile) measurements. Occasionally negative (compressive) stresses occur.

Residual Stress in deposits measured by Brenner Senderoff Contractometer.

The surface tension is maintained at 37 dynes/centimeter. The limits are ±2 dynes/centimeter measured on a Cenco-du Nouy Tensiometer. The automatic equipment will maintain the surface tension at ±1 dyne/centimeter.

TABLE II—TYPICAL REPLENISHMENT REQUIREMENTS

Chemical	*Normal Concentration*	*Addition/amp.-hr.*
Nickel Sulfate	40 oz/gal	0.0042 oz
Nickel Chloride	3.80	0.0004 oz
Boric Acid	5.25	0.0006 oz
Sulfuric Acid	pH 4.0	0.0220 ml
Wetting Agent	Duponol	0.0020 ml
Stress Reliever	Saccharin	0.0010 grams

Tank Volume, 1430 gallons.

Small amounts of chemical additions are made once per week based on analysis since depletion rate is not absolutely linear with ampere hours.

poor-quality plating was expected for several hours. Sometimes it would be necessary to purify the solutions before putting the tanks back into production.

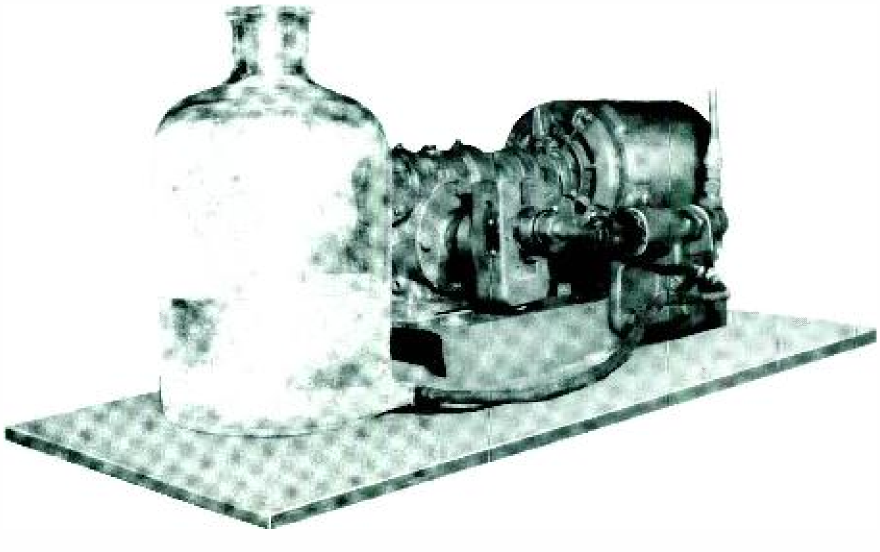
AUTOMATIC EQUIPMENT

To avoid the effect of large additions of salts and a consequent large addition of impurities to the nickel bath, automatic feeders were developed to control and proportion the amount of material to be added to the plating bath. The quantity of material added is based on the ampere-hours used in the plating tank (see Table II). In this manner, the additions are proportioned to the depletion rate, despite the fluctuation due to a variable production rate from shift-to-shift or day-to-day.

Several systems were considered: One was the conventional slurry tank. The principal objection to this equipment is its maintenance problems caused by clogging of the piping with the solid filter aid. For this reason, the soluble materials were kept separate from the insoluble material to be added to the plating bath. When first testing the equipment with the soluble salts, the boric-acid solution crystallized out and formed a hard mass. The boric acid was then put into a dry feeder along with the filter aid. A solution tank and pump were used to feed a solution of nickel chloride and nickel sulphate, and also the sulphuric acid for pH control. A second, small tank and pump were used to maintain the surface tension and minimize stress by the addition of a surface active material and a stress-relieving agent. It was found necessary to separate the wetting agent from the chemical salts tank because air agitation was used to dissolve the salts and this caused excess foaming.

The major components of the system finally used can be seen in Figures 1, 2, 3 and 4. These consist of three units controlled by an ampere-hour meter. These automatically controlled units along with a constant level control add all ingredients to the plating bath except the anode and cathode. These two items are placed in the tank in the conventional manner. The complete system, The *Automatic Addition Flow Plan*, is shown in Figure 5. Two chemical tanks and one dry feeder are controlled by a totalizing ampere-hour meter. These units are sized so as to hold a 24-hour supply of chemicals at full operating loading. The ampere-hour meter seen in the upper-left-hand corner is designed to close a circuit and make a contact 125 times in 24 hours. The contact in turn energizes the timer by means of a guardian relay. This is an interlocking double relay necessary because of the slow motion of the ampere-hour-meter contacts. The timer determines the length of time the pump and dry feeder operate for each contact of the ampere-hour meter. Thus, adjustments in addition rates can be made by adjusting the timer or by changing the concentration of the stock solutions. The larger chemical tank and pump at the top of the chart feeds a solution of nickel sulphate, nickel chloride, and sulphuric acid. A baffle is built into the side of the tank and covers the opening to the pump and prevents the salts from entering the pump or piping which would prevent the flow of solution. The

Fig. 3—Pump and storage bottle contains additions for controlling stress and surface tension.



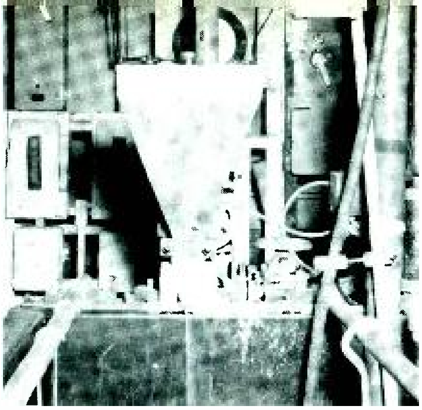


Fig. 4—The dry-feeder hopper stores and feeds filter aid, boric acid and carbon. A small stream of chemicals can be seen dropping into an electrolytic purification tank, part of a large, automatic plating machine.

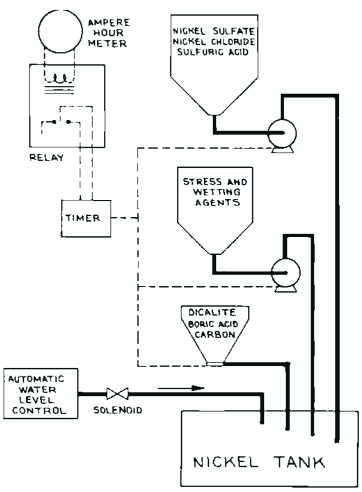
baffle also serves to form a separate compartment for dissolving the salts by use of air agitation. The chemicals are added daily. This usually requires from five to ten minutes of a laboratory technician's time. He fills the hoppers and dissolves the salts each day.

The dry feeder seen just above the plating tank feeds the boric acid and the filter aid. Difficulty in designing the dry feeder was experienced because of the tendency of the diatomaceous filter aids to pack and bridge, but with the use of a vibrator and worm-type feeder the difficulty was overcome. There are now satisfactory feeders of this type available in the size required for small installations.

In the center of Figure 5 is a proportioning pump and a one-gallon tank which stores and feeds the wetting agent to control surface tension and also adds a stress-relieving agent. Originally, the wetting agent was put into the large chemical tank with the nickel salts but, because the air agitation caused excess foaming, a separate tank for wetting agents is now employed.

Last, but not least in importance, is the level control by which deionized water is added to the plating bath. Two types are used: the old float valve, which has been used for years, and the modern electronic capacitor type of control. The manual addition of as much as five gallons of water to a 250-gallon tank has many times caused the rejection of an entire tank load of metal parts because of the effect on the internal stress in the deposit.

Fig. 5—Automatic-addition flow plan.



ADVANTAGES

The performance of this equipment with respect to maintaining pH, nickel sulphate, and nickel chloride is shown in Figs. 6, 7, and 8.

Figure 6 gives the analysis for nickel sulphate. The solid line shows the analyses taken for a one-month period with the use of automatic controls. The desired concentration of nickel sulphate is 40 ounces per gallon in this particular plating bath. Ten analyses were made during the month, and three of these were at the desired concentration. The other seven analyses had a range of 1½ ounces per gallon. The dotted line made over approximately the same length of time demonstrates how difficult it is to maintain the concentration by daily manual additions when the production rate is fluctuating. The range here is 7 ounces per gallon.

The maintenance of the nickel chloride concentration can be see in Figure 7. The curve for the automatic additions shows that the range for the analyses is 0.1 ounces per gallon and that approximately one-third of the analyses were at 3.8 ounces per gallon which is the specification for this particular plating solution. The curve for manual additions shows only one analysis at the desired concentration and that the range is more than five times that for the automatic additions.

