RCA ENGINEER

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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

. . . shows a front view of RCA's new Telecommunications Center situated at Meadow Lands, Pa., near Pittsburgh. Engineered and manufactured here are two-way mobile radio communications equipment and audio-visual products; also manufactured are some broadcast audio, microwave communications, and radiomarine communications products. Shown in the foreground are: (right) E. M. Hinsdale, Mgr., Mobile Communications and Audio-Visual Engineering, and R. E. Wilson, Meadow Lands Plant Manager.

Telecommunications and RCA

Say what you will about the "Television Age," the "Jet Age," the "Space Age" and all the other "Ages," they could not develop except in the *Age of Telecommunications*. Electrical communications are as essential to the body social as food to the individual. The transfer of information over short and long distances is the keystone of 20th Century economic activity, in which radio and wire circuits play a dominant role.

Not so long ago, the wire and the radio engineers were in different camps, with little in common. Nowadays they are all one. The job of telecommunications employs all known means of hauling traffic, using in each case the methods best satisfying the economic and technical conditions. Today, the communication-system engineer works in a broad spectrum of space, time, and techniques to provide the means for keeping pace — or even setting the pace — for phenomenal growth in information transport.

Good communications are so basic to our life, and its benefits accepted and assimilated in such a natural way, that the glamor of its marvels is soon lost in familiarity. One has to go occasionally to places in this world where telecommunications are primitive to realize how far these services have developed here in the U.S.A. and what they mean to our material well-being.

The Radio Corporation of America came to life as a communication company and has kept its position in the forefront of communication technology. Its vast differentiations appear in specialized groups in many of RCA's divisions in widespread locations. Communications of specialized kinds are intimately related to all of our major fields of effort — so much so that one can hardly define any boundaries. In the broad sense, all of we RCA engineers are communication engineers, some in one-way systems and some in two-way. However, it is the latter that we often think about subconsciously as *communications* because the term *broadcasting* covers the first, a field in which we have always been pre-eminent.

Opportunities in the years ahead will certainly lean heavily toward two-way communications, so we must develop objectives that prepare us for an ever more prominent place in military and civil telecommunications. We are solidly based for this effort, and we have only to direct our attention and resources wisely. The technological and business challenges can satisfy the most adventurous men among us. The road ahead is clear — the world always will need more and better telecommunications.

E. A. Laport, Director
Communications Engineering

Research and Engineering
Radio Corporation of America
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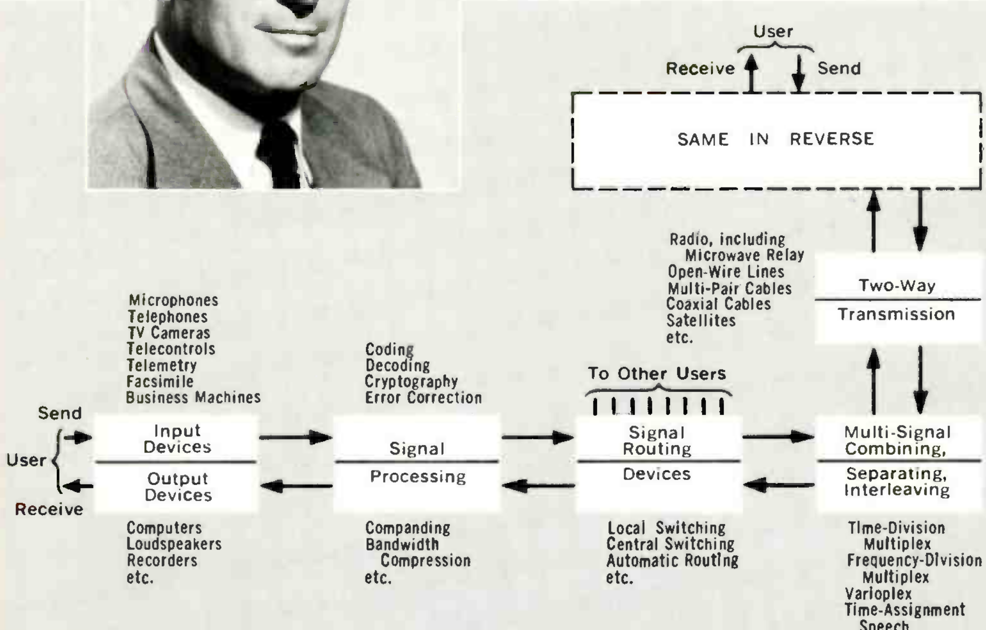

BASIC TELECOMMUNICATION SYSTEMS — MAIN EQUIPMENT CLASSES

CONTENTS

The Engineer and the Corporation: (Mathematics)$^{n+1}$ for Engineering Management ..... C. Fallon 2
Meadow Lands—RCA's New Telecommunications Center ..... N. C. Colby 5
The New E-Line Two-Way Mobile Radio ..... F. Papouschek and W. J. Sweger 8
Four RCA Men Elected IRE Fellows 11
New 5-kw Transmitter Provides Versatile Communications ..... B. Autry and L. Canto 12
SSB Transceiver for Fixed or Mobile Applications ..... E. W. Mahland and C. E. Schneider 15
The White Alice Communications Network ..... F. D. Chiei, Jr. 18
The MM-600 Microwave System Between Rimouski and Mt. Carleton, Canada ..... J. E. H. Elvidge, N. M. Lopianowski, and L. A. Martin 22
Switching in Communications Systems ..... G. F. Abbott and W. B. Groth 26
Automatic Store-And-Forward Message-Switching Centers for ComLogNet ..... R. J. Segal and H. P. Guerber 30
Improved Disturbance Forecasting for the H-F Band ..... J. H. Nelson 34
H-F Radio Communications for International Commercial Service ..... D. S. Rau 37
The Nuvistor Family—Commercial and Developmental Status ..... J. T. Cimorelli 40
560-kw Satellite Surveillance Transmitter ..... J. F. Eckert and J. R. Scheitinger 44
New MM&SR Signal-Processing Skill Center 49
A Versatile Man-Computer Communication Console for Information-Processing Systems ..... P. B. Lazovick, A. W. Reickord and J. C. Trost 50
Interleaved Sound—Standby Audio and TV Picture Transmission over a Single Video Circuit ..... J. L. Hathaway 54
Angle Calibration by Use of the Stars ..... D. R. Billetter 57
Pen and Podium 60
Professional Activities—Dates and Deadlines 60
Patents Granted 61
Engineering News and Highlights 62

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The Engineer and the Corporation

(Mathematics) $^{n+1}$ for Engineering Management

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Mathematics of decision-making, problems of choice, operations research, value engineering, all these terms evoke an anguished sigh from the engineer anxious to progress professionally. Our engineer is frustrated. None of his formal math fits the new pattern—all the endless hours studying classical math, *wasted?*

Not so. Though technology and its management today demand wider and often-specialized *applications* of mathematics, the groundwork of modern and classical mathematics is the same. The engineer is well ahead of the field in his capacity to grasp modern mathematics, and his basic education in math and the physical sciences provide excellent background.

Ever since the time when Galileo taught physics as Professor of Mathematics at Padua, mathematics has been associated with the physical sciences in Western universities. The physical sciences themselves, however, had been long regarded as an intellectual exercise whose utilitarian worth was beneath the interest of true scholars. To this day, classical mathematics is accused of growing up in an ivory tower. To some degree this is true.

After all, beautiful princesses, innocent and untainted by greed, often grow up in ivory towers. Freed from bounds of specialized application, classical mathematics was able to develop into the universal tool that it is today, thanks, in part, to the ivory tower that allowed true abstraction.

PRINCESS OR HANDMAIDEN?

In this ivory tower, mathematics has grown up as a *princess* and not as the handmaiden of science. In the first European universities, Bologna and Modena, the physical sciences were taught *in the faculty of mathematics*, as they were to be taught later at Pisa, Padua, and at the universities which were chartered soon thereafter: Salamanca, Avila, Pamplona, Coimbra, Poitiers, and Paris.

Sometime during the twelfth century, France cut down on foreign aid, and many English students at the University of Paris had to go home. They gathered at Oxford and formed a corporation to continue their studies. Part of the cultural loss that must accompany such a change-over was the demoting of mathematics from a princess to the mere handmaid of science.

This Cinderella-like humility still afflicts some English-speaking mathematicians. "If I had to name one trait that more than any other is characteristic of professional mathematicians," writes R. P. Boas, Jr., in the *American Mathematical Monthly*, "I should say that it is their willingness, even eagerness, to admit that they are wrong. A sure way to make an impression on the mathematical community is to come forward and declare, 'You are doing such-and-such all wrong and you should do it *this* way.' Then everybody says, 'Yes, how clever you are,' and adopts your method."

This scholarly humility is sometimes beamed toward industry. "Tell us what you need," says the University, "and we'll cook up a program."

Frankly, that may be all right for the handmaid of science, but a princess should call the shots.

What happens? A nonmathematician, suddenly discovering the value of mathematics in his own specialty, demands that the classical curriculum be curtailed to make room for his own special mix of mathematical techniques. Like peasants in a royal forest, the "new" techniques invade the campus.

This is not the answer. As engineers, we still need the princess. But we *are* looking for a way to provide future engineering managers with the mathematical tools of management, as well as of engineering. Rather than abandon the classical approach, we can seek out the most suitable peasants and invite them up to the ivory tower.

I refer to such youths as linear programming, operations research, the Monte Carlo method, queuing theory, game theory, and value engineering. While too late to have them grow up pure, you *can* give them a good bath. All these young men have noble traits of character worthy of the princess, but the bath *is* necessary to remove the rampant empiricism concealing their virtues.

You will find that, once cleaned up, these lusty peasants will turn out to be well-born children of the nobility, stolen in their youth by industrial pirates or military robber barons, and taught such vile tricks as catching foxes without a formal fox hunt.

THE NEW MATHEMATICAL TOOLS

Let's look at them first in their peasant's garb. The linear programming of today stems from W. W. Leontieff's input-output method of economic analysis. This had replaced the French technique for solving scarcity problems with simultaneous equations. It was not until George B. Dantzig, of the Rand Corporation, developed practical algorithms for working out the computation that linear programming became an accepted tool in military and industrial planning. Under the garb of a militarized economist, we have a perfectly legitimate, well-born child—our own linear algebra and matrix theory.

Now look at operations research. In World War II, at the lowest ebb in the Battle of Britain, the allied high command decided that an objective and intelligent appraisal of the situation had to be made at once. The top brass knew that they themselves were committed to their special tasks far beyond any hope of overall objectivity. Scientists, being presumably intelligent *and* objective, were hastily gathered into teams to analyze the various aspects of the U-Boat blockade and the air blitz.

We know now that the results of this scientific analysis and the measures it generated were a decisive factor in winning the war. Because it began with research into the effectiveness of military operations, this application of mathematics to broad fields with many variables and much uncertainty, acquired its name of *operations research*.

The task of mathematics and the other disciplines involved was not so much the solution of specific problems but the nobler and far more important task of bringing man face to face with reality. I believe that the chief virtue of operations research today is that it minimizes self deception.

Operations research does not take an exclusively mathematical approach to a problem. One team may be made up of a senior harbor pilot, an assistant harbormaster, two mathematicians, and an engineer. The mathematical techniques are:

Mathematical statistics, including decision theory, game theory, and Monte Carlo methods.
Probability, logic, set theory, and queuing theory.
Matrix theory and linear algebra.
And, of course, numerical analysis.

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These are the same techniques used in value engineering, but in quite different proportions. Operations research uses more probability and statistics, game theory, and queuing theory, while value engineering uses more matrix theory, linear algebra, and numerical analysis.

Operations research is a method for providing management with a scientific basis for the solution of executive problems. Value engineering functions in the more limited area of weighing, comparing, and balancing desirable characteristics in order to achieve the necessary combination at minimum cost in resources.

ENGINEERS AND DOLLARS

Dollars are our major yardstick for measuring resources, and most engineers have to *learn* about dollars. This genteel deficiency stems from the medieval concept of noble, commercial, and plebian occupations. Engineers were *gentlemen* not *tradesmen*, they didn't care about money and they never paid their tailors.

Today we have to pay everybody, and the company has to pay us and others as well. We *have* to know about dollars.

CARLOS FALLON is Administrator of Value Engineering for the Missile and Surface Radar Division of R.C.A. Previously he was Manager of Manufacturing at Tele-Dynamics, Chief Mechanical Design Engineer at Nems-Clarke, Systems Engineer in the Vitro Silver Spring Laboratory, and Production Engineer at Nems-Clarke. In addition to his experience in the design and production of military electronics equipment, he has designed a missile launching system for destroyers, the air-particle sampler used in our nuclear submarines for radiation hazard control, and the 120 Curie gamma ray source for the New York Naval Shipyard. Mr. Fallon's education, equivalent to that of a Master of Science in Mechanical Engineering, was obtained while he was an officer in the Colombian Navy under the British and U. S. Naval Missions. In Colombia, he was a member of the Ministry of War Engineering Board and was in charge of naval construction and repair.

This brings us to the mathematics of finance, really a combination of disciplines: some mathematics *and* some persuasion. It exists for a number of conflicting purposes: *one*—to tell management what is happening; *two*—to tell the banker that the business is doing very well; *three*—to tell the tax collector that the business is not doing well at all; *four*—to apportion investment capital in harmony with *one*, *two*, and *three*.

I believe this problem would have been minimized if the "mathematics of finance" had been taught *as mathematics*, and the presentation of the resulting information had been taught separately. As it is, the engineer has a hard time finding out what some of his operations actually cost. And he *has* to know, if he is a good engineer.

Alas! There is no one to help him. Mankind has not completed the change-over from the bazaar method to the laboratory method of cost accounting.

The engineer, himself, has to wade through the vagaries of finance—the cost of an ECN, the cost of a purchase order, the cost of one hour's drafting, the cost of environmental testing.

"How much for an ECN?" he demands.

And they snow him, winding up with, "The rest is covered by the burden—overhead, you know."

"Just how did you arrive at that burden," he should ask gently. "How much of the cost is variable and controllable and how much is fixed and inexorable? Does it include money that would have to be paid whether the work was done or not?"

Actually, finance people are as conscious of their professional principles as we are of ours. They are usually pleased to have an engineer exchange views with them on a professional level. A working relationship with them is essential to sound decision-making. But neither the mathematics of finance nor conventional engineering mathematics are sufficient to decide most management problems of choice.

For each class of problem one needs limited portions of some of the techniques listed under operations research above. These morsels are frequently offered in "short courses" which take the mystery out of certain special applications, but a tailor-made package lacks the abstractions and *general* applicability of a mathematical method. Operations research, linear programming, and value engineering are *ad hoc* prescriptions for specific situations—and very successful prescriptions at that—but they should not be described as purely mathematical methods.

HOW TO PRACTICE ENGINEERING IN MANAGEMENT

Truly mathematical tools are applicable over broader areas, and engineering management is a very broad area indeed. So broad, in fact, that many an engineer hesitates to go into management for fear of losing touch with his engineering.

He will not lose touch if he applies engineering principles to the art of management itself: scientifically reducing areas of uncertainty, calculating the probabilities of the remaining uncertainties, assigning weights to the various choice factors, and finally evaluating the consequences of possible courses of action. This is as much fun as creative design work and quite as scientific, but the mathematical techniques vary from one application to another in such a way that no single package will do the trick.

Of course, the neophyte manager could seek advance training in all the basic techniques of modern abstract mathematics, but then he would not have time to apply them.

HOW TO ACQUIRE THE NECESSARY TECHNIQUES

A good course of action is to approach each individual decision as scientifically as possible and to master the particular mathematical techniques required in each class of problem as it appears. But you have to know what mathematical techniques are applicable; *this means you have to know a good bit about modern mathematics.*

A good way to start is to join the Mathematical Association of America. It only costs $5 a year and the publications are very good. Then I suggest you go to the library and pick up some of the books in the bibliography included with this article. Start with the elementary ones—they are actually fun to read.

By this time you should receive the *American Mathematical Monthly*. You will enjoy parts of it—there is something in it for everybody—but it is not likely that you will swim deliciously through the contents to surface triumphantly into the sunshine of accomplishment. No, you will probably hit your head on a sunken rock. One of the newer branches of mathematics will have been created, accepted, and permanently established while you were diving.

And there is the problem. Which of the new branches of mathematics can you follow? You know you can't follow them all. With how many can you keep up? It may mean giving up golf or being left hopelessly behind. You *had* been left behind, but you didn't know it. Now it is different.

VALUE ENGINEERING IN WEIGHTING THE ALTERNATIVES

Being a combination of methods for achieving a desired end at minimum cost in resources, value engineering can help you determine what you really want.

The resources in question are spare-time hours, and you have to find the most effective way to use them. This brings into play a complex variable—your wife. And a constant of integration—taking the children to Sunday School.

But even if you can get the variable, within the limits of its range, to cancel out the constant; that is, if you can get her to take the kids herself some of the time, there is really not too much you can do to reduce the expenditure of resources. It is in the upper part of the fraction: *desired end/cost* that the gravy can be harvested.

Your *desired end* was professional improvement. It seemed so important to you that you even considered giving up golf for it. Value engineering asks you these questions. "Is it really that important? Are you *twice* as good in engineering as golf? Would it be three times? You say *half!* . . . ?You mean you are *better* at golf? Why as a golf pro you can make a living and you won't need much mathematics—counting up to ninety, at worst."

At this point value engineering is being carried away by its rigid objectivity. It is supposed to be objective *except* in the area of customer desire. The *desired end* is obviously subjective.

You are the customer. Now let's say you are not the outdoor type. Even if you are better at golf, you still want to improve your engineering management skill—you enjoy it more. Value engineering must accept your final definition of the *desired end*. It takes another look at your resources to see if this final definition changes matters. No, you still need all the spare time you can get, so it makes its first recommendation: Give up golf and make your wife take the children to Sunday School.

Now that available resources have been determined (Saturday afternoons and Sunday mornings), value engineering tries to convert them into your actual requirements. In your case it is simple. You screen the instructional material for digestibility and economic feasibility, eliminating translations from the Russian in which the verbs are omitted and anything for which the first book costs more than $9. Then you survey the selection and assign to each mathematical technique a coefficient of usefulness on the basis of what it can do for you, and a quotient of cost on the basis of the units of time required to gain a reasonable understanding of the subject. The higher fractions would, of course, be the best values.