Maintaining the pH in the nickel bath is relatively simple with this equipment. Figure 8 shows a comparison of manual versus automatic additions taken on twelve consecutive days. The pH shows only one deviation during this period. With the manual additions of acids daily, the pH had a range of 0.5, or nearly ten times greater than the pH when using automatic additions. Normal addition by the automatic equipment maintains copper contamination below 5 milligrams per liter, and iron contamination was below 10 milligrams per liter.

The equipment has been relatively trouble free. Maintenance has been confined primarily to cleaning electrical contacts on the relays, ampere-hour meters, and timers.

The automatic addition of chemicals to the nickel plating bath has made it easier to control stress in the metal deposit much closer than was possible previously. The equipment described has achieved, therefore, the objective of less fluctuation in the physical properties of the electroformed plate by closer control of the plating bath through the control of salt concentration, impurities, pH, and other factors affecting stress.

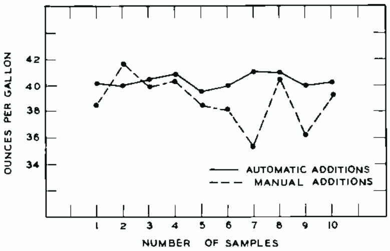


Fig. 6—Effect of manual versus automatic additions on nickel sulfate concentration.

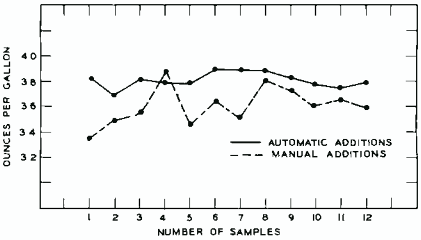


Fig. 7—Effect of manual versus automatic additions on the nickel chloride concentration.

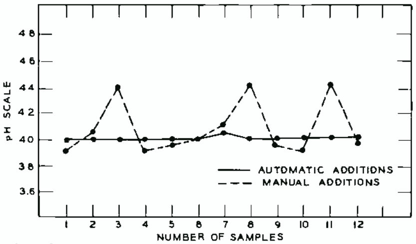


Fig. 8—Effect of manual versus automatic additions on the pH of the nickel solution.

The author wishes to acknowledge the assistance of Dr. A. M. Max and M. Whitehurst in the preparation of the article for publication and is most grateful for assistance given by J. McGriffin, G. K. Stanbrough, W. D. Wehr and J. P. Supple in the development and design of electrical circuits and equipment.

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TELEVISION INTERFERENCE

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To many, TVI (television interference) means interference to television reception caused by signals generated from mobile and fixed transmitters such as police, fire, taxis and call systems, and amateur transmitters; on the other hand, feedback from the second detector of a television receiver is not generally termed TVI. However, all the preceding sources could cause TVI under certain conditions and could be visually detected. In this article, TVI will be considered as interference with the desired television signals by another signal (considered here as *any* radio frequency radiation).

BRIEF HISTORY

TVI is not a new problem; in England during 1939, for example, Jarvis and Seaman[1] were investigating the effects of interference in television, and early in 1946, E. W. Herold[2] made a study of TVI caused by TV receiver local oscillator radiation. As an example of problems to be faced, in 1946 channels 1 (50-56 mc) and 2 (60-66 mc) were allocated in New York City. A pre-war TV receiver tuned to receive channel 1 had its local oscillator operating at 64 mc (picture i-f amplifier at 12.75 mc). This receiver tuned to channel 1 could interfere with receivers tuned to channel 2 through direct local oscillator radiation from the receiver's antenna.

VISUAL EFFECTS

Interference on a TV receiver screen masks picture information. The severity and type of masking is a function of the ratio of signal strengths and frequency difference between the video and interfering signals observed on the picture tube. The lowest level at which TVI can be detected is termed "the perceptible intereference level." At the perceptible level the interference is approximately 40 db below the desired video signal level.

It is also possible to have audio interference; however, since the bandwidth of the video information is much wider than sound, elimination of interference in the picture becomes the greater problem.

TVI SOURCES

Interference signals can be generated by many sources. Some of the sources may be the fixed and mobile transmitters previously mentioned, household appliances such as shavers and mixers, other TV receivers, etc.[3,4]

Interference can be present in areas of the country where many TV and FM signals can be received. For example, when two stations transmit on the same channel, as does happen in New York and Washington, D.C., cochannel interference can occur in the areas lying in between. In these cases, directional antennas are necessary to minimize TVI. Similarly, when two stations are operating on adjacent channels, adjacent channel interference is possible. This type of interference is attenuated in RCA TV receivers by built-in traps in the i-f circuitry. It is also possible to have TVI from FM broadcast stations.[5]

The cause of interference may be spurious radiation from some source (harmonic output for example) and/or deficiencies in the receiver. TVI has been reported on a TV receiver which was normally immune, caused from a transmitter free from spurious radiation. In this instance, re-radiation occurred from a nonlinear device when it was excited by a strong r-f power source.[6]

AMATEUR OPERATORS

One group which has been singled out for creating TVI has been the radio amateur. In the early days of commercial television (1946-1947) not many cases of "ham" TVI were reported nationally, since the number of TV receivers in existence at that time was relatively small. By 1950 more receivers were in the consumers' homes. Ham TVI reports became more numerous. Although amateur transmitters were redesigned and shielded and low pass filters installed, many cases of ham TVI still existed. Many amateur radio clubs formed TVI committees. One of these was the Dallas Amateur Radio Club,[7] whose own TVI committee reported that one of the problems was TV receiver deficiencies. They wrote General Sarnoff. To investigate the problem, R. J. Lewis of the Engineering Department and W. J. Zaun of the Service Company made a trip to Dallas in January of 1951. The results of their conferences were as follows: There were TV receiver deficiencies, and there was harmonic radiation from amateur transmitters when operated without a low-pass filter. The RCA Service Company would install well-shielded high-pass filters on any RCA Television receiver reported as subject to amateur TVI.

At the 21st Annual Convention (August 1951) of the West Gulf Division of the American Radio Relay League. there was a TVI round table. Clifford M. Rigsbee (W2GBU) of the Merchandising Department (then of the Service Company), publicly stated RCA's policy with regard to TVI: RCA Service Company would install an RCA shielded high-pass filter on any RCA Television receiver if it were subject to interference. Presently that policy has been modified, since excellent high-pass filters are built into RCA TV receivers. At this time under severe TVI conditions where the TV

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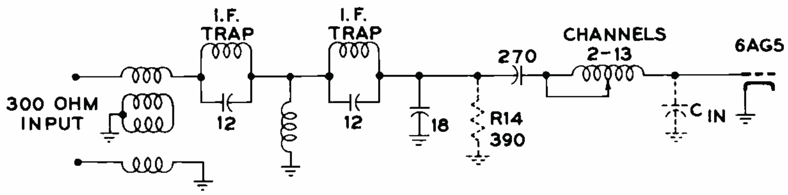

Fig. 1—KRK-5 input circuit.

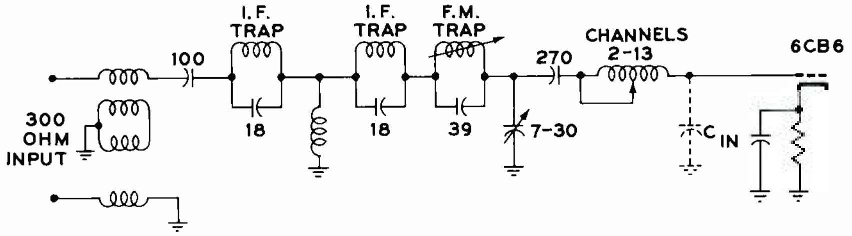

Fig. 2—KRK-8 input circuit.

receiver is within the owner warranty period, the RCA Service Company will install an external high-pass filter. For RCA TV owners whose warranty period has expired, RCA will supply an external filter.

RECEIVER REQUIREMENTS

One of the basic requirements for TV receiver design is minimum susceptibility to interference. However, it is obvious that if the interference is in the same frequency channels as the desired TV signal, attenuation of the interference cannot be accomplished in the receiver without also attenuating the desired signal. The primary engineering goal at RCA is to minimize TVI created by signals outside the desired passband of the r-f stages. The interferences usually associated with the superheterodyne system are intermediate-, and image-frequency signals. Also related, but not common, is the double superheterodyne response, or "double-conversion" interference, which shall be discussed later in this paper. Another form of interference can be caused by strong signals of any frequency, appearing on the grid of the r-f stage, making the r-f amplifier operate over a nonlinear portion of its characteristic, causing the desired signal to be modulated by the interference. This type of interference is termed cross modulation. Strong signals can also produce harmonics at the first r-f grid by rectification.

TVI occurs under certain conditions by direct i-f amplifier pickup and on direct audio detection. In this paper, only interference related to tuner design will be discussed.

AN EARLY TUNER: KRK-2

The KRK-2 was produced in 1946 for the RCA Victor 630 black-and-white TV receiver. The KRK-2 was a three-circuit, three-tube, 13-position switch-type of VHF tuner. The local oscillator was on the high side and produced a picture carrier of 25.75 mc. It tuned in the present 12 channels plus channel 1 (44 to 50 mc), which has since been reserved for other uses. The circuits and tubes were arranged for push-pull tuning. The input circuit was broadly tuned to cover the entire VHF TV spectrum without switching, and provided very excellent match for the transmission line. However, this left the first amplifier stage virtually without isolation from the antenna over a broad frequency spectrum, which would mean a greater susceptibility to cross modulation from strong signals than could be tolerated in today's crowded spectrum. Another more serious problem arose as more stations were allocated, namely, the double superheterodyne problem.

Allocation of channel 5 and 9 within a community is a good example. When the receiver was tuned to channel 5, both channel 5 and 9 signals along with some local oscillator voltage were present at the input to the first amplifier stage. The frequency relation between these signals is such that the difference between the channel 9 signal and the local oscillator falls within the channel 5 passband. Consequently, if the AGC bias was high enough, or the channel 9 signal was strong enough to swing over a nonlinear portion of the characteristic of the input stage, mixing would occur, causing the channel 9 signal to be converted to the channel 5 passband. Although the mixing action was quite inefficient, the converted channel 9 signal was often strong enough to cause appreciable interference with the desired channel 5 signal. To eliminate this interference, traps tuned to the local oscillator frequency of the desired channel were installed in grid circuits of the r-f amplifier. The KRK-2 in its day was considered a good production tuner. However, it cannot meet today's requirements for freedom from interference or fringe area performance.

TRANSITION PERIOD

As a result of field experiences with the KRK-2 and the costs involved installing traps and high-pass filters to eliminate TVI, additional selectivity was required in the basic design to minimize interference susceptibility.

The KRK-5 was the first RCA Postwar TV tuner with filters built in and with a tuned input circuit. The input filter was a full-"T", shunt-"M"-derived, high-pass section. The tuned circuit was a "pi" network to step up from the 300-ohm filter section to the grid of the r-f amplifier (see Fig. 1). Also, the double-tuned circuit between the r-f amplifier and the mixer grid circuit using low-side capacity coupling was first employed in this tuner. This coupling circuit had excellent image rejection and has been used extensively ever since.

Field problems were encountered

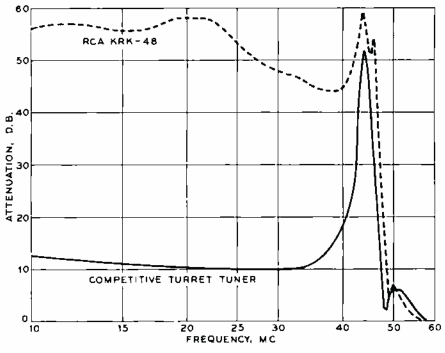

Fig. 3—Present-day specifications for low-frequency attenuation to r-f grid with B+ off; Channel 2.

with the KRK-5, since the "pi" matching tuned circuit was basically a low-pass filter section. R14 (see Fig. 1) was added to attenuate some of the low-frequency responses that were present. The KRK-8 employed basically the same input circuit (see Fig. 2); however, for low-frequency attenuation, a 100-mmf capacitor was put in series with the output of the balun. All the tuners up to this time operated into a 21- to 25-mc i-f amplifier.

In 1950 the KRK-11 was designed for the 41- to 45-mc i-f. The filter circuit designed for the KRK-11 is electrically equivalent to the filter circuits used in current production RCA TV tuners. The circuit of the filter follows in the description of the KRK-48. At that time the filter was mounted externally. The present-day filters are mounted inside the tuners for better grounding and made to be more compatible with the smaller space requirements required for tuners.

In the KRK-11 a tapped inductance input tuned circuit was used for matching. This tuned circuit eliminated all low-frequency responses.

A PRESENT-DAY TUNER: KRK-48

Presently the KRK-48 is being produced for the RCA Victor color TV receivers. The KRK-48 is a four-circuit, 2-tube, 12-position switch-type VHF TV tuner. The local oscillator is on the high side of the r-f carrier and produces a picture carrier of 45.75 mc. Specifications are included for minimum interference. They are:

1. Balanced i-f attenuation—
   75 db (channels 7 to 13)
   65 db (channels 4 to 6)
   60 db (channel 3)
   54 db (channel 2)
2. Unbalanced i-f attenuation—
   over 82 db (channels 7 to 13)
   75 db (channels 5 and 6)
   65 db (channel 4)
   60 db (channel 3)
   54 db (channel 2)
3. Image attenuation—
   75 db (channels 10 to 13)
   80 db (channels 7 to 9)
   over 80 db (channels 2 to 6)
4. Input attenuation for all frequencies between 0.5 to 47 mc, see Fig. 3. Also plotted is a curve of a typical competitive turret tuner.

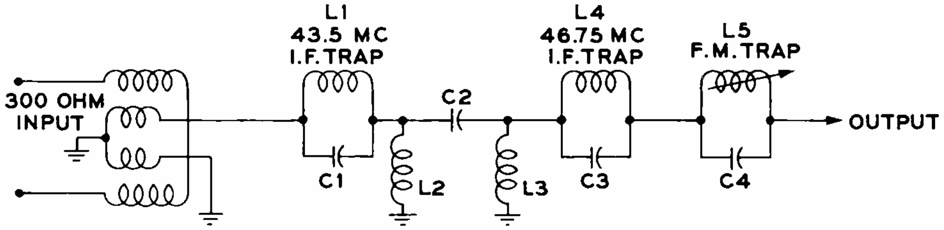

Fig. 4—High-pass filter.

5. Cross modulation for the least desirable r-f amplifier bias condition shall not exceed 1% for signal input levels less than the product of 20 millivolts and the input circuit selectivity ratio at the frequency of the desired and cross-modulating signals.

The attenuation for balanced and unbalanced i-f (push-pull and push-push input) and all other frequencies between 0.5 and 47 mc is obtained by using two balun coils, each having a surge impedance of 150 ohms, transformer connected to match the 300-ohm transmission line to a 300-ohm unbalanced highpass filter. This composite filter (Fig. 4) has maximum attenuation points at 46.75 and 43.5 mc.

The image attenuation is obtained in the double-tuned interstage circuit located between the r-f amplifier plate and mixer grid. Low-side capacity coupling is utilized to obtain the desired attenuation and bandpass characteristics. But additional coupling is necessary when switching from the high channels to the low channels (Fig. 5). Adjustable coupling is provided for tolerance variations on the high channels by capacitor C-14. On the low channels, a close-tolerance capacitor, C-10, is switched in series with C-14 to increase the coupling for proper low-channel bandpass characteristics.

FIELD TESTS

Although laboratory tests indicate the susceptibility of any TV receiver to interference, actual field tests are made as a continual check on all models of new RCA TV receivers, and RCA receivers are then compared with the best competitive makes. Some of the locations chosen for tests are areas near powerful police transmitters, in fringe areas, and also at the American Radio Relay League headquarters in Hartford, Connecticut, under severe conditions.

CONCLUSION

It is obvious with greater use of the radio frequency spectrum, that more possibilities of TVI sources will occur as time advances. Also, that some service allocations make TV tuner costs increase. The two cost design factors with regard to interference which concern TV tuner engineers at this time are (1) i-f attenuation (41.25 to 45.75 mc) and (2), attenuation of signals in the 50 to 54 mc region when the receiver is tuned to channel 2 (54 to 60 mc).

(The author wishes to acknowledge the assistance of J. Achenbach, R. Lewis, and C. Rigsbee in the preparation of this article.)