But you have to take into account all uncertainty associated with the future. Will your golf improve to the point where you owe it to the nation to play professionally? Which of these branches of mathematics will have permanent value and which will fall by the wayside? Will your wife meekly take the children to Sunday School herself or do you have to frame her into being elected a teacher so that she *has* to go? How many friends drop in on you on Saturday afternoons and Sunday mornings? For all this, you have to turn to operations research.

RACKING UP THE RESULTS

Rather than being all probability and statistics, operations research first eliminates many supposed areas of uncertainty, minimizes others, and *then* runs a sound probability study on the rest. By this time you will know:

1) That you can survey n branches of mathematics.
2) That the most promising of these are n_1, n_2, and n_3.
3) That you will have to resign from the golf club.
4) That you will have to frame your wife into being elected a Sunday School teacher.
5) That of the friends who drop in on you Saturday afternoons and Sunday mornings, one may have to be seriously insulted, but the other two can probably be driven away by warning shots.

At this stage, linear programming can find for you the most economical and expeditious path through time and space in order to carry out the study program contemplated in *1* and *2*, and to accomplish tasks *3*, *4*, and *5* in optimum sequence and with minimum time and effort.

MEADOW LANDS
...RCA's New Telecommunications Center

by **N. C. COLBY, Mgr.**
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RCA's new "Telecommunications Center" in Meadow Lands, Pa., shown on the front cover of this issue, provides a centralized, modern home for engineering, and manufacturing activities for many of RCA's communications product lines. The engineering personnel moved in during March 1961, and occupancy was completed when the manufacturing organization was established in July.

At the present time, Meadow Lands is the home office for two product-line engineering and manufacturing organizations — *Two-Way Mobile Radio Communications Equipment* and *Audio Visual Equipment.* (The two-way radio line is described in detail by Papoushek and Sweger elsewhere in this issue.) The audio-visual line consists of three principal product lines—Audio Visual, Teaching Devices, and Engineered Sound Products.

RCA is not a newcomer to the Meadow Lands area (near Pittsburgh), having established record pressing facilities at Canonsbrug, Pa., in 1947 and radio and record manufacturing there in 1950. By 1959 both these activities had been discontinued and forty people remained to produce components for the RCA 501 computer; during this same year, the two-way mobile radio manufacturing activity was moved to Canonsburg.

MEADOW LANDS SITE CONSIDERATIONS

Two conditions existed that led to RCA's establishing a new activity in this area. RCA needed a modern and efficient manufacturing facility to produce communications equipment for a highly competitive market. The Washington–Meadow Lands–Canonsburg area of western Pennsylvania was short on job opportunity and long on manpower, and had a far sighted, aggressive Industrial Development Corporation. After many months of fact gathering a decision was made to locate the Two-Way Mobile Radio Communications activity there.

Of the many considerations involved, an outstanding one was the financial support given the venture by the Greater Canonsburg Industrial Development Corporation and the Pennsylvania Industrial Development Authority. Bonds were purchased by the citizens of the community, employed and jobless alike, in support of the Development Corporation's effort to attract new industry.

Living accommodations are found in the surrounding areas to please every taste—sophisticated metropolitan Mount Lebanon and Pittsburgh, suburban Peters Township and the peaceful, rolling, not-quite-mountainous rural areas to the south and west.

WHERE IT IS AND WHAT IT IS

The new Meadow Lands plant is located approximately 30 miles southwest of Pittsburgh, on a level fifty-acre site surrounded by farm-studded hills. The site may be reached by auto, from the east and west by U.S. Highway 40 and the soon-to-be-completed superhighway Interstate Route 70, and from the north and south by U.S. Highway 19. Visitors arriving by plane land at the Greater Pittsburgh Airport, an easy 30 miles by scenic country highways or a few miles more by less-direct but faster-travelled parkway and U.S. highways. Bus service is available from Pittsburgh. A modern airport, accommodating private planes and small commercial planes, is located a few miles to the south of the plant, on the outskirts of Washington, Pa.

The Meadow Lands facility consists of three distinct buildings connected by ramps and hallways: a factory, a cafeteria and an administration building which includes the engineering laboratories. The manufacturing area has 147,000 sq. ft. of fully air-conditioned space in a modern split-level building; with its vertical white aluminum siding and low lines, it presents a very smart appearance (see cover). The administration building has 46,500 sq. ft. of office and laboratory area on two floors. Contemporary design and imaginative, decorative lighting are effectively combined. The cafeteria ties the other two buildings together, and has a seating capacity

N. C. COLBY received the B.S. and M.S. in Physics from the University of Illinois and then joined the staff of the Radiation Laboratory at M.I.T. He served four years in the radiation laboratory doing research and development work on 30,000 Mc high-definition radar. For a portion of this time he was on loan to the Bureau of Standards, assisting in setting up standards of microwave frequency and power measurements. Mr. Colby joined RCA in 1946, and until July 1960 was engaged in the design and system operation of large scale industrial microwave-communication systems. Since July 1960, he has been Mgr., Systems Engineering, at the Meadow Lands Plant. Mr. Colby is a member of Sigma Xi, the IRE, and the IRE professional groups on Communication Systems, Vehicular Communications, Antennas and Propagation, and Engineering Management.

The author, N. C. Colby (left), and R. E. Wilson, Meadow Lands Plant Mgr., are looking over one of the new "Efficiency-Line" table-top base-station equipments produced at Meadow Lands.

of 240 in the main dining room and 40 in the "special occasions" room. Diners view an outdoor terrace and courtyard through spacious glass sliding doors.

The first floor of the administration building is occupied by Management. Personnel. Marketing. Purchasing. Accounting. and the Dispensary. The upper floor is occupied by Engineering, its laboratories. shops. drafting facilities. environmental test equipment. and library. The telephone system equipment also is on the second floor, at present with 300 satellite phones and tied into RCA's nationwide leased-line system by five tielines.

The factory area is occupied by assembly lines, the Quality Control group, parts and finished-goods inventory, shipping and receiving facilities, the Order Service group, factory-management personnel, and in a well-decorated corner room, the Employees Sales Store.

ENGINEERING AND MANUFACTURING

The Engineering Department, with the present staff of 40 engineers, is responsible for the design of audio-visual and two-way radio equipment, as well as for the design of the Special Products line which includes two-way Citizen's Band radio equipment, interoffice communications equipment, Citizen's-Band radio test equipment, and an economy line of industrial audio amplifiers. The Citizen's-Band radio equipment consists of low-power hand-held fully transistorized equipment and higher-power equipment for base or moblie stations.

A variety of products are manufactured in the Meadow Lands Plant. In addition to items in the two-way radio, audio-visual, and Special-Products lines, the factory produces equipment for other activities. For the Broadcast and Communication Products Division, it produces some audio products, TV camera cables and microwave system components including some for the new Western Union transcontinental microwave system. The SSB-5 equipment is manufactured here for the Radiomarine Department. Some small craft radar and many printed-circuit boards for the RCA 501 and RCA 301 computers are also built.

CONCLUSION

The Meadow Lands plant is among the most modern of the RCA facilities and is destined to play an important role in helping RCA lead the way in developing systems and equipment to meet the ever-increasing need for communications. It is also expected that the Meadow Lands plant will play an important role in the economic development of a fine community in western Pennsylvania.

Fig. 2

Fig. 3

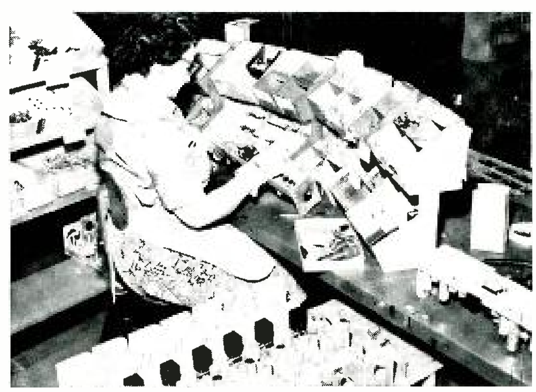


Fig. 4

Fig. 5

Fig. 6

Fig. 1—Engineering offices.

Fig. 2—Assembly lines are laid out to facilitate progressive component assembly, chassis assembly, inspection, and storage. System assembly, system tune-up and test, and packing are done to customer order.

Fig. 3—A first step in manufacture of a receiver "strip" for two-way mobile radio is construction of the wiring harness. June Hood shows use of templates.

Fig. 4—Ilda Scott adding the first components to the bare chassis—the beginning of the "assembly line."

Fig. 5—Preformed wiring harness is added by Lois Koehler to the chassis.

Fig. 6—Completed chassis under final inspection by Agnes Krupar and George Trout.

Fig. 7—After final inspection, chassis is aligned and tested by Thomas Balaban as an operating "strip" and then stored in "strip stock."

Fig. 8—"Buttoning-up" by Ralph Dagnana—a transmitter strip, a receiver "strip" and a power supply for a specific customer are assembled into the mobile unit case.

Fig. 9—As a final step in quality control each mobile transmitter-receiver assembly is tested by operating it for four hours, in a manner programmed to simulate actual on-off use. The unit is next given a vibration test, followed by a complete operational check to verify that all performance specifications are met. Foreground: Rudy Martincic; background (l. to r.) Don Bailey and Norm Colby.

Fig. 10—Completed unit is tuned to a specified transmitting and receiving frequency. l. to r.: John McNansky and Jim Fielding.

Fig. 11—Engineering lab where designs are conceived and executed. Emphasis is on best possible working conditions through air conditioning, adequate lighting, and low background noise.

Fig. 12—George Kamerer starting temperature-humidity cycling of a breadboard circuit.

Fig. 12

Fig. 11

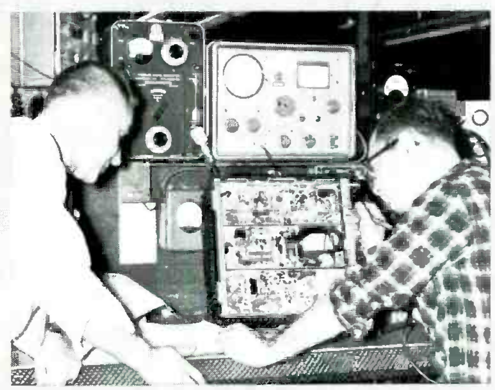


Fig. 10

Fig. 7

Fig. 8

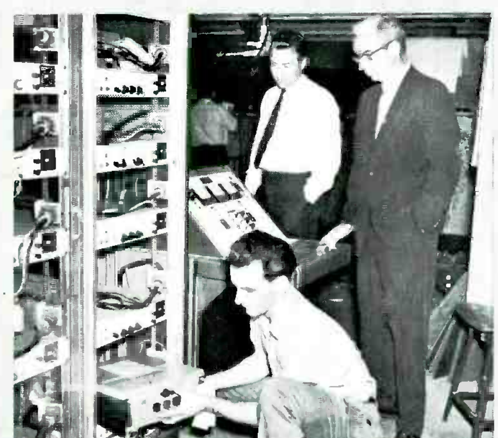


Fig. 9

THE NEW "E-LINE" TWO-WAY MOBILE RADIO

Two-way mobile radios are used extensively today in a communications business that is nearing the $100,000,000 mark in average yearly sales. This important branch of the industry includes equipment providing voice communications between vehicles, or between a vehicle and a base station. Authority has been granted by the FCC to equip more than a million vehicles. Described herein is the engineering of the RCA "E-Line" equipment for that market.

by **F. PAPOUSCHEK and W. J. SWEGER**
Mobile Communications Engineering
RCA Service Co., Meadow Lands, Pa.

THE PRINCIPAL USERS of two-way mobile radio other than private individuals and the familiar taxicab companies are: *public safety radio services,* including police, fire, forestry conservation, highway maintenance, and local government; and *industrial radio services* including motor carriers, railroads, and automobile emergency services. A two-way system may consist of one or more base stations and several mobile radio units each containing a transmitter and a receiver. In most cases, each base station can communicate with all mobile units. The useful base-to-mobile range may vary from 10 to 100 miles, depending on terrain, antenna elevation, and transmitter power output. The range is somewhat less for communication between vehicles, mainly because of practical limitations on the size of the vehicle antenna. Mobile transmitters are designed for radiated power outputs of 15 to 100 watts depending on the frequency and range requirements. Base station transmitters are designed for radiated power of 30 to 350 watts. The range and radiated power of base stations is generally greater than that of mobile stations, since base station antennas can be designed for high gain and can be located at elevated points. Typical sensitivities for both mobile and base station receivers are in the range of 0.3 to 0.8 μv.

GENERAL DESIGN CRITERIA

The use of two-way radios is subject to regulation by the Federal Communications Commission (FCC), which issues licenses and assigns frequencies to users. The FCC specifies certain minimum performance standards for the transmitter, such as carrier frequency stability, spurious radiation, and transmitter modulation. The frequency bands reserved by the FCC for nonmilitary two-way radio traffic are centered on 40 Mc, 150 Mc, and 450 Mc. Because of the rapidly increasing use of two-way mobile radio communication, the available frequency spectrum has become more and more crowded; to make more channels available, the channel spacings were reduced to 20 kc, 30 kc, and 50 kc respectively. Since the demand for more channels continued, the 30-kc channel spacing of the 150-Mc band was further narrowed down to 15 kc. Additional relief by a possible reduction of the 450-Mc channel spacing to 25 kc is under study by everyone concerned; however, one of the principal problems in reducing channel spacing is the increased frequency stability required.

Operating Conditions

Today's commercial two-way mobile communications equipment uses frequency-modulated transmitters and receivers to reduce interference and noise. Because the equipment is installed in passenger cars and trucks, it must be compact and rugged to withstand extreme vibration and shock. The equipment must be designed to operate satisfactorily under a wide range of climatic conditions, including the high temperatures experienced in vehicular installations. Mobile units are powered from the automobile or truck battery; therefore, a low-power drain is essential. To reduce the average current drain and heat dissipation during normal operation, only the receiver is kept *on;* the transmitter is energized only for the short periods of transmissions. To transmit, a *push-to-talk* button on a hand-held microphone is pressed, thus applying power to the transmitter. The mobile transmitters must be designed to operate on a duty cycle of 20 percent; experience has shown this duty cycle to be the maximum transmission time in normal use.

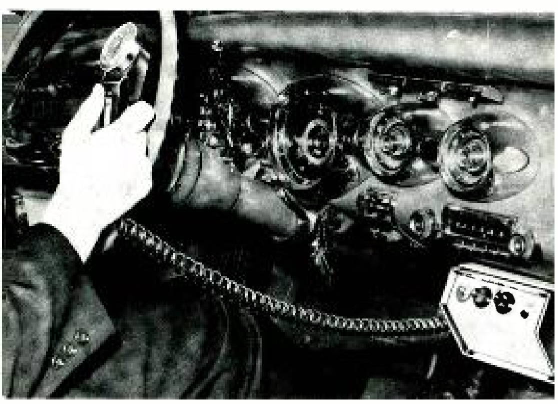


Fig. 1 — E-Line power supply and control unit mounted for vehicle use.

Fig. 2—E-Line 450-Mc transmitter-receiver.

Fig. 3—Desk-top base station.

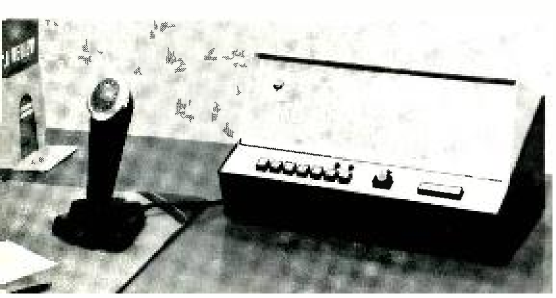
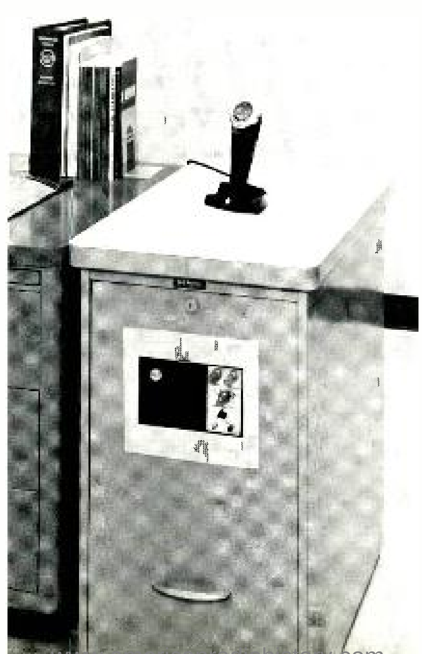


Fig. 4—Remote-control for base-station.

Fig. 5—Floor-cabinet base station.



Selective Call

In many areas it is not possible to assign each user a different frequency; as a result, several systems must operate on the same frequency. To avoid conflicts, selective communication on the same carrier can be provided by incorporating a *quiet-channel unit*, which generates a low-frequency tone for modulating the transmitter carrier. The audio amplifiers of all receivers in the same system are normally biased to cutoff and are equipped with a selective device which responds only to the tone on the transmitted carrier. The quiet-channel tone modulation of the corresponding master transmitter will remove the cutoff bias, causing the audio section of the receiver to operate. Different system receivers in the same area operating on the same carrier frequency are triggered *on* by different quiet-channel tones. A switch allows the operator to disable the quiet channel and monitor the channel before transmitting.

DESIGN REQUIREMENTS

The design of mobile equipment presents challenging problems to the design engineer, since equipment must be as compact as possible without sacrificing reliability and economy of manufacturing and servicing. The total current drain from the car battery must be kept to the lowest possible value. Stringent specifications on harmonic and spurious radiation create severe problems in the shielding and placement of components.

With the required reduction of channel spacing, receiver design is more difficult because of the increased interference caused from the closeness of adjacent channels. In order to reduce spurious reception to an acceptable level, the bandwidth of the receiver must be reduced by using more tuned circuits with improved electrical quality.