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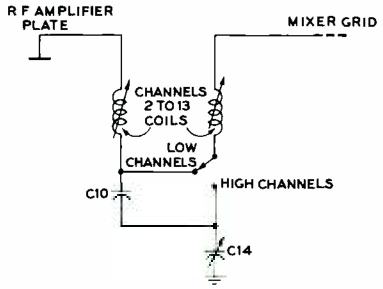
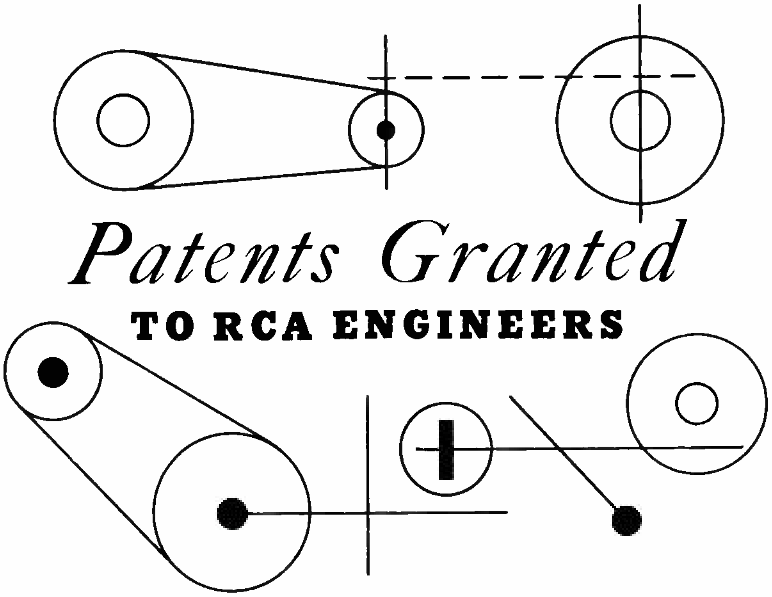


Fig. 5—KRK-48 r-f plate-mixer-grid, low-side, capacity-coupling circuit.



Patents Granted
TO RCA ENGINEERS

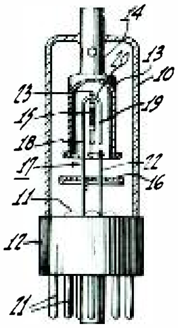
Based on Summaries Received over a period of about two months

DEFENSE ELECTRONIC PRODUCTS

Camden, N. J.

Electronic Circuit
Pat. No. 2,895,108—granted July 14, 1959 to R. A. Haddad and R. E. Schell, IEP.

Semi-Conductor Multivibrator Circuit
Pat. No. 2,901,639—granted August 25, 1959 to H. J. Woll.

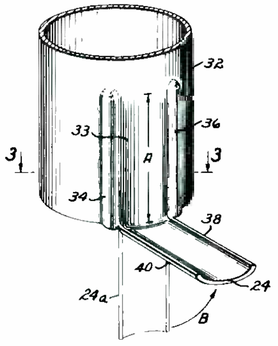


Pat. No. 2,899,589

ELECTRON TUBE DIVISION

Harrison, N. J.

Mount Structure for Electron Tubes
Pat. No. 2,899,589—granted August 11, 1959 to R. D. Reichert.



Pat. No. 2,900,553

Sleeve for Indirectly Heated Cathode
Pat. No. 2,900,554—granted August 18, 1959 to J. G. Woehling, and R. Friedli, Jr.

Electron Tube Electrode
Pat. No. 2,900,553—granted August 18, 1959 to W. K. Batzle.

Lancaster, Pa.

Television Pickup Tube Circuit Arrangements
Pat. No. 2,901,661—granted August 25, 1959 to R. G. Neuhauser.

RCA VICTOR HOME INSTRUMENTS

Cherry Hill, N. J.

Printed Circuit for Multi-Stage Wave Amplifier
Pat. No. 2,895,020—granted July 14, 1959 to F. T. Kay.

Static Magnetic Field Means for Color Television Receivers
Pat. No. 2,898,509—granted August 4, 1959 to B. R. Clay and L. H. Carmen.

Magnetic Two-Angle Demodulator
Pat. No. 2,899,492—granted August 11, 1959 to M. Cooperman and G. L. Grundmann.

Non-Linear Reactance Chrominance Signal Demodulators
Pat. No. 2,899,491—granted August 11, 1959 to G. L. Grundmann, M. Cooperman and R. W. Sonnenfeldt, IEP.

Direct Coupled Feedback Transistor Amplifier Circuits
Pat. No. 2,900,456—granted August 18, 1959 to J. J. Davidson.

Temperature Compensated Electromagnetic Deflection Yoke
Pat. No. 2,900,564—granted August 18, 1959 to W. H. Barkow.

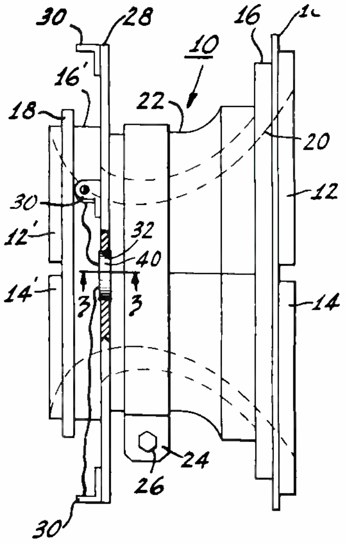
Cathode Ray Tube Deflection Yoke
Pat. No. 2,901,665—granted August 25, 1959 to W. H. Barkow and C. C. Matthews.

Electromagnetic Deflection Yoke
Pat. No. 2,901,650—granted August 25, 1959 to W. H. Barkow and C. C. Matthews.

Television Receiving Systems
Pat. No. 2,901,537—granted August 25, 1959 to D. A. Comninos.

Intercarrier Sound Buzz Reducing Circuit
Pat. No. 2,901,536—granted August 25, 1959 to L. P. Thomas and C. W. Hoyt.

Frequency Selective Signal Attenuating Circuit
Pat. No. 2,901,535—granted August 25, 1959 to E. B. Smith.



Pat. No. 2,900,564

INDUSTRIAL ELECTRONIC PRODUCTS

Camden, N. J.

Registration System
Pat. No. 2,894,058—granted July 7, 1959 to L. Shapiro.

Tone Multiplex Circuit with Narrow Bandwidth Channel-Separating Filters
Pat. No. 2,894,129—granted July 7, 1959 to L. E. Thompson.

Electronic Circuit
Pat. No. 2,895,108—granted July 14, 1959 to R. A. Haddad, DEP, and R. E. Schell.

Parity Generator
Pat. No. 2,894,684—granted July 14, 1959 to D. L. Nettleton.

Radio Relay Station with Drop Channeling
Pat. No. 2,897,274—granted July 28, 1959 to E. J. Forbes.

Diversity Receiver Having Individually Controlled Channel Triggers for Cooperatively Controlling Channel Switching
Pat. No. 2,898,455—granted August 4, 1959 to D. G. Hymas and R. A. McDermody.

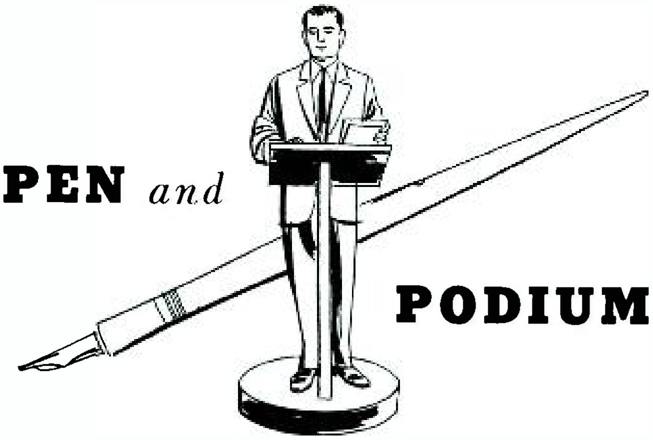
Non-Linear Reactance Chrominance Signal Demodulators
Pat. No. 2,899,491—granted August 11, 1959 to R. W. Sonnenfeldt and G. L. Grundmann and M. Cooperman, Home Instruments.

SEMICONDUCTOR AND MATERIALS DIVISION

Somerville, N. J.

Printed Circuit for High Frequency Amplifier Apparatus
Pat. No. 2,896,028—granted July 21, 1959 to D. Mackey.

PEN and PODIUM



BASED ON REPORTS RECEIVED OVER A PERIOD OF ABOUT TWO MONTHS

DEFENSE ELECTRONIC PRODUCTS

Camden, N. J.

Study of Correlation Instrumentation for Speech Analysis and Synthesis

By D. T. Hoger and F. L. Putzrath: Presented at the Air Force Cambridge Research Center, September 9, 29, 1959. This paper describes three analog pattern comparison methods that could be used to implement a system of speech processing.

Some Characteristics of Tropospheric Scatter Propagation on the North Atlantic Scatter System

By J. B. Potts and I. Benoliel: Presented at the Aero-Communication Symposium, Utica, New York on October 2, 1959. This paper deals with propagation data obtained from the North Atlantic Scatter Systems installed for the Air Force using the first military scatter equipment.

A Fast, Low Power, Magnetic Shift Register

By G. W. Hernan: Submitted as a Master's Thesis at the University of Pennsylvania in October, 1959. This project is concerned with magnetic circuit development. By deviating from the standard magnetic shift register configuations, it is possible to perform the basic operations at speeds three to four times as fast as those presently attainable and with less power dissipation.

RCA BMEWS Systems Management

By R. H. Baker: Presented at the National Airborne Electronics Conference in Dayton, Ohio on May 4, 1959. The purpose of the paper is to describe the organization established to handle the BMEWS Project.

Automatic Checkout Equipment

By O. T. Carver: Mr. Carver was the principle speaker October 27, 1959, at the IRE regular monthly meeting of the Professional Group on Military Electronics.

DEFENSE ELECTRONIC PRODUCTS

Moorestown, N. J.

Effects of Mutual Impedance on the Performance of Large Electrochemical Scanning Arrays

By J. E. Dwight: Submitted as a Master's Thesis at the University of Pennsylvania, Fall of 1959. A general analysis of mutual impedance is presented for the purpose of defining terms and general method of calculating mutual impedance is evolved and applied to simple configuration.

Mean Time Between Threshold Crossings

By E. Rawdin: Presented September 22, 1959 at the Philadelphia Chapter of Operations Research Society of America. In addition to, or instead of, the measures of effectiveness currently applied to queues it is of interest to ascertain the average period between successive occurrences that a queue exceeds a prescribed length.

Automatic System Checkout for BMEWS

By M. Goldman and F. X. Beck: Presented September 17, 1959 at the Third Annual Joint Military-Industrial Electronic Test Equipment Symposium at New York University. The Automatic System Checkout for BMEWS has been designed as an integral part of BMEWS to enhanre reliability.

Management of Design and Development Engineers

By H. A. Brelsford: Presented April 24, 1959 at the Mechanical Engineering Department of the University of Virginia. Specifically designed to give the senior graduating engineer a knowledgeable background concerning the management of design engineers at R.C.A., the paper deals with the needs of requiring managerial control of engineering personnel on projects.

DEFENSE ELECTRONIC PRODUCTS

Princeton, N. J.

An Industrial Dynamic Approach to the Management of Research and Development

By A. Katz: Presented August 18, 1959 at the IRE Western Show and Convention, San Francisco, California. An attempt has been made to identify the factors of major importance in the management of Research and Development, and to organize them into a meaningful whole.

INDUSTRIAL ELECTRONIC PRODUCTS

Camden, N. J.

Understanding the Nature of Matter . . . The Electron Microscope

By F. J. Herrmann: Presented IRE Student Quarterly, Vol. 5, No. 4, May, 1959. A story giving some of the interesting history of the development of the Electron Microsope, how it operates and some of the modern uses in the field of Medicine.

Millimicrosecond Diode Capacitor Memory

By M. M. Kaufman: Presented October 12, 1959, Chicago, Illinois. The diode capacitor storage technique has been studied and a prototype memory has been built to evaluate the difficulties in reducing the cycle time to approximately 10 millimicroseconds.

Microwave Solid-State Techniques for High Speed Computers

By J. W. Leas: Presented at the International Conference on Information Processing, Paris, France June 20, 1959. A parametric subharmonic phase-locked oscillator can be made to gate, amplify, and store binary signals expressed in terms of the two possible phases of its oscillation. Computer systems have been reported with this device as a sole component. Promising results have been obtained with germanium junction diodes.

Autodata—RCA's Automatic Message Switching Center

By J. L. Owings, T. L. Genetta and J. F. Page: Presented October 13, 1959, Sherman Hotel, Chicago, Illinois. This paper will describe the system design of an automatic store and forward type message switching center and will review the implementation of the system requirements.

Message Protection in an Automatic Switching Center

By A. S. Rettig and H. P. Guerber: Presented October 13, 1959, Sherman Hotel, Chicago, Illinois. AutoData is a system of electronic equipment for the collection and dissemination of messages in digital form. It provides the link between communication facilities and digital data handling equipment.

A New High Capacity Microwave Relay System

By R. F. Privett, C. G. Arnold, V. E. Isaac, H. R. Mathwich, and L. E. Thompson: Presented AIEE Meeting, District No. 2, Baltimore, Maryland on May 19, 1959. The MM-600 microwave system which operates in the frequency band of 1700 to 2300 mc. was designed for use in major communication networks to transmit large numbers of signals over distances up to 4000 miles. It is an FM system using heterodyne repeaters with 70 mc. i-f amplifiers and travelling wave tube r-f amplifiers.

RCA VICTOR HOME INSTRUMENTS

Cherry Hill, N. J.

A Suggested Method for Measuring Tape Modulation Noise

By J. J. Davidson: Presented October 6, 1959 at the Audio Engineering Society Convention in New York. One of the most difficult factors to measure in magnetic recording is modulation noise. The presently available methods are all, in a sense, indirect. This paper proposes a new (although far from perfected) technique, which gives a direct and integrated measurement of modulation noise.

NATIONAL BROADCASTING COMPANY, INC.

Color Television

By R. F. Guy: Written for the McGraw-Hill Encyclopedia of Science and Technology. This paper consists of an introduction to color television and describes briefly the technical standards for transmission and reception and the manner in which they were adapted to the monochrome standards.

Network Broadcasting

By R. F. Guy: Published in the McGraw-Hill Encyclopedia of Science and Technology which will consist of 12 or 13 volumes. This paper describes the national networks by which television and sound programs are distributed.

Radio Broadcasting

By R. F. Guy: Published in the Encyclopedia of Science and Technology of McGraw-Hill. This is introductory material which outlines the evolution and growth of radio broadcasting, describes the technical standards and includes explanatory material.

CORPORATE STAFF

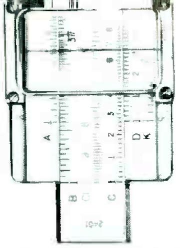
Department of Information

Peering into the Smallest World

By Jack Long: Published in Harper's Magazine, May 1959. A short story of the Electron Microscope and how the electron beam of the super-microscope has become a basic tool in research on disease.

Speeding Prototypes to Production

By D. F. Schmit: Presented at the American Management Association, Research and Development Division in the early part of 1959. This paper discusses the many facets involved in speeding a prototype to the production stage. A prototype may be any model in which a decision is made to schedule production.

Engineering  NEWS *and* HIGHLIGHTS

FIVE NEW DEP DIVISIONS FORMED

In a recent major realignment, the organizational structure of Defense Electronic Products has been increased in scope to include five separate operating units—each one going from departmental to divisional status. The continuing rapid growth in Defense Electronic Products' operations has resulted in a greater need for increased individual responsibility, status, and greater operating autonomy for each unit.

Headed up by A. L. Malcarney, Executive Vice Pres., DEP—the responsibility for the five new divisions is divided between H. R. Wege and W. G. Bain. Mr. Malcarney also announced the following staff appointments of C. A. Gunther, Chief Defense Engineer; Dr. C. B. Jolliffe, Vice Pres. and Technical Director; R. E. Posthauer, Mgr., DEP's Washington office; J. M. Hertzberg, Vice Pres., DEP Marketing; and J. B. Coleman, Administrator, High Power Transmitters.

Mr. Wege, who was promoted to the post of Vice President and General Manager of Missile and Surface Radar, assumes responsibility for two of the new divisions: the West Coast Missile and Surface Radar Division which will be operated under the direction of General Mgr. A. N. Curtiss; and the Moorestown Missile and Surface Radar Division under the direction of S. N. Lev, General Mgr.

A 30-yr. veteran of RCA engineering, Mr. Wege was appointed to his new position of increased responsibility from his former post of General Mgr., Missile and Surface Radar Division. Mr. Curtiss was formerly Mgr., West Coast Missile and Surface Radar Department prior to its elevation to a divisional status. Mr. Lev was formerly Mgr., Airborne Systems Department, Camden, N. J.

W. G. Bain, who has been made Vice Pres. and General Mgr. of Communications and Missile Electronics, has under his direction three separate divisions: the Airborne Systems Division, headed up by Irving K. Kessler, General Mgr.; Missile Electronics and Controls Division headed up by W. B. Kirkpatrick, General Mgr.; and the Surface Communications Division headed up by S. W. Cochran, General Mgr.

Mr. Bain was formerly Vice President in charge of DEP's Washington Office, coming to RCA earlier this year from the Republic Aviation Corporation where he was Vice Pres. and General Mgr. Mr. Kessler was formerly in charge of Management Engineering, DEP, in Camden. Mr. Cochran was formerly Mgr., Surface Communications Department before its elevation to a divisional status, and similarity, Mr. Kirkpatrick was Mgr., Missile Electronics Control Department, before it became a division.

The organizational chart below shows the relative positions of G. F. Breitwieser, J. B. Cecil, J. D. Woodward, O. B. Cunningham, and Dr. R. C. Seamans . . . the Chief Engineers who are responsible for technical activities in the five new divisions.