"LOW-DRAIN" — 40 AND 150 MC

For the past two years RCA has produced, in addition to earlier all-tube designs, the *low-drain* line of equipment for operation in the 40-Mc and the 150-Mc band. Low-drain equipment is very popular because of its excellent performance, low standby-current drain, and low cost. The low current drain is achieved by transistorizing the low i-f and audio sections of the receiver. In a mobile installation, the transmitter, receiver, and power supply are contained in a case suitable for mounting in the vehicle trunk compartment. All controls are contained in a small unit mounted under the dashboard of the car. The loudspeaker is separate and may be mounted in any convenient location.

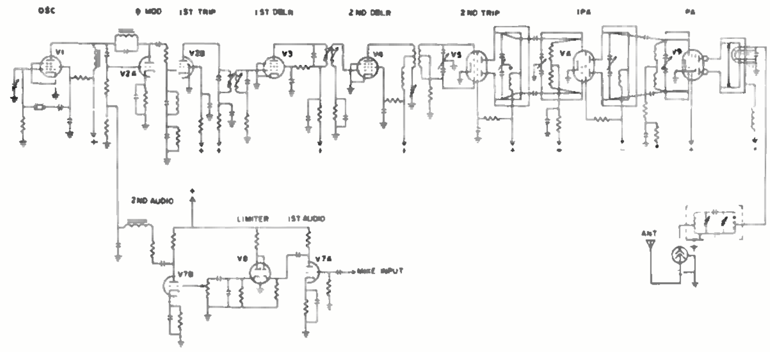


Fig. 6 — Simplified schematic of the 450-Mc E-Line transmitter.

"EFFICIENCY LINE" — 450 MC

To meet the growing use of the 450-Mc band in mobile two-way traffic, emphasis was placed in 1960 on the development of a top performance 450-Mc equipment. The new 450-Mc equipment is called the efficiency, or *E-Line*, equipment and is for 50-kc channel spacing (Figs. 1-7).

To achieve economy, the E-Line was designed solely with tubes except for the power supply; the E-Line power supply is transistorized (as in the power supply of the "low-drain" line, which has proved to be a very reliable unit). For flexibility and economy of space, the entire equipment is mounted in only two enclosures. The transmitter and the receiver (Fig. 2) are mounted in a steel case which can be installed anywhere in the car. The converter is mounted in the control unit, thus reducing the size of the transmitter-receiver container. Placement of the converter in the control unit also solves a difficult component temperature problem, since heat generated in the output stages of the transmitter-receiver does not affect the power-supply transistors. The E-Line control unit which contains all controls and the loudspeaker, is usually mounted under the dashboard (Fig. 1).

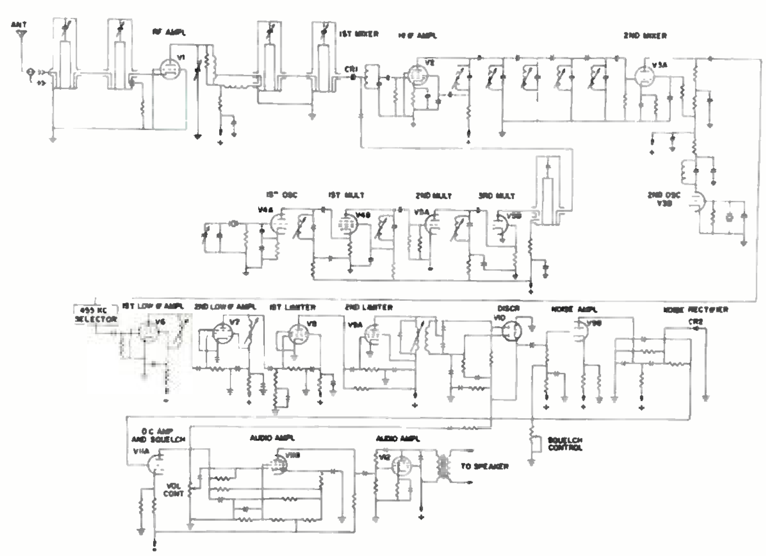
Transmitter

The basic schematic of the transmitter is shown on Fig. 6. Oscillator frequency is produced by high-precision crystals in a temperature-controlled oven held to tight temperature tolerances to limit frequency variations over the operating temperature range to within ±0.0003 percent. When operation on two frequencies is required, a second oscillator can be included and a control-unit switch can be provided for frequency selection.

Either a carbon or a dynamic microphone may be used for voice modulation. Audio from the microphone is amplified in two amplifier stages, which include a *symmetric clipper* (Fig. 6). The symmetric clipper is necessary to limit the frequency deviation to ±15 kc; maximum deviation is adjusted by a potentiometer and the upper audio frequency is limited to 3000 cps by an audio rolloff filter.

Oscillator output and audio are applied to the phase-modulator; the crystal frequency (12.5 to 13.05 Mc) is multiplied 36 times to arrive at the output frequency of 450 to 470 Mc. Single-ended circuits are used up to the second tripler; from there on to the output, push-pull circuits are used. A 6939 type tube serves as the second tripler and as the driver, while a 6524 type tube in the output power stage delivers 15 to 22 watts to the antenna. Finally, a tuned line is used in the plate circuit, and a twin-cavity filter is inserted in the antenna

Fig. 7—Simplified schematic of the 450-Mc E-Line receiver.



lead to attenuate harmonic and spurious outputs.

Receiver

Fig. 7 shows the basic schematic of the dual-conversion receiver with crystal-controlled oscillators for the first and second injection frequencies. The frequency of the first oscillator is about 13 Mc, and is multiplied 36 times to obtain the first injection frequency. Two oscillators may be installed for two-frequency operation and may be switched from the control unit; spacing of these two frequencies is limited by the bandwidth of the receiver.

Four tuned cavities are used ahead of the first mixer to obtain the desired image rejection and minimum cross-modulation. A grounded-grid triode is used as the r-f amplifier. Five high-Q, tuned circuits minimize spurious reception in the first i-f (15.145 Mc). The second mixer and second oscillator (15.6 Mc) convert the first i-f signal to 455 kc; the 455-kc i-f filter in the plate of the second mixer is responsible for almost all the receiver selectivity. The low i-f section consists of four amplifier-limited stages and a discriminator as the FM demodulator.

Two audio stages provide an output of 3 watts. The receiver is equipped with a squelch circuit in which a threshold point, or gating level is adjusted by the squelch control. In the absence of a carrier, noise at the output of the discriminator is amplified and rectified. The rectified noise voltage is used to cut off the audio amplifier; carrier signals above 0.4 μv remove the noise and open the audio channel. In cases where more than one system are operating on a single frequency, the quiet-channel unit may be used; operation is identical to that used in the low-drain equipment.

Control Unit and Power Supply

All E-Line units are wired by series-parallel connection of the tube filaments for 6.3 and 13.6 volts and are, therefore, directly interchangeable in 6- or 12-volt systems. Two types of control units are available, one for 12-volt operation, the other for both 6 and 12 volts. Field conversion from 6 to 12 volts (or vice versa) can be accomplished in a few minutes.

Base Stations

RCA has developed a complete new line of base stations for all three frequency bands: for low-, medium-, and high-power outputs. Base stations are available in a large variety of configurations; a desk top unit, a floor cabinet, a rack-mounted unit, a wall-mounted cabinet, and a pole-mount type. Receiver, transmitter, and power-supply units are the same as those used in the mobile equipment. This mutual usage achieves maximum economy from the standpoint of manufacturing, inventory, parts stocking, instruction books and service.

As a companion of the E-Line mobile units, the base-station design satisfies most of the basic two-way communications requirements. The desk-top model shown in Fig. 3 is only 6¼ by 14½ by 19 inches in size and is available in low- and medium-power output models for 50-Mc, 150-Mc and 450-Mc bands. Although normally controlled from the front panel, the base-station equipment can also be used with a separate control unit in addition to, or less the front-panel control facilities. Another choice is remote control over a two- or four-wire line by the addition of a line termination unit; the remote-control model is shown in Fig. 4.

The floor cabinet version (see Fig. 5) is a more sophisticated model which can be connected for the large variety of operational modes occurring in two-way communication. Built and styled for office use beside the operator's desk, provisions are made for either front-panel control or remote control by use of a desk-control unit located as far away as 100 feet; another mode of operation is remote control over a telephone line with the companion line termination panel incorporated in the unit. A second receiver with its own power supply can also be employed for simultaneous reception of two frequencies or for two widely spaced frequencies.

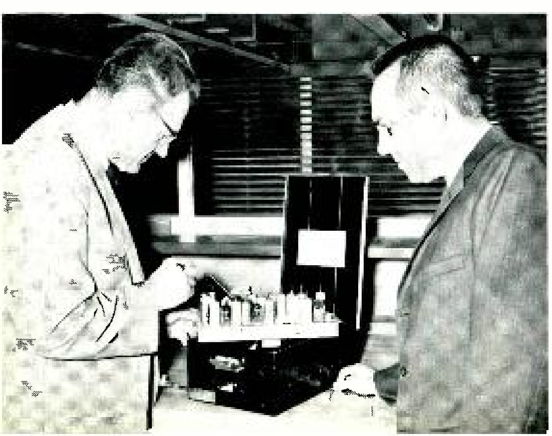
Another option is the use of a carrier-operated relay controlled by the carrier frequency of one of the receivers; the relay may be used to switch the second receiver or to key a transmitter. Four-frequency operation with quiet-channel units incorporated in both receivers is a further possibility. A convenient meter panel is provided in all models to check the alignment of the units and for ease of servicing. All the combinations described may be mounted in a wall cabinet, or located wherever space is available. The operator may find the small desk-top control unit convenient for operating the system. Larger units, especially those with high-power amplifiers, are mounted in standard rack cabinets. Where Pole-Mount cabinets are used for outdoor installations, separate desk-control units similar to those of the wall-mount models are used.

CONCLUSION

The E-Line two-way mobile radio is a versatile assortment of communications equipment including transmitter-receiver, power supply and control unit, base-station equipments and remote-control unit that provides a wide choice of operating modes.

FRANZ PAPOUSCHEK received his *Diplom Ingenieur's* degree (MEE) at the Prague University, Czechoslovakia. He took post graduate courses in Mathematics at the Berlin University, and postgraduate courses in electronics at the McGill University in Montreal, Canada. He has been concerned with the development of communications and broadcast equipment since 1930. He joined RCA, Montreal, in 1951, as project and development engineer in commercial and military communications projects, including communications receivers, SSB equipment, airborne and marine communications equipment, FM multiplexing receivers, and systems engineering. He was granted several patents in the field of frequency synthesizers and communication circuitry. He joined the communications group in Meadow Lands in 1960, and is responsible for the development of mobile and base-station equipment.

W. J. SWEGER received his B.A. in Physics from Washington and Jefferson College in 1949. From 1951 until 1955, he was with the Naval Ordnance Laboratory as an electronic engineer in research, design, and development of radio-type proximity fuzes for projectiles and rockets. From 1955 to 1956, he was a fuze design engineer with the R&D Division at the Navy Bureau of Ordnance, with responsibility for coordination and administrative direction of VT fuze R&D programs at the Naval Ordnance Laboratory, and at BuOrd Contractors. In 1956, he joined the Physics Division, Nuclear Instrumentation and Controls Group of Curtiss-Wright Research Division's Nuclear Power Department. From 1958 to 1959, he was Group Leader of the Reactor Instrumentation and Controls Section. In May 1960, he joined the RCA Telecommunication Center at Meadow Lands, Pa. He is presently responsible for coordinating instruction-book services for the two-way radio product line.



F. Papouschek (l.) and W. J. Sweger

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. . . for contributions to color television and to digital techniques

RICHARD W. SONNENFELDT, an honor graduate of Johns Hopkins University in 1949, joined RCA that year and participated in the development of the RCA system of color television. His experience includes contributions to RCA's Data Link and AGACS Systems, as well as development of multiplex pulse systems; noise, interference and cross-modulation-elimination techniques; several test instruments; and circuit development. Upon transferring to RCA Electronic Data Processing, he assumed engineering responsibilities for the development of control and automation systems and special-purpose computers. Establishment of the Industrial Computer Systems Department at Natick, Mass. early in 1960 was followed by his appointment as Manager of Engineering there. In this capacity he led in the development of the RCA 110 and other industrial computer systems. In 1956, Mr. Sonnenfeldt received the *RCA Award of Merit* for his engineering contributions and for organizing and teaching a course in "Pulse Systems and Techniques." He is the author of many technical publications, and the holder of more than 25 U. S. Patents.

. . . for early contributions to electronic circuits.

DR. H. N. KOZANOWSKI received his B.S. in Physics from the University of Buffalo, N.Y. in 1927 and his M.A. from that University in 1928. He also served as a Teaching Assistant at the University of Buffalo. He then received his Ph.D. in Physics from the University of Michigan, Ann Arbor, Mich. in 1930, serving there as a Research Assistant in 1930. He was with the Westinghouse Research Laboratories from 1930 to 1935. In 1935, he joined RCA in the Research Department. Then in 1941, Dr. Kozanowski moved to RCA Television Advanced Development, the activity in which he has worked to date. He is currently Manager, Television Product Advanced Development, Broadcast and Communications Products Division, Camden. In 1956 he received the *RCA Award of Merit*. He is a Member of the Television Committee of the Society of Motion Picture and Television Engineers, and a *Fellow* of that Society. In addition to the IRE, Dr. Kozanowski is a Member of Sigma Xi, Phi Beta Kappa, the Franklin Institute, and the American Physical Society.

FOUR RCA MEN ELECTED IRE FELLOWS

The four RCA men appearing on this page have been honored for their professional achievements by being elected *Fellows* of the Institute of Radio Engineers. This high honor is bestowed each year upon those who have made outstanding contributions to the field of electronics.

. . . for contributions to tube and transistor circuitry

Dr. H. J. WOLL received his BSEE from North Dakota State University in 1940 and his Ph.D. from the University of Pennsylvania in 1953. From 1941, when he joined RCA, to 1947 he worked on circuit development; he then attended the University of Penna. from 1947 to 1948 as the first recipient of an *RCA Employee Fellowship*. From 1948 to 1953 he continued in circuit development, and also contributed to color-correction computers for multicolor printing. From 1953 to 1955, he trained and led a group in the development of transistor circuits for computers, audio, video, and r-f applications; this group developed and built the first transistor digital computer in RCA. He contributed to the organization of the first RCA transistor training program, and later was responsible for this program and lectured in it. From 1955-58, he directed a group in development of advanced transistor switching, avalanche, and rotating-field techniques and applications. Since 1958, Dr. Woll has been Manager of DEP Applied Research, planning and directing work in pattern recognition, adaptive systems, integrated electronics, thermoelectrics, electrostatic printing, fiber optics, atomic clocks, and plasma physics. In addition to the IRE, Dr. Woll is a member of AIEE and Phi Kappa Phi. He was program chairman of the 1956 IRE Transistor Circuits Conference, is past chairman of the Philadelphia Chapter of the IRE Professional Group on Circuit Theory, past chairman of the Symposia Committee, and is now Vice-Chairman of the Philadelphia Section. He co-authored the *Handbook of Semiconductor Electronics*, is listed in *American Men of Science*, and holds 16 U.S. patents.

. . . for contributions to color-television circuitry

HARRY KIHN has made major contributions to color television circuit development and to radar and microwave communication techniques. He received his B.S. degree in electrical engineering from The Cooper Union Institute of Technology in 1934, and his M.S. degree from the University of Pennsylvania in 1952. Mr. Kihn joined RCA in 1939 as a research engineer associated with television receiver and circuitry development. During World War II, as a member of the technical staff of RCA Laboratories at Princeton, he performed research relating to radar for automatic bombing and altimeters. With the advent of color television development in the post-war period, he played a prominent part in the development of receiver circuitry. Subsequently he was engaged in further radar research and directed research in pulse code and digital communication and computer systems. Since early 1960, he has been a Staff Engineer on the RCA Research and Engineering Staff, in charge of coordinating RCA Technical activities in data processing and semiconductors, including both defense and commercial applications. He is a Senior Member of the Institute of Radio Engineers, and is a member of Sigma Xi, and the American Institute of Electrical Engineers.

NEW 5-KW TRANSMITTER PROVIDES VERSATILE COMMUNICATIONS

This medium-power transmitter utilizes a variety of transmission media (SSB, AM, CW) and new features of remote control and automatic tuning, in addition to many proven features of earlier RCA transmitters. It is designed primarily for foreign markets, and for international communications applications. (For a low-power SSB transceiver, see Mahland and Schneider, this issue.)

by **B. AUTRY and L. CANTO**
Radiomarine Communications Equipment Engineering
Broadcast and Communications Products Division
Camden, N.J.

THE WORLD telecommunication market of today provides new challenges for the engineer to design versatile yet economical remote-controlled transmitters that will satisfy a wide range of services. Applications include point-to-point communications for foreign service such as those required by the RCA International Division.[1] and world-wide services exemplified by the needs of RCA Communications, Inc., for commercial operations between the U.S. and other countries.

A typical example of a transmitter especially designed for these foreign markets is the new IST-5K, 5-kw Transmitter which operates in the 3- to 30-Mc frequency range. It incorporates remote control and other unique features making it equally suitable for government or commercial applications. Although primarily designed for fixed-station operation, one of the first applications will be for high-seas telecommunication service aboard the "*SS Longlines*," a cable ship of the American Telephone and Telegraph Company.

Because of the remote-control feature and the variety of transmission media provided (SSB, AM, and CW), it is expected that the IST-5K design will find other new applications in the telecommunications market. As a medium-power transmitter, the IST-5K fulfills the need for a transmitter between RCA's high- and low-power SSB units[2,6] previously designed for communications use.

The IST-5K transmitter not only provides the newer features of remote control and antomatic tuning, but also has many proven features of earlier transmitters such as the variable output tuning network[3] of the SSB-T3 which results in substantially reduced harmonic output.

TABLE I—DESIGN SPECIFICATIONS

Power Output	3000-5000 watts, PEP
Intermodulation Distortion	—40 db, at PEP
Frequency Range	3 to 30 Mc
Output Impedance	600 ohm, balanced 50 ohm, unbalanced
Audio Bandwidth	6 kc each sideband
Carrier Rejection	—60 db below PEP
Harmonic Rejection	—80 db
Hum and Noise	—50 db below PEP
Input Voltage	230-398 volt, 3-phase, 50-60 cycles
Temperature Range	0 to 50°C
Altitude	0 to 10,000 feet
Tuning	Continuous
Operation	Manual and Automatic, with provision for remote control of the automatic version

Accessibility was given prime consideration in the final design.

EARLY DESIGN CHALLENGES

Some of the first requirements imposed on our design group were to provide automatic preset tuning and remote control features. Additionally, we were called upon to design a transmitter having substantially distortionless output, low-harmonic carrier, and a convenient selection of single-sideband, double-sideband, or *on-off* telegraph operation; adequate bandwidths were required so that multiplex terminal equipment could be used for simultaneous message transmission.[4,5]

Although these were the major considerations in the design of the equipment, the general specifications listed in Table I were established as design parameters which would insure versatile operation of the equipment. This article describes how these specifications were met in the development and design of the IST-5K.

MECHANICAL DESIGN FEATURES

The entire 5-kw unit is completely housed in a single-unit cabinet having light-cobalt-blue front panels and dark-cobalt-blue frame and doors (Fig. 1). Mechanically, all construction is steel for ruggedness except the power amplifier section which requires aluminum because of high-frequency considerations; good shielding of r-f stages dictated the use of unpainted inner doors. All interior steel parts are cadmium plated with a bronze-chromatic conversion coating for maximum protection; all materials are treated for resistance to moisture and fungus in anticipation of severe service conditions. A 1500-cfm blower pressurizes the cabinets and cools the 5-kw power-amplifier tube, the intermediate power amplifier, and the r-f inductors.

Accessibility features were given prime consideration; i.e., the transmitter is designed with slide-out chassis and hinged panels and doors (see Fig. 2) so that all amplifier stages and control circuits are easily serviceable.

The transmitter is supplied complete with single-sideband generator, exciter, power supplies, power-control circuits, and circuitry permitting automatic tuning to any of 10 preset frequencies; a companion remote-control unit provides convenient dial-type remote operation up to ten miles from the transmitter. The remote unit fits on a desk top or in a standard 19-inch relay rack (Fig. 3).

A *remote-local-manual* selector provides manual control of the automatic transmitter by disabling the tuning drives and completing the emission selector and keying circuits. A completely "manual" transmitter can be furnished by omitting the automatic and remote-control units, drive-motor assemblies, and associated cabling.

CIRCUIT DESIGN

Power Amplifier and Output Tuning Networks

Our experience in building and testing the RCA SSB-T3 20-kw transmitter[3] pointed to the desirability of using a single 4CX5000A as the power amplifier (PA.). By maintaining a constant LC ratio in the plate tank and by holding the screen current to approximately zero, adequate power output and good linearity are assured.

Fig. 1—IST-5K, 5-KW transmitter. L. Canto, author (left) and W. H. Horton, technician, are at the left-hand section which contains automatic-control, exciter, generator and power supplies. The right-hand section houses high-power r-f amplifiers and power control circuits.

The PA plate tank is coupled through a variable link to the output tuning network which consists of a split-parallel tuned tank with variable inductors and vacuum variable capacitors. The inductors are varied by inserting a brass cup to produce a "shorted-turn" effect. A Faraday shield fabricated by using printed-board techniques aids in reducing harmonics to an extremely low value. The output impedance is basically 600-ohms balanced with a tap and coaxial jack provided for 50-ohms unbalanced.

Intermediate Power Amplifier

A parallel pair of 4X250-B tubes provide drive to the PA through a π network. The wide tuning range and constant LC ratio are obtained through the use of vacuum capacitors having low minimum capacitance.

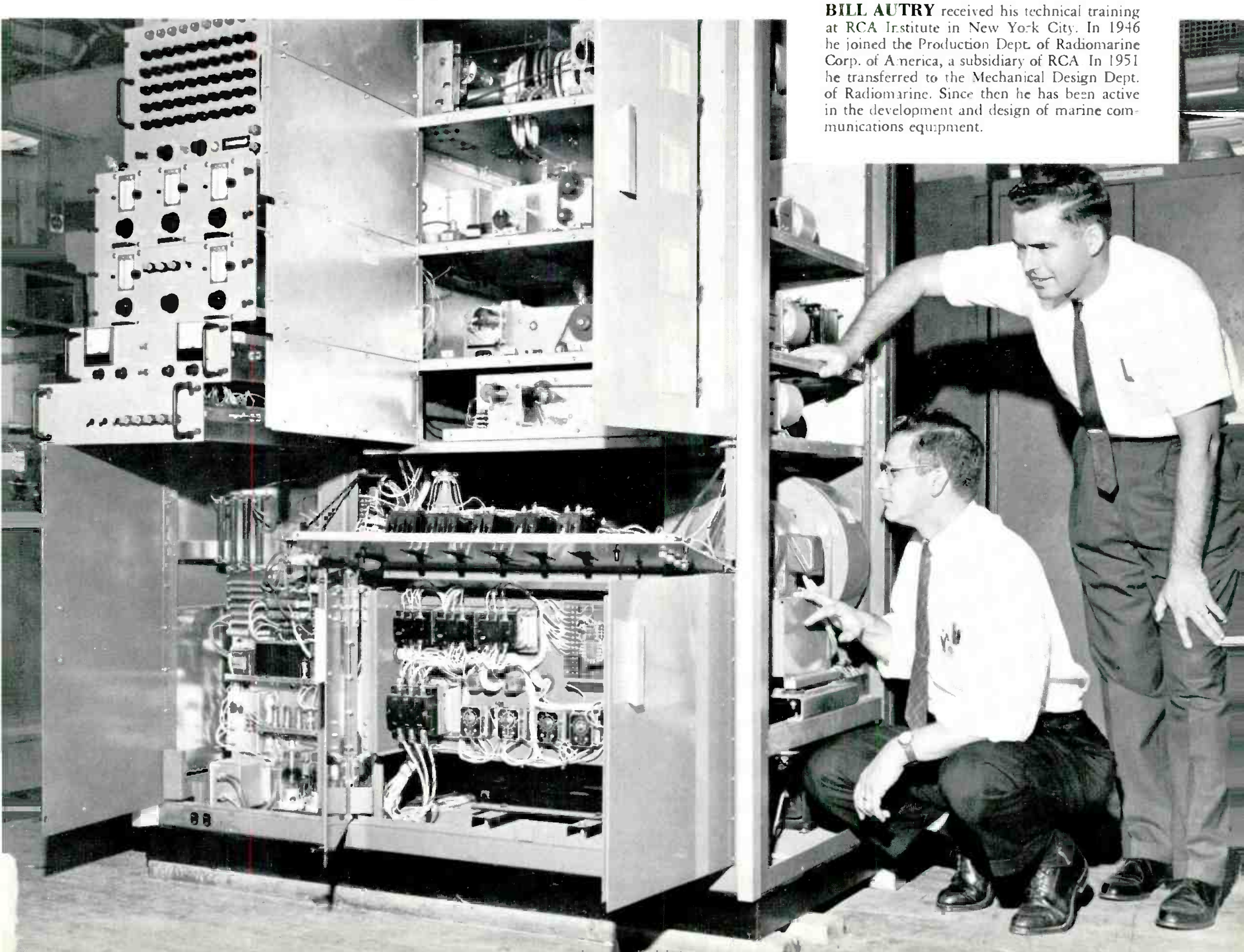
A 200-ohm resistor connected from the PA grid to ground provides a low-impedance load for the intermediate power amplifier (IPA) and stabilizes the PA. This low-impedance PA input helps provide greater linearity and broadens the tuning of the IPA tank circuits. Experience with earlier transmitters indicated that the best linearity is obtained when the IPA is detuned from resonance toward a lower frequency, by 6 db; however, in the IST-5K, best linearity was obtained at resonance, because of the PA grid loading. With the IPA operating at resonance instead of operating on the slope of the resonance curve, the ability to reset automatic tuning was vastly improved.

Linear Amplifiers

Two 6146 tubes operating in Class A are used in cascade to drive the IPA. The second tube is used in a π network for

Fig. 3—The companion remote control unit is designed to fit on a desk-top, or may be mounted in a standard 19" cabinet rack. The remote unit provides master "telephone-dial" control of the IST-5K transmitter's automatic circuits over distances up to 10 miles.

Fig. 2—Accessibility to every stage and circuit is provided in the over-all design; at far right, the authors, Bill Autry and Lou Canto (kneeling), are inspecting the power control section. Control contactors and relays are on a swing-out panel. Access to internal circuits are by swing-out doors and slide-out chassis; doors are interlocked to remove all d-c voltages above 50 volts.



LOUIS CANTO attended RCA Institutes, graduating from the Advanced Technology Course in 1950 at which time he was employed by RCA Radiomarine at 75 Varick St., N. Y. C. Prior to attending the Institute he served with the 3118th Signal Service Battalion in Frankfurt A/M, Germany. He also spent a year at the USFET Transmission Station, in Frankfurt, as a civilian employee.

BILL AUTRY received his technical training at RCA Institute in New York City. In 1946 he joined the Production Dept. of Radiomarine Corp. of America, a subsidiary of RCA. In 1951 he transferred to the Mechanical Design Dept. of Radiomarine. Since then he has been active in the development and design of marine communications equipment.

low-impedance feed to the IPA grid located several feet away. These stages are on a completely shielded slide-out chassis; tube replacement is done through a door on the rear of the chassis.

Generator and Exciter

To expedite the design we proposed to adapt the exciter from RCA's ET-8063A, 1-kw SSB transmitter and to design a new SSB generator and power supply.

The type ET-8063A exciter was designed for marine applications; five individual chassis in the exciter provide 10 frequencies over a portion of the h-f spectrum. A total coverage of 50 crystal-controlled frequencies in the 2- to 30-Mc range is thereby provided. Any frequency in any band can be selected by supplying the proper information to the motor-driven exciter switches.

Incorporation of this unit into the IST-5K meant that the transmitter must select 10 of the 50 possible frequencies and apply them to any of the 10 transmitter channels. A programming panel was designed and included in the power supply so that several motor-controlled switches and relays could be used to select the proper frequency.

The generator of the ET-8063A could not be used since it utilized 250-kc mechanical filters providing only ±3 kc sidebands. In order to provide a design in the shortest possible time, it was decided to use available 100-kc crystal filters giving the 6-kc bandwidths desired. and then convert to 250 kc, the proper driving frequency for the exciter. The 100-kc signals are heterodyned with a 350-kc signal to produce the 250-kc signal. The final generator produces a 0.1-volt output at 250 kc, with −52-db intermodulation distortion, −50-db hum and noise and −60-db carrier rejection.

To allow remote selection of emission (SSB, AM, or CW), relays and appropriate interlocking circuits were used to prevent a local operator from taking control during *Remote* operation.

Automatic Control Unit

The automatic control unit converts the dial pulses, polar voltages, or grounded leads from the remote-control unit into the information needed to provide channel and frequency selection of the exciter and motor control voltage for the r-f tuning elements. When dial pulses are received (for channel selection) a stepping switch provides a ground to the motor control switch, stopping it at the proper channel. A ground supplied to the programming panel in the power supply causes the proper band and channel to be selected in the exciter. Five bridge circuits are completed causing polarized relays to energize the tuning drive motors. The motor-controlled switch also feeds a voltage back to the remote unit indicating the channel selected.

There are 50 dual potentiometers in the automatic control unit, five for each of the 10 possible channels. These potentiometers are one arm of a bridge providing coarse and fine adjustments; the other arm is a 10-turn potentiometer coupled to the motor-driven elements in the r-f portion of the transmitter. When the bridge is balanced the system is at rest; when the bridge is unbalanced by the selection of a different channel, the motors run clockwise or counter clockwise depending on the polarity of the voltage applied by the bridge arms to the polarized relay; this motor tuning action continues until a balance is reached and the system comes to rest.

Initial tuning of the transmitter to a particular frequency is always done manually; then, each of the five bridges (one for each control) is balanced; balancing is accomplished without disturbing the setting of the tuning controls. A switch selects the proper bridge and a bridge-balance meter is used to indicate perfect balance. During balancing, the bridge selection switch removes the motor relay voltage and reapplies the voltage when in the *normal* position. The accuracy of resetting the r-f tuning elements is determined mainly by the sensitivity of the polarized relay but is enhanced by the type of motor used; a permanent-magnet, synchronous motor with an output speed of 72 rpm and 150-ounce-inch torque serves admirably; stopping in 5° of rotation with no internal braking. Total time required to tune from 3 to 30 Mc is 55 seconds.

Remote Control Unit

The remote unit is capable of controlling the transmitter over a short distance (several hundred feet) by multiconductor cable, or up to 10 miles with two telephone-pair and ground return. When telephone lines are used, adapters are placed in both the remote and automatic control units. Remote control units (from different locations) can be used in parallel; the unit which first has control retains it until relinquished.

Transistorized audio amplifiers are used in each sideband to provide a gain of at least 90 db to accommodate microphone input. Channel selection is provided by pulses from a telephone type dial. Emission selection is effected by grounded leads in the multiwire connection, and in the telephone line connection by polarized voltages. The remote control unit allows the following control functions to be performed:

1) power *on-off*
2) emission selection, SSB-AM-CW
3) transmitter *on-standby*
4) individual sideband gain
5) channel selection
6) CW keying
7) transmitter channel indication

Power Supplies and Control Circuits

The transmitter has five d-c power supplies ranging from −300 volts up to +7500 volts. All except the +250-volt supply are on a vertical panel in the left-hand section; the high-voltage (7500-volt) transformer and filter are mounted in the right hand section under the r-f unit.

Control circuits use a-c contactors and circuit breakers, with time relay relays controlling the d-c voltages. Fuses are used for protection in circuits where individual loads are far below the circuit breaker rating. An automatic reclosure circuit is included to reapply the d-c voltage two times after a fault and then "lock-out" until reset by the operator.

CONCLUSION

The development and design of the 5-kw (peak envelope power) IST-5K transmitter provides versatile and economical point-to-point communications. The remote control and frequency selection features of the equipment open up new markets for high-frequency operation. This rugged, easy-to-service communication equipment is especially attractive for use in the many remote areas of the world which comprise the market of the RCA International Division.

ACKNOWLEDGEMENT

N. L. Barlow and K. L. Neuman provided guidance during the design program and Radiomarine engineers R. G. Berge and R. S. Fow assisted with actual design.

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Fig. 1—SSB-5 Transceiver; only five controls are needed for complete operation.

SSB TRANSCEIVER FOR FIXED OR MOBILE APPLICATIONS

This compact, inexpensive transceiver realizes many of the advantages of SSB transmission. Use of the RCA 7360 beam-deflection tube simplifies design and maintenance by replacing the three tubes usually required to generate the basic SSB signal. For mobile operation, a pretuned antenna may be selected to match the frequency range, thus eliminating bulky antenna tuning units.

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TABLE I—SSB vs. AM TRANSMISSION[4,5]

Advantages	*Disadvantages*
Up to 9 db power savings; i.e., a 125-watt SSB unit can replace a 1000-watt AM system.	The SSB transmission must justify its use in terms of cost factors and economics in operation, if existing users of radio communications are to change from AM operation. This transition requires compatibility between AM and SSB operation.
Primary power cost is less.	Standardization of SSB technique is required.
Transmission line and antenna costs can be reduced because peak voltages are less.	The SSB receiver must have suitable demodulating carrier with highly stable frequency control of transmitter and receiver.
Cost of transmitter buildings is lower, since less floor space is required and weight is lower.	The r-f parts of an SSB transmitter generally cause a moderate increase in the number of components, stages and vacuum tubes over that of an AM transmitter of comparable power rating.
Total radiated power may be reduced to accomplish a given communication function.	The SSB operation requires critically designed sideband separation filter, either crystal or mechanical. High-performance filter results in minimum bandwidth.
Higher efficiency of sideband power generation.	
High-power SSB suppressed carrier transmission equipment compares favorably to similar high-power AM equipment.	
Conservation of frequency spectrum because only ½ the bandwidth of an AM system is required.	
Narrow bandwidth results in improved signal-to-noise ratio.	
Man-made interference is minimized.	

During the past few years the trend in the radio communications field has been toward increased use of single-sideband (SSB) transmission and reception.[1-3] Although some disadvantages do exist, the many advantages of SSB operation far outweigh them, as may be seen in Table I. The RCA Radiomarine SSB-5 Transceiver is an application of SSB transmission; many of the advantages shown in Table I are included in the design, the obvious one being its small size. Table II lists detailed specifications. The SSB-5 Transceiver, which may be used in either a mobile or fixed station, has a transmitter output power of 125 watts and a receiver output of 4.5 watts. Use of either of two external power supplies allows for mobile or fixed station operation. As depicted in Fig. 1, the Transceiver requires only five front-panel controls.

The *channel selector* permits selection of any one of four available channels. Channels 1 and 2 cover the frequencies of 3 to 6.7 Mc, while channels 3 and 4 allow operation at frequencies between 6.7 and 15 Mc. This same control also provides channel switching information for possible use of a remote antenna tuner or other auxiliary equipment. The *sideband selector* switches from upper or lower sideband, with or without full carrier. The *trim* control is a "fine" frequency adjustment (described below in more detail). Receiver *volume*, power *off*, and *transmitter gain* comprise the remaining front-panel controls.

Fig. 1 also illustrates one means of attaching the carbon microphone. Antennas for mobile operation consist of separate pre-tuned helical whips, approximately 8 feet long for each operating frequency. For fixed station operation, a single antenna may be used for up to four channels by employing an external antenna tuner; again, separate antennas may be used for each output frequency.

TRANSMITTER CIRCUITRY

The transmitter of the SSB-5 Transceiver is comprised of only seven tubes (Fig. 2): a microphone amplifier, an audio amplifier, two RCA 7360 tubes used in balanced modulators, an r-f amplifier, a driver, and two power amplifier tubes in parallel.

The first balanced modulator is a combination modulator-oscillator (Fig. 4). The oscillator circuit generates a 1400-kc signal which is heterodyned with the audio signal applied to one of the deflection electrodes. A capacitor diode in the oscillator circuit is varied by adjusting the *trim* control on the front panel. This capacitance variation, of one

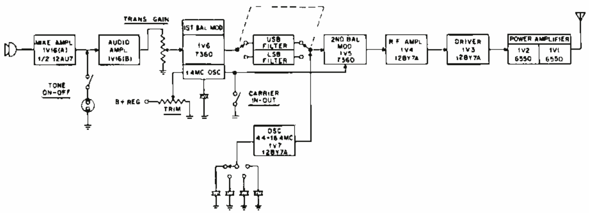


Fig. 2—Simplified block diagram of the SSB-5 transmitter.