H. R. Wege


G. F. Breitwieser


O. B. Cunningham


J. D. Woodward


J. B. Cecil


R. C. Seamans


W. G. Bain

DEAN OF RCA ENGINEERING WRITING RETIRES

R. S. Burnap

E. C. Hughes

After 35 years as Manager of Commercial Engineering for the RCA Electron Tube Division and predecessor companies, **Robert S. Burnap** retired on July 31, 1959, taking on new duties as a consultant to the Division. **E. C. Hughes, Jr.** has been appointed his successor as Manager of Commercial Engineering. In this position, he will be responsible for all technical publications issued by both Electron Tube Division and Semiconductor and Materials Division.

Bob Burnap not only helped pioneer the RCA ENGINEER from its inception, but has been looked upon by technical writers at RCA as the "engineer-writer's writer." Bob wore many editorial hats as far as the RCA ENGINEER was concerned. One was that of engineering editor on the editorial staff; another, that of manager of Commercial Engineering in Harrison, where he assured the high standards and quality of engineering material going to the RCA ENGINEER and various outside publications. Then, every other month, Bob Burnap would participate actively at Advisory Board meetings of the RCA ENGINEER in order to provide guidance and counsel. The name of Bob Burnap will not only be remembered by the Editorial Staff of the RCA ENGINEER, but respected in all RCA technical groups . . . and in industry circles where he served as an efficient coordinator for establishing industry standards for electron tube nomenclature and data. (See his article, RCA ENGINEER, Vol. 1, No. 1, entitled *The Philosophy of JETEC Tube Type Designations.* We are looking forward to further contributions from Bob Burnap in the future, giving our engineers, particularly the uninitiated, the benefit of his wide experience in Electronics at RCA and in the industry at large.

Robert S. Burnap has been associated with RCA and predecessor companies for 42 years since receiving the S. B. degree from the Massachusetts Institute of Technology. He started his career as an engineer with the Edison Lamp Works of the General Electric Company at Harrison and, except for a span of service with the Signal Corps during World War I, remained with them and advanced to the position of Manager of the Commercial Engineering Section of the Lamp Works in 1924. He transferred to RCA in the same position in 1930. Mr. Burnap holds several patents on lamp design, and has been active on many professional society and industry standardization committees. He was elected a Fellow of the Society of Motion Picture and Television Engineers in 1934, of the Institute of Radio Engineers in 1947, and of the American Institute of Electrical Engineers in 1951.

E. C. Hughes, Jr. has been associated with RCA for 29 years since receiving his Electrical Engineering degree from Rensselaer Polytechnic Institute. He started as a technical writer in the Sales Promotion activity at the Harrison tube plant, and was subsequently promoted to Manager of Amateur Radio Tube and Apparatus Sales, Assistant to the Manager of Renewal Sales, Assistant to the General Manager of the Tube Department, and Assistant to the Vice President of Technical Products. He received the RCA Victor Award of Merit for his outstanding accomplishments in 1949. He served as Assistant to the RCA Executive Vice President in New York from 1952 to 1955, and then became Manager, Technical Services for the Commercial Department at Princeton, N. J. Since September, 1958, he has been Administrator, Commercial Engineering Programs of the Electron Tube Division. He is a Senior Member of the IRE.

DEGREES AWARDED

J. J. Frank, VHF and Microwave Transmitter Mechanical Engineering Group, Missile and Surface Radar, DEP, has been awarded an MS in Mechanical Engineering from the University of Delaware in June 1959. **H. W. Stewart,** RCA Service Co., received his MS in EE in June 1959 from the Rensselaer Polytechnic Institute, under the David Sarnoff Fellowship Program. **G. Herskowitz,** Astro-Electronic Products Division, recently received his MSEE from Rutgers University. **S. Petrovsky,** Commercial Engineering, Tube Division, Harrison, N. J., has received his BS in Physics from the City College of New York.

E. M. HINSDALE NAMED CHIEF ENGINEER FOR IEP's COMMUNICATIONS PRODUCTS

Edwin M. Hinsdale, who played a role in the World War II development of the electronic navigation and target-spotting system known as *Shoran*, has been named Chief Engineer, RCA Communications Products Department. In the Shoran project, Mr. Hinsdale was associated both with the RCA laboratory development work and in field tests of the equipment conducted in the European and Pacific areas. He also was instrumental in the design of a simplified color television receiver. A native of Knoxville, Tenn., Mr. Hinsdale is a graduate of the University of Tennessee. Before coming to RCA, he served as a communications specialist with Pan American World Airways, supervising a number of overseas ground installations, including one in Liberia. From 1946 to 1951, he was a partner in the Washington, D. C., engineering consulting firm of Glen B. Gillett Associates. Prior to his present post, he served as Section Leader in the RCA Industry Service Laboratory in New York and as a member of the Technical Staff, RCA Laboratories, Princeton. He is a senior member of the IRE.

E. M. Hinsdale

NEW SEMICONDUCTOR PLANT

RCA's plans for major expansion of transistor and rectifier manufacturing facilities of the Radio Corporation of America call for the construction of a 120,000-square-foot plant in Mountaintop, Pa., devoted exclusively to products of the RCA Semiconductor and Materials Division. Production of high-reliability germanium and silicon semiconductor devices for military, industrial, and computer applications will be underway by mid-1960 when several hundred employees will be on the job.

The new manufacturing facility will be situated on a 38-acre tract in Chestwood Industrial Park, seven miles southwest of Wilkes-Barre.

FARWELL NAMED RCA VICE-PRESIDENT

Fred M. Farwell has assumed the newly created cooperative staff position of Vice President, Marketing. He will participate in the formulation of the company's total marketing policies and objectives, and work with divisional marketing organizations on plans, programs and personnel, and provide marketing services in areas and products in which RCA is not currently active. Reporting to Mr. Farwell will be Dr. Wendell R. Smith, Director of Marketing Research and Development; R. H. Coffin, Vice President, Advertising and Sales Promotion, and P. B. Reed, Vice President, Government Business Relations. Since May, 1957, Mr. Farwell has been Executive Vice President of International Telephone and Telegraph Company in charge of IT&T's U. S. Group operations. A native of Chicago, he was graduated from Yale University's Sheffield Scientific School.

ENGINEERS IN NEW POSTS

Dr. R. M. Wilmotte, research consultant and authority in the fields of antenna theory, radar and communications, and **R. W. Hanford,** an authority in missile guidance, fire-control systems and nuclear instrumentation, have joined the staff of Advanced Military Systems, DEP.

Elsewhere in DEP, new appointments are as follows: in ASD, **R. Trachenberg** as Manager, Airborne Design and Development Engineering; and **Dr. E. M. Pritchard** as Chief Systems Engineer; in West Coast Missile and Surface Radar, **J. H. Rothrock** as Manager, Product Development Planning, in Missile and Surface Radar, **C. J. Molthop,** as Administrator, DAMP Program, and **F. W. Widmann** as Manager, Development and Design Engineering. In the Defense Engineering Department, **R. H. Aires** and **J. N. Tariot** have been appointed Staff Engineers, and **I. K. Munson** has been appointed Manager, Central Engineering. In the Surface Communications Division, **R. E. Patterson** has been appointed Administrator, Engineering Controls, and has formed a Data Control Group consisting of **W. H. Thomas, L. T. Carr, C. W. Fields,** and **C. R. Doughten;** this group will be responsible for the technical data and all publications originating within Surfcom. Also in Surfcom: **R. C. Biting** has been appointed Manager, Minuteman Program; **H. K. Fesq** has been named Program Manager of Development Engineering's Project STAR, which is concerned with the development of a 6-mc bandwidth tape-recorder system, including a miniaturized satellite recorder. This program is under the overall direction of **W. R. Isom.**

In the Semiconductor and Materials Division, **E. O. Johnson** has been named Manager, Advanced Development, taking over a post previously held by **Dr. W. M. Webster,** who has moved to the RCA Laboratories staff. **G. W. Longacre** has been appointed Acting Manager, Equipment Development, and **W. A. Pond** has been named Coordinator, Field Engineering. At Needham, **W. J. Olander** has been appointed to the Technical Staff, and will be responsible for all applications engineering there.

Within the Tube Division, **G. W. Crawford** has been assigned to the newly created position of Manager, Operations Planning and **A. E. Linton** has been named Manager, Manufacturing Planning, both in Receiving Tube Operations.

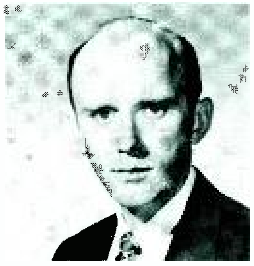
At IEP, **R. A. Wallace** has assumed the post of Manager, Mechanical Design, Electronic Data Processing.