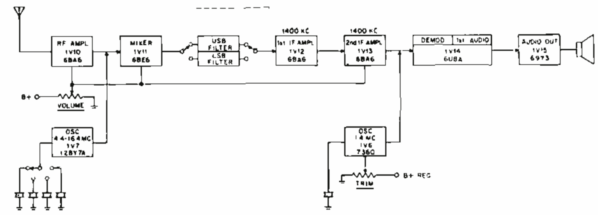


Fig. 3—Simplified block diagram of the SSB-5 receiver.

of the oscillator circuits constants, will vary the crystal frequency over a frequency range of 1400 kc ± 75 cycles. This frequency variation permits compensation for slight frequency differences that may exist in a circuit with other stations. The output of the first balanced modulator consists of the sum and difference frequencies of 1400 kc and the audio or modulating frequency. The 1400-kc carrier is balanced out in the RCA 7360 plate circuit.

USE OF RCA 7360 SIMPLIFIES DESIGN

Use of the RCA 7360 tubes in the balanced modulator circuits has greatly simplified the design and reduced the cost and the maintenance problem.

Normally, up to three tubes are required to generate the basic SSB signal. The RCA-7360 beam-deflection tube is so constructed that it performs the required function of these three tubes thus conserving valuable space and components.

The RCA 7360 is a dual controlled beam-deflection tube having a cathode, control grid, screen grid, two deflection electrodes and two output plates.

The design features provide balanced, push-pull output from a single-ended input, improved performance, and simple circuits when used as a balanced modulator. Long-term stability is achieved because the electron flow to each plate is derived from a single beam of electrons. High transconductance, high deflection sensitivity, and low interelectrode capacitance are features.

When used as a balanced modulator (Fig. 5), it provides a carrier suppression of 60 db or more, with third-order distortion of at least −47 db. The total beam current is controlled by the bias on the control and screen grids. When balanced, the gain between the control grid and each plate will be equal. The total beam current will remain constant but the division of beam current between the two plates is controlled by the potential difference between the deflection electrodes. When the plate current in one plate circuit is decreased, the plate current in the other plate circuit is increased. Therefore, if there is an a-c current in one plate circuit, there will be an equal a-c current in the other plate circuit, but of the opposite phase. This provides a balanced push-pull output from a single-ended input.

The sideband filters are switched into the output of the first balance modulator to select the sideband to be transmitted (Fig. 2). These crystal-lattice filters require no adjustment and operate in the 1400-kc range.

Operation of the second balance modulator is similar to the first balance modulator, i.e., it also uses a 7360 and heterodynes the "single-sideband" signal developed at the filter output, with a suitable "channel-oscillator" signal to produce a signal at the desired r-f output frequency. This signal is then amplified in two amplifier stages (1V4 and 1V3).

The power amplifier consists of two type 6550 tubes in parallel and a π-type plate circuit; it operates in class AB-1. This results in a linear amplifier with 125-watt-PEP output and an over-all third-order distortion of better than −35 db below the level of either tone of a two-tone test signal.

RECEIVER CIRCUITRY

For SSB reception, the receiver design principles are conventional (Fig. 3) although as shown in Table I and below, frequency control is of great importance. The main difference from an AM receiver is the selection of either the upper or lower sideband (selectivity) and the reinsertion of the carrier at the proper level and point for demodulation. Stability is also a prime consideration. Drift and difference in frequency should not be more than 30 cycles.

The SSB signal is applied through the proper antenna coils to the r-f amplifier (1V10), from where it is coupled through another set of r-f coils to the grid of 1V11 to be combined with the local oscillator frequency for an intermediate frequency output of 1400 kc. This i-f frequency is then applied to either of the highly selective upper- or lower-sideband crystal filters. These filters are fixed-tuned to reject the unwanted sideband (when present) and any extraneous signals. (Refer to Fig. 6 for selectivity characteristics). To keep the cost of this equipment to a minimum, only one set of filters is required for the transmitter and receiver through the use of a simple coupling and isolating arrangement common to both.

The i-f signal (1400 kc) after passing through the sideband filter, is amplified and applied to the demodulator along with the carrier reinsertion frequency of 1400 kc (1V6) for demodulation. The 1400-kc oscillator is also common to the transmitter for proper generation of the transmitted sideband signal. The *trim* control is used for compensating or slight frequency differences of the received signal (other transmitter) should they exist. The demodulated signal is

Fig. 4—First balanced modulator, a combination modulator and oscillator.

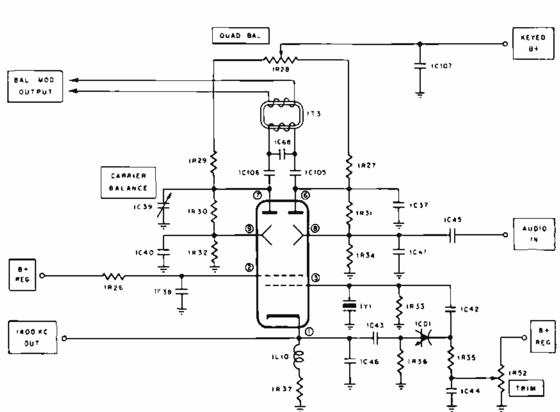
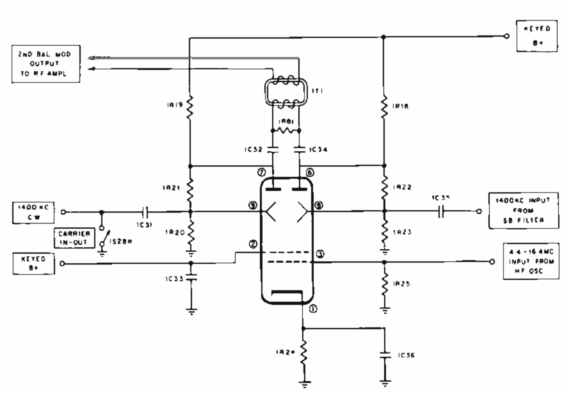


Fig. 5—Balanced push-pull output circuit provided from a single-ended or unbalanced input.



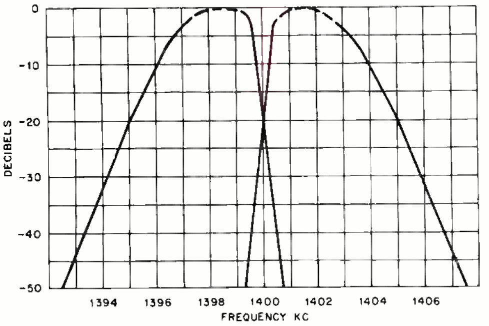


Fig. 6—Highly selective upper or lower sideband crystal filters reject extraneous or unwanted sideband signals. The above curves show the receiver's sharp selectivity characteristic.

next amplified to the proper level to drive the audio output tube to a maximum of 4.5-watt output.

All oscillators in the SSB-5 are crystal controlled and common to both receiver and transmitter to conserve space. Volume is adjusted by manually varying the bias on the r-f stage, mixer, and first i-f amplifier. To keep the cost at a minimum, conserve space, and simplify operation, it was decided not to include an agc system. Adequate frequency stability is realized by the use of precision channel crystals, maintained at a constant oven-controlled temperature.

ANTENNA SYSTEMS

The π-network output circuit of the SSB-5 Transceiver will match an antenna impedance of 10 to 80 ohms resistive. For fixed station operation, a single antenna may be used for up to four channels through the use of an external antenna tuner, such as the RCA type AAT-100. Separate matched transmission line antennas or separate quarter-wavelength antennas may be used for each channel.

In mobile operation, separate pretuned helical whip antennas are used which are approximately 8 feet long. A series of fifteen antennas are available to cover the range of frequencies and slight trimming will put an antenna on the exact operating frequency within its range. This results in greater efficiency of operation and eliminates the need for bulky antenna tuning units.

POWER SUPPLIES

The power supply for fixed station operation is connected to a 115-230-volt, 50-60-cycle power line. All rectifiers are of the silicon diode type, thus providing instant voltages when the power is applied. Available output voltages are −100, +300, +800 and 12.6 volts.

For mobile operation, the input power is obtained from the vehicle's 12-volt d-c system. Four germanium power transistors are employed in a conventional overdriven push-pull transformer-coupled oscillator. The input power terminal board provides simple connections to permit operation from either a positive or negative grounded source of 12 volts d-c. A relay is provided in the transistor circuit to permit reduced source current in the *receive* position, thus conserving battery power. (*Receive* or *transmit* is controlled by the *push-to-talk* button on the microphone.) By-passing and decoupling reduces the "birdies" commonly generated in this type of supply.

Careful transformer design further reduced the usual audible whistle (1500 cycles) to a negligible value. The efficiency is approximately 80 percent under full load. The type of rectifiers and the available output voltages are identical to those for the d-c power supply. If desired, this power supply may also be used for a fixed installation.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the contributions of B. Autry, W. Horton, J. Blake and K. Laighton. Credit is extended to Niles Barlow, Manager, Radiomarine Engineering, for the basic specifications and helpful suggestions.

TABLE II—Specifications, SSB-5 Transceiver

Designed around RCA 7360 dual-controlled beam deflection tube; common rcvr-xmtr circuitry in oscillators, sideband filters, crystals and ovens, switches, and controls.	
Xmtr-rcvr: 16 lbs, 7½ x 12½ x 13 inches; 16 tubes, *8 diodes.*	
115-230 pwr sply: 23 lbs, 6⅝ x 5¼ x 13½ inches; *9 diodes.*	
12v-dc pwr sply: 8 lbs, 7½ x 11 x 7½ inches; *10 diodes, 4 transistors.*	
Channels 1 & 2	3.0-6.7 Mc
Channels 3 & 4	6.7-15.0 Mc
Antenna Impedance	10-80 ohms
Crystals, four CR-27/U; channel crystals 1400 kc higher than desired operating frequency; same crystal serves xmtr and rcvr.	
Freq. stability	±0.0002%
Emission	A3J SSB suppressed carrier; A3H SSB with full carrier
TRANSMITTER:	
Power output	125 watts PEP
Transmitted sideband, upper or lower; selectable sideband output available if both upper and lower sideband filters are installed	
Unwanted sideband suppression	50 db
Carrier suppression	50 db
Audio fidelity	±3 db, 400-2900 cps
Speech clipping	12 db
Distortion products	35 db below either tone of two-tone test signal at PEP output
RECEIVER:	
Sensitivity	Better than 1 μv for 50-mw output with 10-db signal-to-noise/noise
Selectivity	2.5-kc nom. bandwidth for 3-db attenuation 7.5-kc bandwidth for 40-db attenuation
Audio output	4.5 watts max in ldspkr
Audio fidelity	± 3 db, 400-2900 cps
Audio distortion	2.5% (1 kc at 50-mw output)
POWER:	
115-230 v, 60 c, single-phase power-supply line supply:	
Power load, rcvr only	135 watts
Power load, xmtr & rcvr:	
no sig, pwr on	160 watts
avg voice modulation	290 watts
12-v-dc power supply (battery):	
Drain, rcvr only	12 amps
Drain, rcvr & xmtr:	
no sig, pwr on	17 amps
avg voice modulation	25 amps

EDWARD W. MAHLAND joined the Engineering Department of the Radiomarine Corporation in October, 1945. Previous to his 3-year enlistment in the U. S. Navy, he worked for the Sperry Gyroscope Company in their Bombsight Division. Mr. Mahland graduated from the Bliss Electrical School in 1943 and the Capitol Radio Engineering Institute in 1951. Since then he has worked mainly in the design of radio and radar receivers, radio direction finders, single-sideband diversity systems, teletype diversity receiving systems, facsimile and miscellaneous transistorized equipments. At present, he is an Engineering Leader in RCA's Radiomarine Engineering group. Mr. Mahland is a member of the IRE.

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CHARLES E. SCHNEIDER joined the Radiomarine Corporation in March, 1941, to work in radio and radar receiver and transmitter test and development. He graduated from the RCA Institutes in 1941 and the Capital Radio Engineering Institute in 1951. From 1943 to 1946 Mr. Schneider served in the U. S. Air Force as Communications Officer in the Pacific Theater, and from 1951 to 1952 as Communications Officer in Korea. After his release from active duty in 1952 he entered the RCA Transmitter Division and designed marine radio telephone and telegraph transmitters. His primary interest in the past few years has been single-sideband transmission, co-designing the SSB-1, designing the SSB-30M, SSB-1 Mark IIA, and co-designing the ET-8063, ET-8063A and SSB-5. Mr. Schneider is now Systems Engineer of the Radiomarine Engineering group, Broadcast and Communications Products Division.

Fig. 1—Alaska superimposed on a map of United States. The locations (dots) of White Alice system sites include Alaska and the Aleutians. The Tin City site comes within 32 miles of the iron curtain.

THE WHITE-ALICE COMMUNICATIONS NETWORK

The "White Alice" Alaskan communications system is a network of 65 tropospheric-scatter and microwave stations to provide the USAF and other military agencies with the facility to communicate instantly. Of secondary importance, but vital to Alaskans, is White Alice's role of providing voice communication and teletype facilities for civilian use—in many areas served, the telephone was unknown a decade ago.

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At the risk of over-simplification, the White Alice system could be termed a telephone network. However, the similarity ends with this comparison, since White Alice goes far beyond the usual telephone-company concept. Today, White Alice is a versatile defense communication agency which ties together and serves the combined needs of the Air Force, Army, Navy, Coast Guard, FAA, the Alaska Communications System, and various civilian-owned telephone systems and companies. The voice and teletype communication channels criss-cross the length and breadth of Alaska, extending as far as the Tin City site, only 32 miles from the iron curtain (Fig. 1).

EARLY HISTORY OF ALASKA COMMUNICATIONS

Efforts to establish modern communications were first made several years before United States purchased Alaska from Czarist Russia. The Western Union Co. envisioned a telegraph link between the New World, Europe, and Asia, using overland lines from the U. S. through Canada and what was then Russian-America; thence, by submarine cable across the Bering Strait to Siberia, and across Russia into Europe. Surveys and initial construction began in 1866. However, work suddenly halted, when completion of the first Atlantic cable made the less-economical Western Union plan obsolete. So, for the next 30 years Alaskan communications consisted of dog-team trips and an occasional steamship visit.

As radio came of age in the late twenties, radio-telephone and telegraph began to augment and/or supplant land lines. Facilities were sparse, maintenance was rare, and reliability was poor.

The situation was alleviated to a degree during World War II when radio networks, teletype service, overseas radio-telephone circuits, submarine cable links, and finally, microwave connections between military installations were established. However, military reliability standards could not be met, since vhf point-to-point stations were subject to long periods of weather blackout. Widespread use of line-of-sight communications was impossible because of the vast distances, adverse weather, and wilderness areas encountered.

Recognizing that aircraft control and warning systems could function only with a thoroughly reliable long-lines telephone system, the Air Force Alaskan Command undertook a program in 1952 to engineer and develop such a system. The prime requirement was maximum reliability. Civilian needs as well as those of the other military and government agencies were to be considered in planning system capacity. Weather and atmospheric phenomena were to be taken into account. Such factors dictated selection of a new type of system—*forward tropospheric scatter radio propagation.*

RCA, the Lincoln Laboratory of MIT, General Electric, and Bell Laboratories were among those who had studied tropospheric scatter, at the experimental level, for several years. White Alice was to become the first large-scale application providing a trial run of this mode of beyond-the-horizon radio propagation. Under Air Force sponsorship, the Western Electric Company conducted systems engineering and design effort for a preliminary site in 1953 and 1954. Findings brought construction authorization from the Joint Chiefs of Staff in 1955, although the construction effort covered 1955 and 1956. The name assigned to the project was White Alice, a peculiarly appropriate name in view of the vast areas of ice and snow. "White Alice" is not an acronym, but is a name coined to designate the system complex.

The first call was transmitted over the system Nov. 29, 1956. At the time of Air Force acceptance, 12 sites were operational. Remaining stations were phased-in rapidly to bring the number of the initial network sites up to the planned 33 in a short time; 28 sites were attended, 5 were unattended relay stations. Several firms, including RCA (by Air Force request) submitted proposals for the management, operation, and maintenance of White Alice. Federal Electric Co. was awarded the first operation and maintenance contract, and functioned from May 1957 until July 1960.

RCA SERVICE COMPANY ASSUMES RESPONSIBILITY

In 1960, the Air Force invited commercial organizations to submit technical and cost proposals for an operation and maintenance contract of competitive procurement. RCA Service Company successfully negotiated a one-year, cost-plus-fixed-fee contract with an option clause for two additional years.

Phase-in commenced with the arrival of RCA's management team in Anchorage on July 1, 1960. Site-by-site phase-in operations began in September; the undertaking was accomplished with speed and efficiency. All sites were phased-in on schedule, and in many cases were taken over ahead of the deadline dates called for in the contract. By November 9, 1960, all stations and supporting facilities had been brought under RCA Service Company control.

Smoothness of the transition can be attributed in part to the utilization of a large number of the technical personnel who had operated the system under the previous contractor. Employing these people assured a nucleus of trained, experienced technicians, thus saving the Air Force considerable training expense and providing a high system reliability record during the phase-in period.

During the first year of contract, BMEWS REARWARD and BLUEGRASS Systems came into being and were incorporated into the White Alice system. During installation phases of these systems RCA provided support services for the equipment contractor, Western Electric. Upon completion of installation, equipment operation and maintenance responsibility was assumed by RCA.

Also during the first contract year, planning for operation and maintenance of a 4-A crossbar switching system was undertaken by RCA. Manning of toll centers at Anchorage and Fairbanks and assistance in staffing of the Defense Communications Agency added to the increasingly important responsibilities. The second-year contract beginning July 1, 1961 took into account additional engineering tasks to update and modernize the system.

At this writing, the White Alice system includes 67 tributary stations and sites; 33 are tropospheric scatter facilities, 32 are TD-2 microwave stations and 2 are toll center and switching locations. This increase was effected by subsequent amendment to the contract. In addition to present reserve capacity, capabilities have been boosted by additional 4-A crossbar switching equipment, similar to direct distance dialing, now in service between many of the major cities of the U. S. The 4-A crossbar provides a high degree of channel utilization and avoids the need for new facilities.