In the RCA Victor Record Division, **S. D. Ransburg** has been appointed Manager, Manufacturing in the newly created Magnetic Tape Plant being set up in Indianapolis. Also, in the Record Division's regular Indianapolis facility, **H. D. Ward** has been named Manager of Record Quality and Process Control and **W. H. Dearborn** has been named Manager of Record Manufacturing. **H. W. Hittie** has been appointed to the newly-created position of Manager, Packaging and Standards Processing.

Dr. G. L. Beers has assumed the job of Technical Advisor, Commercial Department, Patent Services, of the RCA Laboratories. He was formerly Administrative Engineer, Product Engineering, RCA Staff. **C. J. Hirsch** has been appointed Administrative Engineer on the Staff of **Dr. G. H. Brown,** Vice President, Engineering. **Dr. W. M. Webster** has been named Director, Electronic Research, RCA Laboratories.

In the Electron Tube Division, **C. D. Mitchell** becomes Administrator, Commercial Engineering Coordination and **John F. Wilhelm** becomes Manager, Power-Tube and Cathode-Ray-Tube Commercial Engineering under **E. C. Hughes, Jr.**


Dr. R. M. Wilmotte


R. H. Aires


I. K. Munson


R. C. Biting


E. O. Johnson

NEW EDITORIAL REPRESENTATIVES

At the Needham Laboratory of the Semiconductor and Materials Division, **L. A. Wood** has replaced T. A. Richard as Editorial Representative for the RCA Engineer. At Entertainment Tube Products, Tube Division, Harrison, **T. M. Cunningham** has assumed the duties of Editorial Representative that had been held by R. L. Klem. At the RCA Record Division, Indianapolis, **M. L. Whitehurst** has replaced S. D. Ransburg as Editorial Representative. **J. D. Young** has been appointed Editorial Representative for the Findlay, Ohio activities of the Semiconductor and Materials Division.

L. A. Wood received the BS in Chemical Engineering from Purdue University in 1936. He was engaged in chemical work from then until July 1943, when he joined the Record Division at Indianapolis. He was later appointed Manager, Product Engineering; and in July 1956 he was promoted to the position of Administrator, New Process Development, Manufacturing, RCA Staff, Camden, New Jersey. In February of this year Mr. Wood became Manager, New Product Engineering, at the Needham Materials Laboratory of the Semi-conductor and Materials Division.

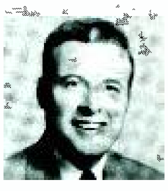
T. M. Cunningham, Administrator, Engineering Administration, Receiving Tube Engineering, received a BS in EE from Purdue University in 1951, and is presently doing graduate work at Stevens Institute of Technology. He served in the United States Navy from 1942 to 1947, where he attended schools and did work in communications. After graduation from Purdue, he joined RCA as a Specialized Engineering Trainee and, at the completion of his training program, was assigned to Receiving Tube Engineering at Harrison. Mr. Cunningham was appointed Engineering Leader in the Receiving Tube Design Group in 1955, and recently he was appointed to his present position. He is a member of Eta Kappa Nu, Institute of Radio Engineers, and the Newark, New Jersey, Junior Chamber of Commerce.

M. L. Whitehurst received his BS, ChE from Indiana Technical College in 1943. In August 1943, he joined RCA Indianapolis Record Engineering where, except for a stint from June 1944 to March of 1946 in the Navy, he has remained.

Mr. Whitehurst's work has been primarily concerned with metallizing and electroforming. He has made contributions to gold sputtering and copper preplating of wax recordings, and silvering of lacquer recordings which culminated in the chamber for automatic silvering of lacquers. His work on the control of stress in the Watts nickel plating solution led to the substitution of nickel preplating for copper preplating which contributed materially to lower noise levels on matrix parts. A program of surface conductivity measurements correlated with static electricity aided substantially in understanding phenomena which led to the development of anti-static records. He has authored and co-authored sixteen engineering memoranda as well as two technical papers. He is a member of the American Chemical Society and the American Electroplaters Society. He is a past president of the Indianapolis branch of the latter organization.

J. D. Young graduated from the Indiana Technical College in 1955 with a BS in EE in 1955 and joined RCA that same year as a Development Engineer in the Component and Television Engineer. Since the first part of 1959 he has been with the Semiconductor and Materials Division, and is concerned with the drift transistor at the Findlay plant.


L. A. Wood


T. M. Cunningham


M. L. Whitehurst


J. D. Young

MEETINGS, COURSES AND SEMINARS

IRE Professional Group on Engineering Writing and Speech, 1959 Dual National Symposia

Miss Eleanor McElwee, Tube Division, Harrison, served as moderator in the *Problems in Communications* panel of the Boston session, held Sept. 17-18. This IRE group held concurrent meetings in Los Angeles and Boston and was concerned with the subjects of *More Effective Communication of Scientific and Engineering Personnel.*

Second RCA Plasma Physics Symposium

Several RCA engineers and scientists took an active role in this symposium held at the David Sarnoff Research Center, Princeton, New Jersey, on Sept. 21 and 22. These were: **Dr. T. W. Johnson,** RCA Victor, Montreal; **Prof. M. Lessen** and **John Jarem,** RCA; **Dr. H. Staras,** RCA Princeton; **D. J. Blattner,** RCA Princeton; **Dr. G. A. Swartz,** RCA Princeton; **C. M. Burrill,** RCA Princeton; **Dr. W. Carlson,** RCA Moorestown; and **D. Skinner,** RCA Camden.

TVM Microwave Seminar

A summer seminar was held in Chicago by **John B. Black** for 25 technical employees of the Illinois Bell Telephone Co. The discussions and demonstrations covered techniques in using RCA TVM-1A equipment. —*J. H. Roe*

DEP Teaches Technical Writing

Within Development Engineering, DEP, Camden, an after-hours course in transmitting technical information via technical writing is being conducted by **F. W. Whittier** for interested engineering personnel. The objectives of the seminar are to examine the communications processes with a view to clear writing techniques, and methods of presenting technical information. A series of 15 sessions consisting of lectures, discussions, and practice are being kept broad in scope and are particularly designed for engineers, leaders, and managers responsible for writing and approving engineering reports, proposals, articles, and presentations.

Foreign Electronics Activities

Dr. R. W. Engstrom, Manager of Photo and Image Tube Engineering, Lancaster has returned from a visit to a number of laboratories in England, France, Germany, and Switzerland. In conferences with leading European authorities he discussed recent developments relating to multiplier phototubes, image converter tubes, and photoconductive cells.—*W. G. Fahnestock*

Research and Development Management

D. E. Loomis and **R. W. Hagmann** of Color Kinescope Engineering at Lancaster attended a one-week Seminar on Research and Development Management at Pennsylvania State University.—*D. G. Garvin*

Video-Tape-Recording Equipment Training

The first group of Technical Products Service Representatives completed a comprehensive training course on the new RCA Video Tape Recording equipment. The training course was directed by **R. S. Koerner,** Broadcast Administrator of the RCA Service Company under the direction of **E. Stanko,** Manager of Engineering, and **T. Griffin,** Manager of Broadcast Operations.

Scientific Russian

In early August, six students enrolled in a course in Scientific Russian, took their final examination at the Astro-Electronic Products Division of RCA. The objective of the after-hours course was to make it possible for engineers to translate basic Russian technical information and thus to provide a basis for increased technical communication with Russian technical sources. Taught by **Miss Sima Miluschewa,** an AEP engineer working on problems involving thermal equilibrium calculations on space vehicles . . . students learned how to translate and write in the Russian language. Those who have completed the course are: **S. H. Winkler, C. M. Burrill, C. J. Busanovich, B. W. Richards, Jr., J. Baumunk** and **T. C. Henneberger, Jr.**—*L. A. Thomas*

SMPTE Session on Space Technology

Representatives of the Astro-Electronic Products Division were active at the 86th SMPTE Convention, Session on Space Technology and Image Sensing, held on Oct. 5, 1959, at the Statler Hilton Hotel in New York City. The following subjects were presented: *Electrostatic Imaging and Lunar Exploration*, by **S. Spaulding;** *Image Sensors and Space Environment*, by **M. Ritter** and **M. Mesner;** *Pictorial Data Transmission from a Space Vehicle*, by **J. Baumunk** and **S. Roth. Sidney Sternberg,** Chief Engineer of the Astro-Electronic Products Division of RCA, was Program Chairman.—*L. A. Thomas*

Dynamical Astronomy

Joseph B. Newman and **Douglas Climenson,** Astro-Electronics Products, attended the Summer Institute in Dynamical Astronomy at Yale University. Covering classical celestial mechanics, practical astronomy, modern orbital calculation techniques and computer programming, the four-week course featured lectures by noted technical experts—and was attended by people from government, educational and industrial fields.—*L. A. Thomas*