Step-by-step selectors located at four junction stations on the system route

Fig. 2.—Ice and snow from the first storm of the winter at Cape Lisburne, one of the Far North White Alice Sites. Shown is the base structure of a 30-foot dish type antenna.

and at the mainland terminus for the Aleutian Island stations are capable of automatically directing calls over several alternate routes. The selector first seeks the most direct route for a call. If all channels are in use, alternate routes are sampled until an open channel is found and locked in; switching is accomplished almost instantaneously.

Augmenting the high utilization-time ratio feature, automatic switching permits use of priority channels which were held open constantly under manual switching. The 4-A crossbar is equipped with a *preset pre-emptory priority* for certain command calls. Should automatic switching fail to open an immediate routing for these calls, a button can be actuated to pre-empt a direct channel; this frees priority channels for normal use.

SITES AND EQUIPMENT

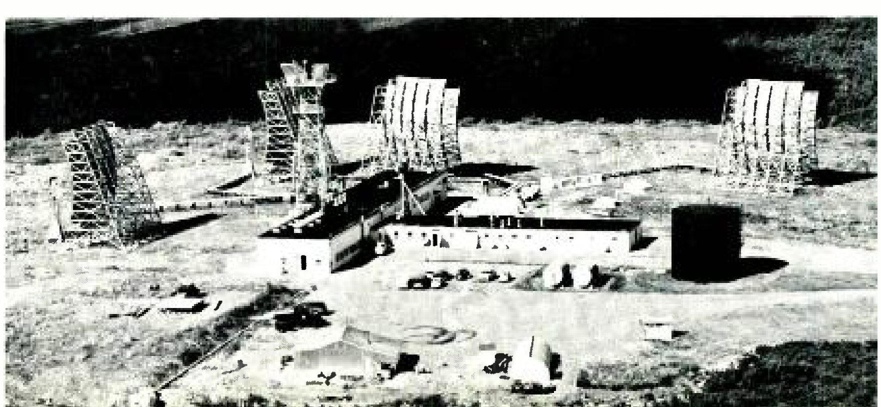
Sites are scattered over a wide area (Fig. 1). Each was gouged from a reluctant wilderness, with some far above the Arctic Circle and on the Aleutian Chain. Relentless winds, snow, subzero temperatures, and other extremes impose severe requirements on men, machines, buildings, and equipment (Fig. 2).

Eighteen site locations are operated in conjunction with the Air Force's Aircraft Control and Warning System. RCA personnel are maintained by the USAF along with their own men at these bases. Sixteen are dormitory sites; personnel live at these and are maintained wholly by the RCA Service Company via air lifts. Only nine stations are in proximity to towns and villages where technicians can live within the framework of the local economy. The 22 unmanned stations are TD-2 microwave equipped. Personnel from neighboring manned sites conduct periodic inspection and maintenance.

The most outstanding physical features of the tropo-scatter locations are the huge antennas (Fig. 3). There are two kinds: 100-ton scoop types, 60 feet high and shaped like a drive-in motion-picture screen; and dish types, 30 feet in diameter. The feed horn for the larger antenna is a tower located directly in front of the scoop; on the other antenna, it is a rod-like projection at the center of the dish. In each case, signals are splayed against the face of the antenna and bounced skyward to be reflected over the horizon to the next station. Each antenna transmits and receives signals simultaneously. A branching filter separates the very strong transmissions from the much weaker incoming signals. Since signals being received are only about one ten-trillionth the power transmitted, precise antenna placement is requisite.

Surrounding the antennas (there are four to each site to provide back-up capability and permit selection of the best-quality received signal) are buildings for inside communications and electronics equipment, quarters, dining and culinary facilities, recreation and storage rooms (see Fig. 3). More often than not an RCA-operated airstrip is adjacent, with parking areas for caterpillars, snow weasels and other vehicles for road and airstrip maintenance.

Fig. 3—An aerial view showing the site configuration at Pedro Dome. Note the slight "off-set" of the huge tropo scatter antennae. This permits selection of the best of two reflected signals. Buildings house Communication and Electronic Equipment and serve as living quarters for technicians.



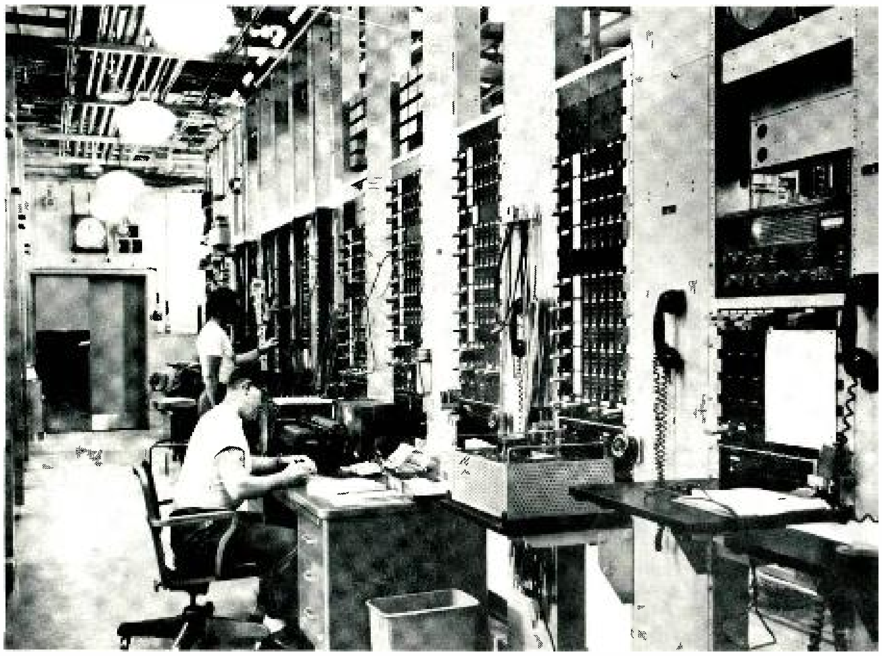


Fig. 4—A view of a typical equipment bank at one of the White Alice sites; these panels include patching facilities, exciters and receivers.

Since White Alice is the first large-scale application of tropo-scatter propagation, much of the communications and electronics equipment is of special or modified design. Major components include: the antennas, branching filters for each (10 kw to 1 kw); and on the BLUEGRASS segments, 50-kw transmitters, bandpass filters, receiver and exciter patch panels (Fig. 4), receivers, exciters, multiplexers, and carrier-frequency telephone terminals. Fig. 5 is a simplified block diagram of the radio telephone equipment. The BLUEGRASS stations are located in the Aleutian chain.

The TD-2 microwave stations, used for links where line-of-sight transmission is feasible, do not differ basically from those widely used for long-distance telephone service throughout the U. S.

OPERATION AND MAINTENANCE

In the order of their priority, system functions include: 1) direct linking of the various defense warning systems to NORAD headquarters, 2) provisions of long lines for the myriad inter-Alaska activities of the Air Force, Army, Navy, and Coast Guard, 3) long-distance and message service required by Federal Aviation Authority, the Atomic Energy Commission, and other Government agencies, 4) long lines and toll switching facilities to tie the various local telephone systems with the Continental U. S.

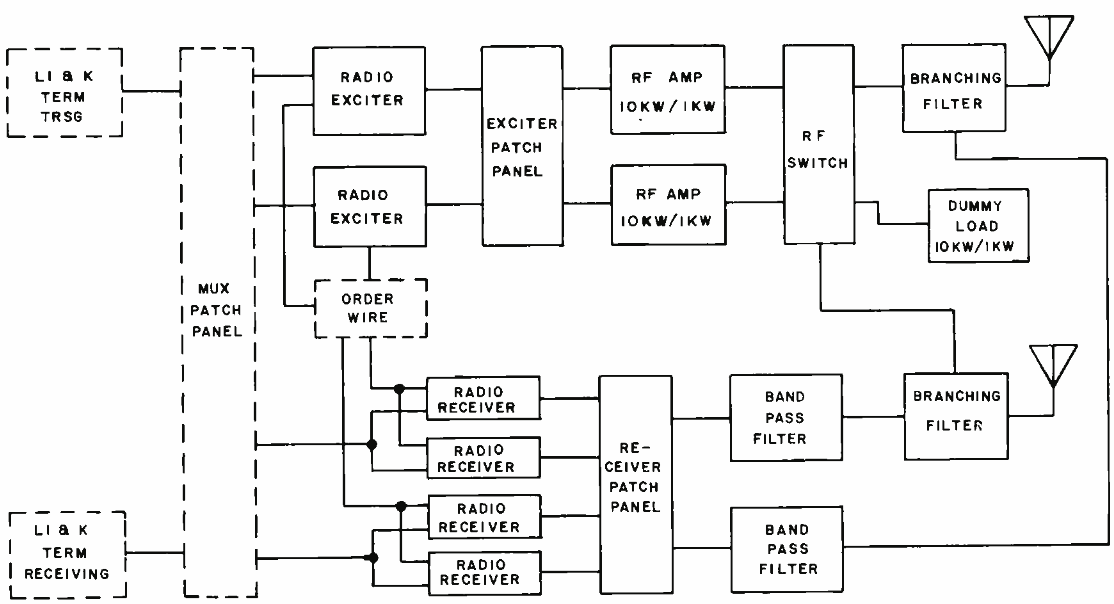
To assure that all functions are accomplished with a high degree of reliability, White Alice management has inaugurated the following objectives:

1) Delegation of authority to site supervisors, allowing independent action.
2) Establishment of technical training programs to provide thorough orientation of personnel before assignment to sites with continued on-the-job training for "on site" personnel.
3) Establishment of a communications and electronics maintenance center to provide depot-level repair for all communications, electronics, and test equipment.
4) Continuing study of the quality index to further improve system service.

ENGINEERING

Numerous related engineering tasks are planned and recommended to the Air Force; approval for some of these efforts was given during the 1961 fiscal year under supplemental funding. Additional engineering projects are in the program for the current contract year. Projects include improvement and expansion of the system, repair and rehabilitation undertakings to raise the system to optimum operating efficiency, major repair

Fig. 5—Simplied block diagram of the forward tropospheric scatter radio-telephone equipment.



and minor construction projects, a time and motion study, and an analysis of the preventive maintenance routine.

The bulk of the engineering activity during the current contract period falls in the expansion, repair and rehabilitation areas. Noted below are some of the major engineering efforts:

1) Phase-in of BMEWS REARWARD, BLUEGRASS and 4-A Crossbar Systems.
2) Planning, procurement and installation of additional toll terminal equipment to permit immediate implementation of circuit orders.
3) Addition of Model-28 teletype equipment at all manned stations of the original White Alice system to make these compatible with the BMEWS REARWARD and BLUEGRASS sites.
4) Addition of needed on-site test equipment to improve field maintenance.
5) Implementation of a program of maintenance calibration and certification of test equipment to hold shipment and handling of such equipment to a minimum.
6) Numerous renovation and improvement programs upon real property.
7) Engineering, procurement and installation of system-modernizing features such as hub telegraph-boards, parametric amplifiers, private branch exchanges and telephones, ring-down trunks, power alarms, increased entrance cable capacity, antenna relocation and TD-2 modification.

QUALITY CONTROL

Quality control inspectors are in the field constantly; every aspect of site operation and maintenance practice is checked. Reports go to management and also to site supervisors for recommended corrective action.

Comprehensive preventive maintenance routines have been established since high reliability is of cardinal importance in the White Alice system. It is the responsibility of each site supervisor to assign elements of these routines to each shift under his direction. The program is perpetual. Some functions are daily, others weekly, monthly, quarterly, or even yearly. As in all preventive maintenance programs, the purpose is to pinpoint potential trouble spots and inherent system weaknesses and to correct them before a station breakdown occurs. A valuable adjunct to this program is the continuing improvement of equipment and performance.

Site technicians are trained to react quickly to put into emergency operation whatever back-up equipment is needed to assure continued operations. Back-up units for communications and electronics equipment are provided at all stations; in many cases the back-ups cut in automatically; others, however, require manual switch-over by site personnel. Assignments are planned to assure that one technician is on duty at all times who is qualified to cope with any maintenance situation.

All malfunctions are noted on a trouble slip which records the nature of the trouble, equipment involved and the probable cause. These slips are forwarded to the quality control section at Anchorage. IBM punch cards are prepared and run from the data supplied by the trouble slips. The information gleaned is the basis for reports and recommendations to the responsible operating sections and to management.

PERSONNEL AND LOGISTICS

The number of employees required to operate White Alice is impressive, since it represents a 37-percent reduction over that previously required when the system was less than half its present size. The personnel section administers a comprehensive recruiting and screening program, oversees many recreational and civic activities for site and headquarters personnel, and handles the detail of the RCA program of employee benefits. Last year, these efforts combined with on-the-job training resulted in a low employee-attrition figure of only 2 percent per month—an impressive record in view of the strenuous circumstances under which many site personnel must work.

Requirements for spare parts and operational material, food, recreation and training supplies and all other needs must be anticipated as far in advance as one year. Automated resupply techniques have been instituted to aid in the monumental logistics task. Through periodic mechanical reviews of needs and changing requirements based on previous useage, countless manhours are saved—to say nothing of the considerable waste and duplication which was unavoidable under manual methods. Since virtually all supply efforts are by air—either USAF, charter or commercial carrier—automation of resupply has made schedule planning considerably simpler. The system also enhances efficiency of an inventory and stock control program responsible for line items valued in excess of three million dollars and numbering over 35,000. Through quick detection and redistribution of surplus materials nearly 1,500 excess items valued at nearly a half million dollars were returned to the Air Force during the first year of RCA Service Company management.

Catering services, warehouse workers, heavy equipment and mechanical operators are under subcontract to Universal Service, Inc. High quality of the culinary and housekeeping functions by this firm has contributed immeasurably to the morale of site personnel. Such tasks as snow removal and road and airstrip maintenance are done speedily.

CONCLUSION

The expansion program and the management and operation of the entire White Alice communications system are being performed successfully by the RCA Service Company. A philosophy of cost consciousness, instant service and high reliability has resulted in a better all-around performance than ever before; tasks for an enlarged system are accomplished with less personnel than that of the original installation; the reliability record is only a few tenths below 100%.

White Alice's has tremendous value to our defense effort and to Alaskans since modern communications will play a major role in the future growth and development of the state.

F. D. CHIEI, JR. attended College City of New York, majoring in mathematics and physics and received his B.S. in E.E. degree from Grove City College, Pa.; he has also completed courses in Navy technical schools and RCA Institutes. Mr. Chiei has been associated with the RCA Service Company for more than ten years. Initially, he worked with Loran equipments and on the installation and services of RCA television equipment. From 1951 to 1954, he was Manager of the Field Engineering Support Group and in 1954 served as Manager of Technical Operations for Government Services for the development of field facilities to undertake end-product contracts. In 1957-58 Mr. Chiei managed the Products Services groups which provided field support for RCA defense equipment and systems. In 1960, Mr. Chiei became Manager of the White Alice project, responsible for supervision of technical and administrative phases.

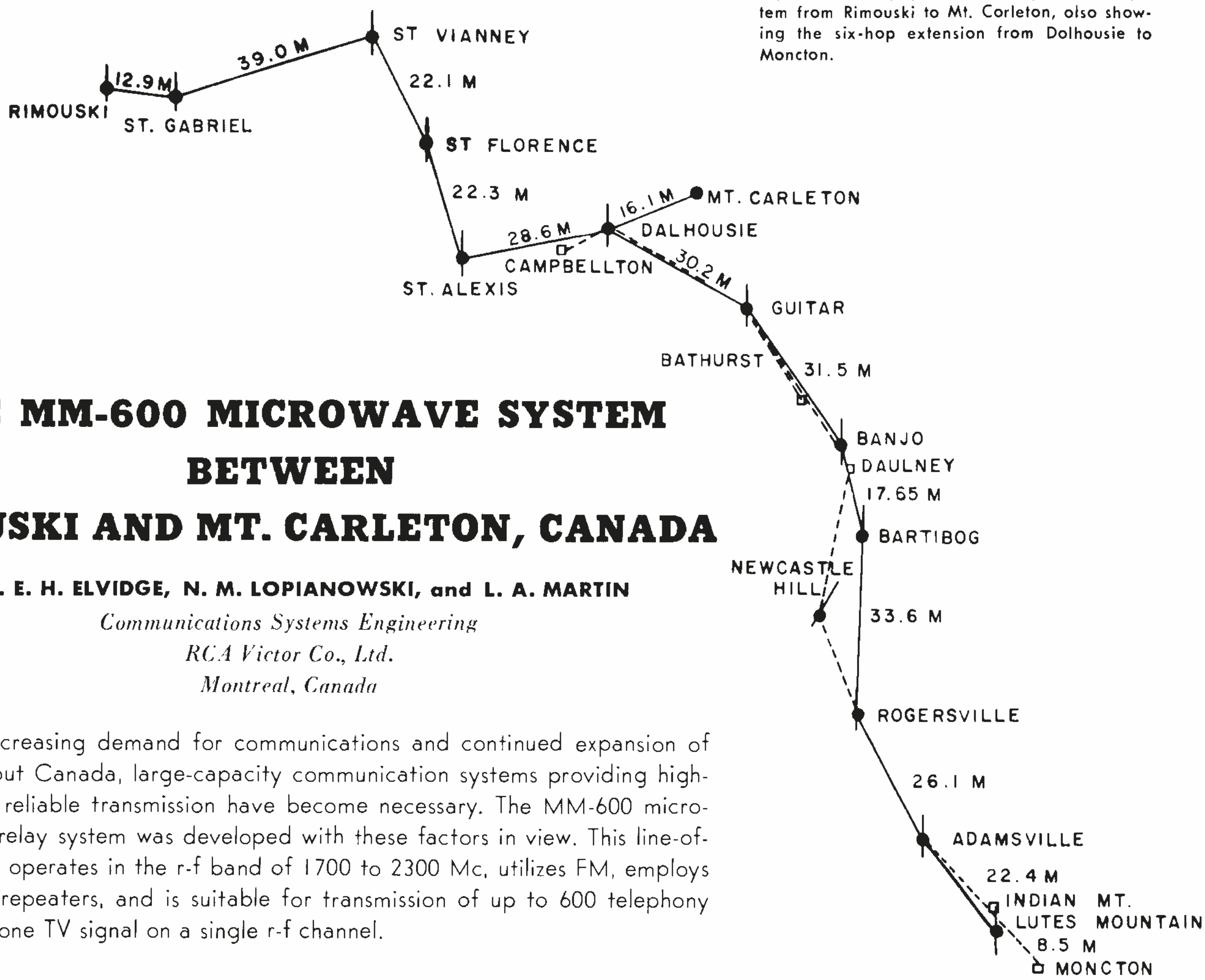


Fig. 1—Geography of the six-hop MM-600 system from Rimouski to Mt. Carleton, also showing the six-hop extension from Dalhousie to Moncton.

THE MM-600 MICROWAVE SYSTEM BETWEEN RIMOUSKI AND MT. CARLETON, CANADA

by **J. E. H. ELVIDGE, N. M. LOPIANOWSKI, and L. A. MARTIN**

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With the increasing demand for communications and continued expansion of TV throughout Canada, large-capacity communication systems providing high-quality and reliable transmission have become necessary. The MM-600 microwave radio relay system was developed with these factors in view. This line-of-sight system operates in the r-f band of 1700 to 2300 Mc, utilizes FM, employs heterodyne repeaters, and is suitable for transmission of up to 600 telephony channels or one TV signal on a single r-f channel.

J. E. H. ELVIDGE is a holder of a Higher National Certificate in Radio Engineering and is a graduate of the Institution of Electrical Engineers (1957). From 1953 until 1959 he was an assistant engineer with the British Post Office. He worked with a group responsible for the provision and maintenance of vhf, uhf and shf systems for transmission of TV and telephony signals throughout the United Kingdom. In 1960 Mr. Elvidge joined RCA Victor Co. Ltd., Engineering Systems Group, Montreal.

N. M. LOPIANOWSKI received a B.Sc. (Eng.) Honors Degree from the University of London in 1955, then spent five months as a development engineer on vhf signal generators at the British Communications Corp., Wembley. He then moved to Canada and spent a year and a half as a transmission engineer with Northern Electric Co. Ltd., Montreal. In 1957 Mr. Lopianowski joined RCA Victor Co. Ltd., serving first with the Radio Relay Systems Group, then the Communications Systems Group.

L. A. MARTIN graduated with honors in Electrical Engineering from the University of Toronto in 1955. He then joined Shell Oil Co. and worked at various sites in North America doing electrical distribution design, piping, automatic control design and various other operations. Mr. Martin joined RCA Victor Co. Ltd. in 1958 as an engineer in the Communications Systems Group.

THE FIRST SYSTEM using the MM-600 equipment was completed in 1960 between Rimouski and Mt. Carleton, Quebec. Primarily, it serves to extend the Canadian Broadcasting Company French Television Network to the southern part of the Gaspe peninsula. The system consists of two parallel channels; one is reversible to allow programs to be fed back into the network from Carleton, if necessary. The original six-hop system was extended in 1961 to include six more hops from Dalhousie to Moncton (see geographical layout, Fig. 1). This extension uses a later version of the MM-600 equipment (not described here).

LAYOUT AND SPECIAL FEATURES

The basic MM-600 stations employ a relatively simple equipment configuration. A typical radio equipment arrangement at one of the repeater stations on the system is shown in Fig. 2. Repeaters are heterodyne type with the r-f signal received and stepped down to an intermediate frequency of 70 Mc; the signal is amplified, transformed back into r-f, and re-transmitted. There is a provision for easily dropping information at any station; this is accomplished by use of i-f amplifiers designed with two identical outputs. One output is normally fed into the transmitter while the other is either terminated or, as is the case in this system, is fed into a demodulator and a video amplifier thus making each station a drop repeater. Fig. 3 shows the block diagram of the Rimouski radio equipment which can be considered a typical terminal station. Figs. 4 and 5 show the actual rack-panel arrangement.

One of the more interesting features of the MM-600 transmitter equipment is the use of travelling wave tubes (TWT's) with periodic permanent magnet focusing. The longitudinal magnetic field required in the TWT for focusing the electron beam travelling inside the helix is produced by a stack of magnetic ferrite rings; these are assembled so that like poles of adjacent magnets are touching. Such an arrangement results in a strong periodic type magnetic field, just as effective for maintaining the electron beam focus as a uniform field.

The weight of the ring magnets is relatively small: a stack 10 inches high weighs only about 1½ pounds. As well as being lighter and less bulky than its electromagnetic counterpart, there are resultant savings in power supply requirements. A further advantage is that the external field some distance from the TWT is very small; most of the field is confined to the required axis. Two TWT's can be seen in the Fig. 5 photo showing the front of an MM-600 transmitter

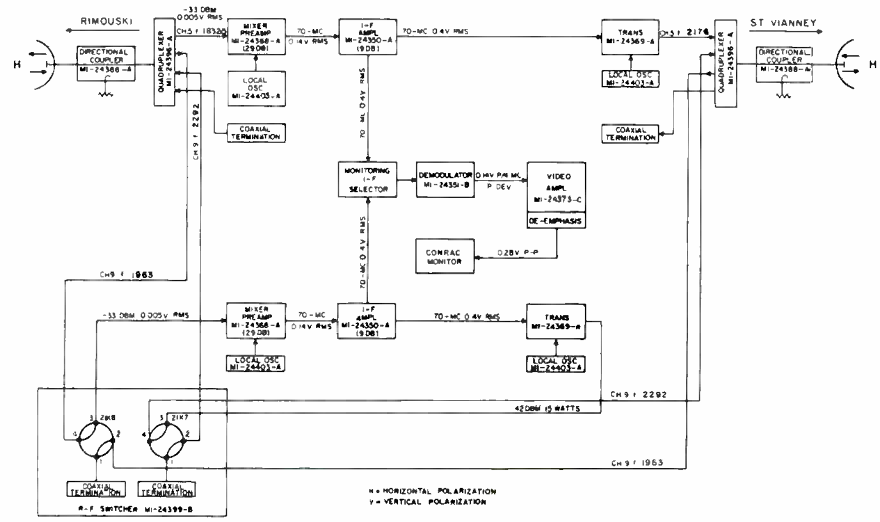


Fig. 2—Typical repeater-station.

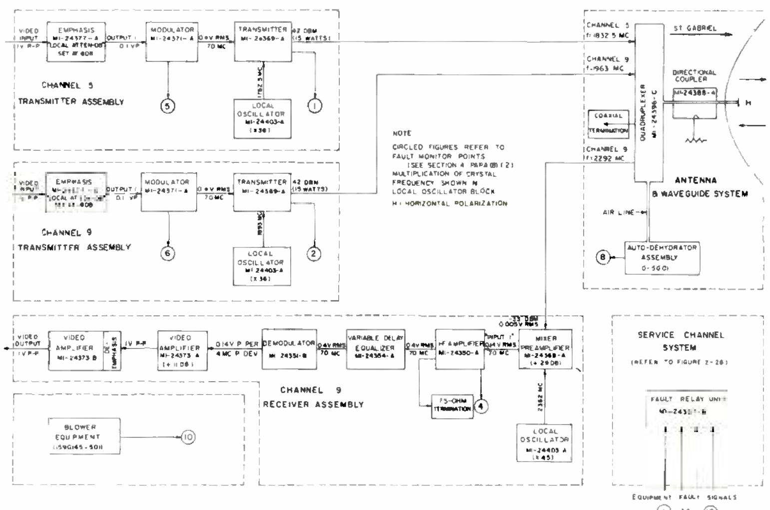


Fig. 3—Typical terminal station (Rimouski).

Fig. 4—Transmitter front panel, showing TWT's for intermediate power amplifier (left) and final power amplifier (right).

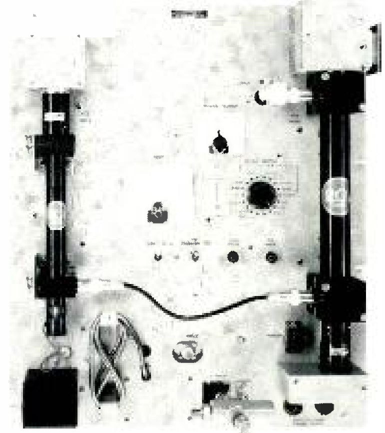
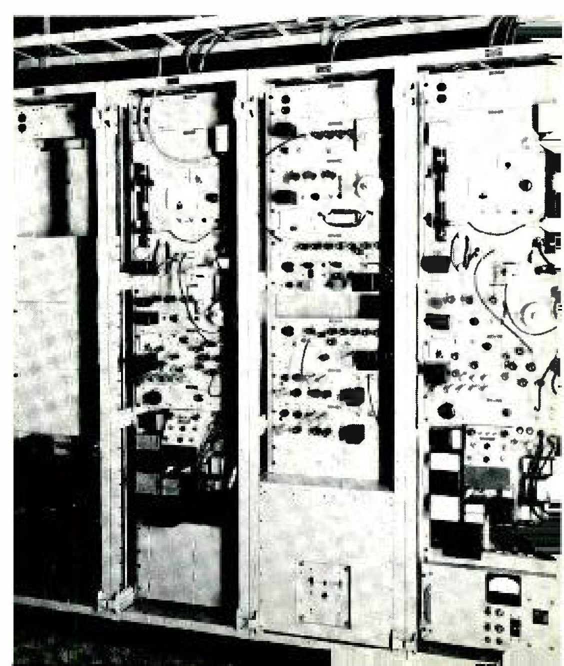
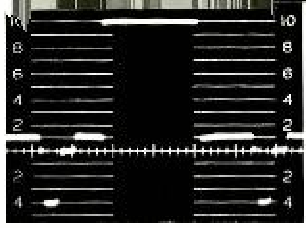


Fig. 5—The Rimouski terminal equipment. (See Fig. 3 diagram.)

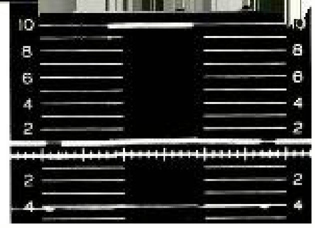


9a

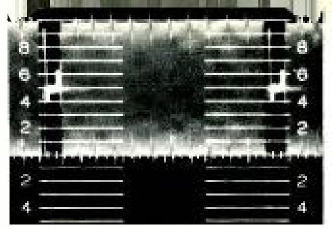
9b



9c



9d



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Figs. 9a, 9b—Transmitted window signals from Rimouski at line and field rates, respectively.

Figs. 9c, 9d—Received window signals at Mt. Carleton, Channel 9, corresponding to 9a, 9b, respectively.

Fig. 10—Differential gain for received modulated staircase signal, after passing through high-pass filter.

Fig. 11a—Transmitted staircase signal from Rimouski.

Fig. 11b—Received staircase signal at Mt. Carleton, Channel 9, corresponding to 11a.

Fig. 12a—Transmitted multiburst signal from Rimouski.

Figs. 12b, 12c—Received multiburst signals at Mt. Carleton corresponding to 12a, before and after trial period, respectively.

panel: The left-hand one is the intermediate power amplifier giving an output of 63 mw with a gain of 27 db; the right-hand one is the final power amplifier having a gain of approximately 24 db to produce a power output of at least 15 watts at 2 kMc. (A later version, MM-600/2 uses only one TWT.)

An interesting feature of the transmitter and receiver local oscillator is the use of varactor diodes recently developed for frequency multiplication at uhf frequencies. When a signal of varying amplitude is impressed across a varactor diode, the diode appears to the signal as a nonlinear variable capacitance; thus, harmonic currents of this signal are produced. In view of the low ohmic loss in a varactor diode the device acts as a very efficient harmonic generator.

Basically, the transmitter and receiver local oscillator consists of a crystal oscillator at a frequency around 50 Mc followed by two conventional type triplers and a varactor multiplier; the frequency applied to the varactor being is the order of 450 Mc. The varactor output is fed into a cavity where either fourth or fifth harmonics can be chosen and applied to the transmitter or receiver r-f mixer depending on the frequency plan of the system.

ANTENNA AND FEEDER SYSTEM

The MM-600 antenna used in the system is a unique paraboloid antenna employing a central reflector feed which is a development of the hoghorn antenna as shown in Fig. 6. Conventional hoghorn antennas could not be considered because of their size at 2000 Mc; the vertex-plate compensated paraboloid type was excluded due to performance considerations. The following descriptions and the sketches of Figs. 6a through 6d illustrate how the MM-600 antenna evolved:

6a) Shows the normal shape of a hoghorn whose frontal area is a sector of a circle.

6b) The same hoghorn but with its feed turned through 90°.

6c) Shows how it is possible to use the whole circle. This gives us an antenna which for the same useful area is greatly reduced in height and depth compared with hoghorn antenna.[1]

6d) General shape, final antenna.

Fig. 7 is a photo of the end product after further modifications to the basic shape had been made in order to get a good impedance match; typical performance values obtained over the 1700-to-2300-Mc band are: 1) gain 32 to 36 db; back-to-front ratio 58 to 64 db; and 3) a VSWR of 1.05.

The feeder system employs a rectangular aluminum waveguide of outside dimensions 4.3 by 2.15 inches and has a measured attenuation of only 0.5 db per 100 feet. In order to reduce internal reflections in the waveguide, quarterwavelength spacers were fitted at each joint to introduce two reflections (instead of one) which tend to cancel each other. The VSWR measured over the band of complete antenna and feeder system was of the order of 1.1. The waveguide runs are suspended rigidly from a single platform located at an elevation 2/3 the tower height. This allows for expansion of the waveguide to take place in either direction; expansion is taken up in flexible waveguide sections at both top and bottom of the vertical runs.

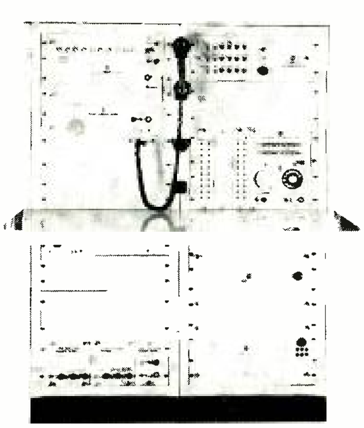
SERVICE CHANNEL EQUIPMENT

The term *service channel system* denotes all communication and control facilities used in the maintenance and operation of the radio system. Although the service channel system forms only an auxiliary part of the MM-600, it is worthy of special mention; it is a completely transistorized system employing logic and computer circuitry and represents a fairly new application of solid-state devices in such microwave systems.

The system can conveniently be divided into two parts, the *order wire* facilities for communication between stations, and the *alarm and control* facilities. Since the radio system described here is purely a TV-carrying one, the service channel facilities are carried by an auxiliary radio link which will not be described here. Rimouski was the supervisory station (a supervisory console is shown in Fig. 8) for the section first installed. All alarm and remote control facilities were at first monitored and operated from Rimouski; now, Moncton shares this function with Rimouski.

The monitoring of equipment fault status conditions along the system is performed by the automatic interrogation system which fulfills a mandatory requirement that a supervisory station receives accurate and frequent information on the status of all remote stations. Automatic interrogation is accomplished by repetitive transmission of subsequential tone pulses on individual tone chan-

Fig. 8—Rimouski supervisory console.



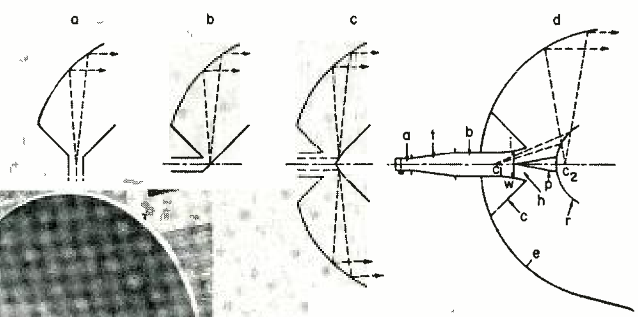
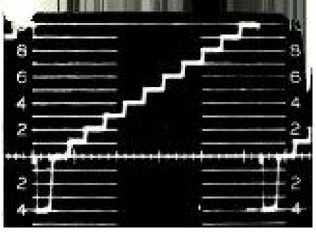
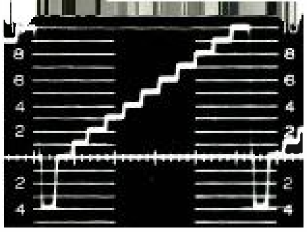


Fig. 6—Evolution of the unique MM-600 paraboloid antenna from the basic hoghorn type.

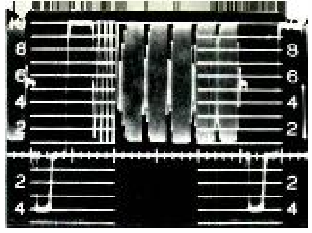
Fig. 7—Actual MM-600 antenna, general shape as in Fig. 6d.



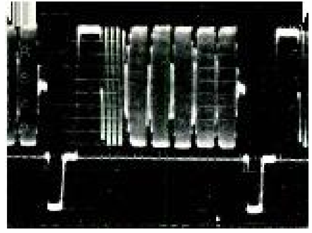
11a



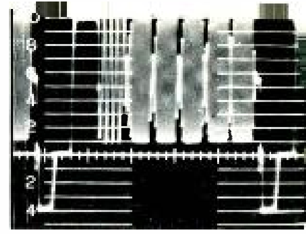
11b



12a



12b



12c

nel frequencies in the 4- to 8-kc band. Each tone frequency is exclusively associated with a particular remote station, and each remote station is interrogated once during an interrogation cycle. Since 400 msec is required to interrogate a remote station, the frequency of interrogation of any one station will depend upon the number of stations in a section.