Infrared Radiation Detection

J. R. Stanisjewski and **M. Ritter** of the Astro-Electronic Products Division attended a two-week summer course in Infrared Radiation Detection at UCLA. The course covered the basic physics of infrared radiation, including sources, transmission, propagation, and detection, and considered the problems of military and industrial applications. The course was taught by Dr. Max B. Garbug of Westinghouse Electric Co. —*L. A. Thomas*

International Scientific Radio Union

The fall meeting of the International Scientific Radio Union (URSI) was held on Oct. 21, 1959 at the El Cortez Hotel, Balboa Park, San Diego, California. Among those active were **R. Goerss** and **Miss S. Miluschewa,** engineers from the Astro-Electronic Products Division, who presented a talk entitled *"Ray Tracing for Whistler-Mode Signals at Low Frequencies."* —*L. A. Thomas*

S. D. Ransburg

FROM ED REP TO MANAGER

The RCA ENGINEER has lost **S. D. Ransburg** as its editorial representative from the Record Division. Mr. Ransburg received a promotion to Manager of Manufacturing in the newly created Magnetic Tape Plant being set up in Indianapolis. He leaves his engineering activities after 16 years' service in which he made major contributions to such new developments as the introduction of 45 records and the redesign of L. P.'s to the Gruve-Gard concept, and most recently by helping bring out anti-static stereo discs. His career started when he joined the company in 1943 upon completion of his undergraduate studies at Tri-State College, Angola, Indiana where he received the B.S. degree in Chemical Engineering. After a period of Navy service during which he received electronics training, he returned to RCA in 1946.

He has been very active as a member of the Society of Plastics Engineers, having served as a member of the Board of Directors for three years and President of the Central Indiana Section for one year.

His new activities move him from an engineering function to that of a management function in one of the newest ventures RCA has considered. Magnetic tape manufacture shows great promise for the future in the video-recording, business-machine, and the home-recording field, and many technical and engineering problems face this new enterprise. His long engineering career will be a great asset to him in this new assignment.—*M. L. Whitehurst.*

DEP-IEP DRAFTING MANAGERS COMMITTEE

A joint committee of drafting representatives, from DEP and IEP divisions, has been established to resolve the unique drafting requirements of various military agencies as they affect the Defense Electronic Products Division and also to establish uniform drafting practices between the Defense and Industrial Electronics Divisions of RCA. The committee consists of managers or their representatives from all drafting departments of DEP and IEP. Exofficio membership also includes drafting managers of Missile Electronics at Burlington and Astro-Electronics at Princeton.

The chairman of this joint DEP-IEP committee is M. S. Gokhale of DEP Central Services and Engineering. As spokesman for the Drafting Managers, Mr. Gokhale further establishes the necessary liaison for the Defense Drafting Standards, an activity which he officially represents.

Left to right:
J. Cimba,
M. L. Payne,
E. S. Clark,
H. W. Dover,
R. S. Koerner.

COMMITTEE APPOINTMENTS

Development Engineering—Camden

Walter H. Erickson has been appointed Editor-in-Chief of the Journal of the Audio Engineering Society, and was Chairman of all magnetic-recording sessions of that Society's 1959 Convention, a post he held in the 1957 and 1958 conventions. He is also Chairman of their Technical Committee on Magnetic Recording.—*F. W. Whittier.*

DEP Central Engineering—Camden

J. W. Kaufman has been appointed by RCA to represent the company in the American Society of Metals. He has also been appointed to a two-year chairmanship by their Philadelphia chapter to represent ASM in the Engineering and Technical Societies of Philadelphia, whose purpose is to guide educational programs in career selection in the Delaware Valley. He has also been appointed by the Council as advisor to the Junior Engineering Technical Society, a nationwide group of academically sponsored clubs.—*H. L. Wuerffel*

RCA Institutes, New York City

Henry M. Nodleman, Head of the Mathematics and Physics Dept., has been appointed to the Educational Committee of the New York Section of the Communications Division of the AIEE. He is also now serving as a member of the Mathematics Education Coordination Committee of the New York Metropolitan Section of the Mathematical Association of America.

Industrial Electronic Products, Camden

W. Lyons is Chairman, Papers Study and Procurement Committee of IRE-PGCS. **C. W. Sall** has been named Chairman of the IRE National Convention Technical Program Committee to represent PGEWS on the March 1960 IRE Program in New York. **C. G. Dietsch,** RCAC, has been appointed a member of IRE Committee 15 on Radio Transmitters. **J. M. Walsh** has been appointed a member of the Radio Communications Systems Committee of the AIEE. **E. G. Becken** has been appointed as a member at large on the AIEE Communication Division Committee.—*C. W. Sall*

Airborne Systems Division, DEP, Camden

W. M. Morsell is a member of the Airborne Electronic Section of the American Ordnance Association.—*J. W. Biewener*

Surface Communications Engineering, DEP, Camden

W. A. Miller is a member of the Magnetic Devices Subcommittee (IRE 28.6) of the Solid-State Devices Committee.

Missile and Surface Radar, DEP, Moorestown

R. E. Killion has been elected Chairman, and **G. H. Beckhart** was elected Secretary of the Professional Group on Quality Control, IRE.

Tube Parts Manufacturing, Lancaster

H. B. Walton has been appointed to the Promotion and Publicity Committee of the Eastern Pennsylvania Council of Industrial Management Clubs.—*H. S. Lovatt*

Commercial Engineering, Tube Division, Harrison

Miss E. M. McElwee has been elected to a second three-year term on the Administrative Committee of the IRE Professional Group on Engineering Writing and Speech, and has been reappointed as Secretary of the Committee for 1959-1960.

EDP CENTER MADE AVAILABLE TO RCA ENGINEERING

To foster a more-widespread use of electronic data-processing techniques as an engineering tool, the EDP Center Bizmac System in Camden is now available.

It includes an organization of analysts, programmers, operators, equipment servicing personnel and a complete operating Bizmac EDP System. Its charter is to provide men and machines to fulfil the data processing needs of internal RCA departments. Although developed primarily for business applications, the EDP Center Bizmac System has proven to be of extreme value in the solution of engineering data-processing problems. Those wishing to discuss particulars can contact R. A. C. Lane, Mgr., RCA EDP Center, Bldg. 10—floor 2, Camden, N. J.

COLLEGE PROFS "SUMMER" AT CANAVERAL

Fifteen distinguished college professors were hired last summer by RCA Service Company to spend their vacation time at the Cape Canaveral missile range. These Profs, specialists in mathematics, astronomy, and electronics, worked to assist Service Company engineers in solution of current problems, devising new methods of data processing, and in planning range operations.

P. A. METZGER DIES

P. A. Metzger, Manager, Development Shop Engineering, Color Kinescopes, Lancaster, passed away June 3, 1959 after an extended illness. Mr. Metzger was RCA ENGINEER Assistant Editorial Representative for the area. R. A. Nolan has been appointed to the position Mr. Metzger formerly held.
—*D. Garvin*

HAMMOND AND WOLFF HONORED

J. H. Hammond, Jr., a member of the RCA Board of Directors since 1923, and I. Wolff, Vice President, Research, RCA Laboratories, have been named winners of the Elliot Cresson Medals from the Franklin Institute.

MURIKAMI AND CORRINGTON RECEIVE AWARD

On Oct. 14 a Presentation of a certificate and $100 award was made to T. Murikami and M. S. Corrington for their joint paper "Tracing Distortion in Stereophonic Disc Recording" which appeared in the 1958 IRE National Convention Record, pt. 7, p. 73. This paper was also published or presented in: *RCA Review,* vol. 19, June 1958, *Acoustical Society of America* Meeting, May 1958, Wash., D. C. Canadian IRE Convention, Oct. 9, 1958, Toronto, Canada, 1958, *Canadian Convention Record,* and is scheduled to be published in *Audio Engineering Society Journal.*—*D. Carlson.*

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ENGINEERING MEETINGS AND CONVENTIONS

DECEMBER 1-2
4th Midwest Symposium on Circuit Theory, PGCT, Marquette University, Brooks Memorial Union, Marquette University, Milwaukee, Wisc.

DECEMBER 1-3
Eastern Joint Computer Conference, PGEC, AIEE, ACM, Statler Hotel, Boston, Mass.

DECEMBER 3-4
PGVC Annual Meeting, PGVC, Florida West Coast Section, St. Petersburg, Florida, Colonial Inn and Desert Ranch.

JANUARY 11-13
6th National Symposium on Reliability and Quality Control, PGRQC, AIEE, ASQC, EIA, Statler-Hilton Hotel, Washington, D. C.

FEBRUARY 3-5
PGMIL Winter Meeting, PGMIL, Ambassador Hotel, Los Angeles.

FEBRUARY 10-12
Solid State Circuits Conference, PGCT, AIEE, University of Pennsylvania, Philadelphia, Pa.

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