Upon receipt of an interrogation pulse, the automatic responder at the remote station sends out one of the following three reply pulse lengths depending on the fault status: *no-fault*, *minor-fault*, or *major-fault* condition. By means of timing circuits, the automatic interrogator at the supervisory station analyzes the reply and suitably displays it on the console. A *no reply* from a remote station indicates a *system inoperative* condition providing fail-safe operation. Should a fault occur at any station, more specific information as to the nature of the fault can be obtained by taking this station out of the automatic interrogation cycle and manually interrogating it. This is done by transmitting a train of pulses to the remote station, and by means of multivibrators, gates, and timing circuits, synchronizing the reply and transmitted pulses. The reply pulses are decoded and the status of up to ten different faults and conditions may be displayed on a panel either as an *on* or *off* condition of indicator tubes —an extinguished tube indicating a *fault* condition, and an ignited one, *no fault*.

PERFORMANCE

Attention will be confined here to the over-all system performance between Rimouski and Mt. Carleton as the general performance of the MM-600 equipment has been described previously.[2]

Video Performance

The system performance can best be judged from comparison of the sent and received video waveforms (Figs. 9 through 13): these are typical of the results obtained on either channel.

Figs. 9a-d shows the window signal at line and field rates; negligible distortion of the signal occurs and less than 1-percent deviation from the maximum amplitude of the white level portion is experienced in each case. The system linearity as normally measured with a staircase waveform is shown in Fig. 11a, the transmitted waveform, and Fig. 11b, the received waveform. Once again, little or no distortion of the signal occurs. A more precise means, however, of measuring nonlinearity is to use a derivative technique. An equipment to do this, the Delay and Linearity Test Set was developed as part of the MM-600 program; it is capable of measuring changes in the slope of the transfer characteristic to less than one-half percent. Fig. 13a shows the results of such a measurement made over the system.

Figs. 12a-b indicate the systems gain-frequency characteristic; Fig. 12c shows the same channel measured one month later, exhibiting that very little deterioration occurred over this period.

Although the present system is now used to transmit monochrome signals only, it was required that conditions for color transmission be met. To test its suitability for color, the system differential gain and phase were measured by modulating a staircase signal at the color subcarrier frequency. The signal after being passed through a high-pass filter to remove the luminance signal, is shown in Fig. 10. As can be seen, the differential gain is better than 5 percent, while the measured differential phase is about 1°. The latter was confirmed by i-f group-delay measured after equalization over an 8-Mc band (Fig. 13b).

No direct measurements were made of the difference in transmission delays between the luminance and chrominance signals. However, knowing the performance of the individual baseband units, performance in this respect is expected to be more than adequate based on the i-f group-delay measurements.

Telephony Performance

Since the Rimouski-Mt. Carleton system was the first to be installed using the MM-600 equipment, tests were also made to determine its suitability for the transmission of up to 600 telephone channels.

Measurements of the performance were made, in accordance with CCIR recommendations, using a signal having a continuously uniform spectrum (white noise) to simulate the multichannel multiplex signal. The weighted signal-to-noise ratios obtained from these measurements are given in Table I. It should be remembered that these results were obtained on a system engineered for the transmission of video signals and with no special precautions being taken to get optimum telephony performance.

TABLE I—Weighted Signal-to-Noise

Radio Channel	*Center freq. of measuring channel, kc*	*Signal-to-noise in db (FIA weighted)*	
		System unloaded	*System loaded*
5	70	67.0	60.5
	1002	68.0	61.0
	2438	67.0	61.0
9	70	67.0	65.0
	1002	68.0	63.5
	2438	69.0	64.0

CONCLUSIONS

The Rimouski-Mt. Carleton system has been in operation and carrying television programs since the middle of June 1960. No major fault has occurred nor has any serious degradation in performance taken place during this time. Thus, the system has proved itself capable of providing the high-quality, reliable performance required of today's high-capacity systems.

ACKNOWLEDGEMENTS

The authors responsible for system planning and testing acknowledge the assistance of their colleagues in Microwave Equipment Engineering (Broadcast and Communications Products Div.) in Camden, N. J., and in RCA Victor Co. Ltd., Montreal, who were responsible for the development of the MM-600 equipment. Thanks are also due to the Canadian Pacific and Canadian National Railway Companies for permission to publish this paper.

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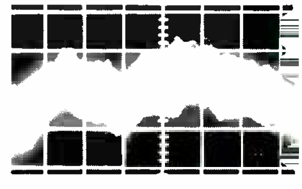

Fig. 13a—System linearity using RCA Delay and Linearity measuring equipment. Each horizontal division, 1 Mc; each vertical, ½ percent.

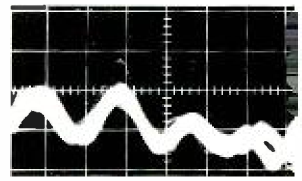

Fig. 13b—System i-f group delay using RCA Delay and Linearity measuring equipment. Each horizontal division, 1 Mc; each vertical, 5 nsec.

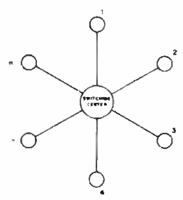

Fig. 1—Switched system.

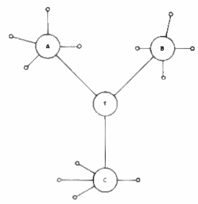

Fig. 2—Three switching centers.

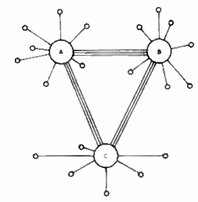

Fig. 3—Tandem switching.

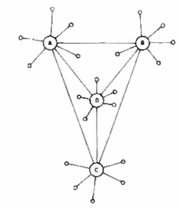

Fig. 4—Alternate routing.

SWITCHING IN COMMUNICATION SYSTEMS

A survey of modern switching systems and their relation to over-all communication-system organization, control philosophies and network arrangement. For a specific application, see Segal and Guerber on ComLog-Net, this issue.

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THE DESIGN OF THE over-all communication system and of its switching equipment must be closely interrelated to achieve an optimum system performance. Usually, either the communication system or the switching equipment is already designed, and a "marriage of convenience" is arranged.

From the viewpoint of the *communications system engineer*, the most important switching-center characteristics are: terminal capacity, traffic capacity, supervisory and control signalling methods, and switching speed. From the viewpoint of the *switching-system engineer* the most important factors are: network configuration, quality of system transmission media, traffic statistics offered to switching center, and the grade of service desired.

SWITCHING AND WHY IT IS DESIRABLE

Communications switching and alternate routing are best described as related to a clearly defined communications system. A model system might comprise:

1) Subscribers or stations which offer traffic to the system and require random interconnection, though in accordance with established statistical knowledge.
2) Communication channels which may be interconnected and over which traffic may be transmitted at certain levels of performance, i.e., bit rate, error rate, etc.
3) Means for interconnecting the subscribers via the transmission channels in accordance with traffic requirements.

Thus, a communications system generally consists of three groups of equipment: 1) station, or subscriber, equipment; 2) transmission facilities; and 3) interconnecting, or switching, equipment. The lines separating these three categories are often not clear-cut; frequently, transmission channelizing gear is closely associated with subscriber station apparatus, or multiplexing gear is closely integrated with the switching equipment. This paper is not concerned with such subtleties, but rather discusses the capabilities of modern switching equipment, and the effects upon the communications system organization.

For example, in a communication system of n subscribers, having only station equipment and transmission facilities (no switching) each subscriber must be able to communicate with every other subscriber. Therefore, every station must terminate n-1 transmission channels. The total number of channels in this system will be $n(n-1)/2$, assuming that each is a two-way channel. Further, assuming that each station engages in one transaction at a time, only $n/2$ channels will be in use even when all stations are in simultaneous operation. Thus, maximum channel occupancy in such a system is only $1/n\text{-}1 \times 100\%$. This is not an efficient approach to the design of a system of considerable size.

Another example is a communications system of n stations, including a switching facility. Fig. 1 shows such a system wherein each station need terminate only one channel, and the upper limit on channel occupancy is 100 percent, assuming that the switching facility is non-blocking. In this arrangement, transmission facilities are more efficiently utilized, although this benefit is not free; the switching facility must be paid for, and the stations must communicate with the switching center.

In a communications system where stations are distributed over a wide geographical area, more than one switching center is desirable. In Fig. 2, several switching centers are located to minimize the total transmission plant. In addition, transmission paths between switching centers provide stations (served by one switching center) with access to stations served by other switching centers.

Extending this concept to a system with many switching centers, the same logic of providing switching for channels interconnecting the switching centers may be applied. In Fig. 3, switching centers are served by another tandem or transit center; in this case, the tandem center serves no stations, only trunks. Fig. 4 is another version of this concept wherein each switching center serves a dual purpose, that of switching both stations and trunks from other centers.

Fig. 4 illustrates alternate routing, another feature of communications systems using switching. Suppose a station served by switching center *A* wishes to call a station served by *C*. When the route is denied, several alternate routes are available to provide increased system reliability: *A-B-C*, *A-D-C*, *A-B-D-C*, and *A-D-B-C*. However, an interconnection delay is introduced; also, routing design must be such that "Ring Around the Rosy" cannot occur.

There are two general categories of switching: 1) *circuit switching*, also known as line switching, real-time switching, and user-to-user switching; and, 2) *message switching*, also known as "store-and-forward" switching. The following discussion deals with these two types of switching, and also shows an example of communications system design combining both.

CIRCUIT-SWITCHING

In order to design a communications system with circuit switching, it is necessary to determine such system parameters as the number of trunks, traffic capacity of switching centers, types of supervision and signalling, transmission characteristics, and operating speed of the switching equipment. These parameters are strongly interrelated; desired system performance determines required traffic capacity, characteristics of the traffic affect the size of the trunk groups, and the required transmission performance affects the method of switching center implementation.

Traffic Considerations

The traffic that a communications system can handle is determined by the number of channels available to the traffic, and the statistics of the traffic. It is desirable to utilize the system at a high level of efficiency and it is desirable to provide a high grade of service. A near optimum compromise between these two conflicting requirements may be obtained through traffic engineering. The underlying principle of traffic engineering is that all subscribers or stations do not generate traffic all the time. Thus, the system need not provide sufficient channels for all stations to be served simultaneously, if a certain probability of call loss or delay is acceptable. To determine the grade of service, it is necessary to know the statistical characteristics of the offered traffic. A very reliable statistical model of telephone traffic has been created from data compiled by the telephone industry for more than 50 years.

When engineering a new system, the behavior of the subscriber is not easy to envision. For example, if a new communications system were being designed to function in the wake of a nuclear attack, actual traffic data could not be measured. Here the system engineer would have to estimate the subscriber behavior on the basis on such considerations as the type of message to be handled, the speed of transmission, the number and disposition of stations, and finally, extrapolation of his own experience.

Signalling

In a communication system using circuit switching the subscribers must contact the switching centers to establish connections, e.g., dialing in the civil telephone system. In addition, the switching equipment must determine line or trunk status; i.e., busy or idle, requesting service or not, etc. Further, in tandem connections, there must be communication between switching centers to establish the connection. All this communicating is called signalling; there are two types, control and supervisory. Control signalling involves the transmission of information regarding the ultimate disposition of the call; supervisory signals involve the status of a connection after it has been established.

In systems where the transmission channels are subject to a high error rate, the control-signalling may provide acknowledgement after every digit or charter to insure accurate reception. This may be done by error-checking codes, or by retransmitting the address back to its origination for comparison.

There are a number of ways to transmit supervisory and control signals. In an elementary telephone system, the d-c condition of the line transmits the intelligence. Where metallic connections are not available, as in radio or carrier links, the signals must be transmitted as tones or frequencies. These tones may be within the bandwidth occupied by the traffic carried through the system or outside this band.

The system engineer must choose the technique to be used to assure that the transmission facilities will accommodate the existing technique. Often, the new system may be required to work compatibly with an existing system; the signalling standards of an existing system must be closely examined to determine the interface problems between systems. Frequently the best solution will be for the new system to adopt the signalling scheme of the old, if all the operational requirements of the new system can be met with the old signalling.

The over-all system performance is greatly affected by the speed of the control signalling. For example, it takes 10 to 15 seconds to dial a 10-digit code in a conventional telephone system. The central office will be able to retransmit this code to another central office in 1 to 2 seconds.

The signalling methods in a system using circuit switching are varied, and the selection of method depends upon considerations, such as compatibility with existing plant, the availability of equipment for the new system, and the characteristics of the transmission facilities. The system engineer should devote a great deal of effort to the study of signalling early in the design of the system. No other item will have so profound an effect upon over-all performance.

Transmission Considerations

The transmission capabilities of a communications system are usually determined by the transmission facilities and the type of information to be carried. The switching equipment should impose no transmission limitations. Thus if the transmission facilities are 4-wire, so should be the switching equipment. The bandwidth of the switch gear should be sufficiently greater than that of the transmission channel so that no amplitude or phase distortion is introduced into the switched channel. Also, noise and crosstalk performance should not be degraded.

While these requirements appear obvious, there is frequently strong pressure to compromise them. For example, a 4-wire switching center is more expensive than a 2-wire. Similarly, it is cheaper to use common-return rather than balanced paths through the switching network. This, of course, may degrade the crosstalk performance.

Also, the switching technique may impose transmission limitations. For example, in time-division systems the sampling rate directly controls the bandwidth, and the complexity and cost of the system increases with sampling rate. In space-division systems, the choice of switching elements can largely affect bandwidth, distortion, and crosstalk. Thus, the systems engineer must consider switching center implementation as a part of the whole system.

Speed of Operation

In systems where the users are human beings, and the message duration is some 3 or 4 minutes, it makes little difference if the connection is established in 5 seconds or 5 milliseconds. When the users are machines, and the message holding time is some 5 seconds, it matters a great deal. In digital signalling at say, 2400

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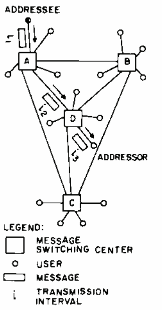

Fig. 5—Message switching system.

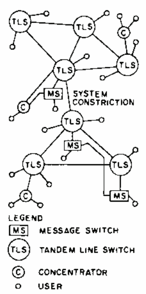

Fig. 6—Communication system with line and message switching.

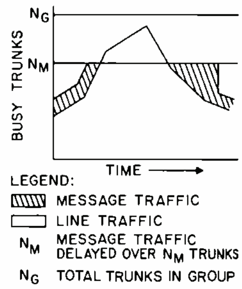

Fig. 7—Traffic leveling with line and message switching.

bits/sec, a 10-digit code in binary-coded decimal would require 40 bits, or about 18 msec for transmission, neglecting transmission delay. Here would be reason to speed up the switching center, assuming of course the user would utilize the speed of connection. While there may be good reasons for increasing switching speed regardless of user appreciation, the over-all speed of systems operation is a combination of the performance of various portions of the system, and must be evaluated from an over-all system point of view.

MESSAGE-SWITCHING

The system configuration of Fig. 5 is an arrangement comprising users and lines, combined local-tandem switching centers, and tandem trunks featuring a multi-alternate-routing capability. This arrangement can apply equally well for message and circuit switching and result in efficiency, flexibility and economy.

Basic Store-and-Forward Operation

The flow of a *store-and-forward* communication in this configuration would characteristically be as follows: a man or machine prepared message is placed on line to be recorded in its respective switching center, e.g., *A*. The matter of permanent records is attended to and an idle trunk to the terminating center, e.g., *D* is seized. The message is forwarded to *D*, recorded and sent to the addressee when his line is idle. The sequential nature of the operation is indicated by message transmission intervals, i_1, i_2, etc. in Fig 5. The entire sequence involves one-way communication. Since an end-to-end connection is not involved, an answer or acknowledgement will constitute a new message from former addressee to addressor. As in circuit switching, centers *A* and *D* may be arranged to cause an alternate routing attempt via center *B* or *C*.

Queuing

A basic and valuable characteristic of a message switching center is its ability to arrange outgoing messages in file on any given output channel. This operation is known as queuing. Messages arriving at a given switching center are steered into storage units, one for each outgoing channel, and within any given outgoing unit arranged in order of arrival for retransmission. This treatment assumes that all messages are of equal urgency.

With a higher degree of sophistication in the queuing technique, messages of greater urgency can be given preferential treatment for greater speed of delivery than would otherwise result. Several levels of precedence can be established for a range of selective treatment. The precedence indicator is usually placed in the message header. Such treatment has its application in both civil and military communications for preferential handling of urgent messages.

Message Interpolation

A technique related to queuing is message interpolation in which a long message may be interrupted to permit the forwarding of a short message. Retransmission of a long message on the request for interpolation, is continued to the conclusion of the current message block. The short message is then forwarded, followed by remaining stored sections of the long message.

Individual blocks must be numbered and accounted for to maintain proper sequence of transmission without repetition or loss. Intact messages must be collected and assembled at each *via* point. For efficient operation with message interpolation the length of each message must be known and there must be fixed limits based upon some optimum relationship of interrupting and interrupted message lengths. The length of messages can be simply indicated to the message switching center by placing a block count indicator in the message header.

Pre-emption

In some instances it may be found that the delays suffered by urgent messages in awaiting retransmission are intolerable. The technique of pre-emption may then be applied. This permits immediate seizure of a desired line in use for a lower priority message with the possible loss of some of its message content. The interrupted message may be forwarded later in blocks, in sections, or in full depending upon the degree of sophistication of record keeping. Sufficient repetition of text transmission to cover lost message content is involved. Complete retransmission between two message switching centers involves the simplest record keeping.

Multi-Address

A communication requirement which can be simply achieved with store-and-forward treatment is that of multi-address message transmission. The requirement is that a message generated by one user be transmitted to several others. With no real-time end-to-end requirement, the message may be forwarded in sequential transmission once to each addressee. Since it is assumed in this discussion that each user has but one line to a switching center, sequential transmission from the addressor would merely result in *n* messages for the case of *n* addresees, and the system would be loaded with *n* times the traffic of a single-address message. Improvement in transmission facility holding time can be achieved by a single message transmission to the switching center and subsequent simultaneous forwarding from the center to addressees.

Language and Speed Conversions

The message switching center is adaptable to performing conversions of language and speed of message transmission useful in resolving compatibility problems between various kinds of user devices. In the application of conversion features, suitable programming and storage facilities must be provided.

Language incompatibility and need for conversion[1] might arise in a situation as follows: A data communications system is to serve two groups of users, each widely distributed in the same large area, each with its high community of intra-group communication interests and each, therefore, with a machine family and data language, best suited to its own needs. One group might use teletypewriter machinery generating data in the Baudot code (5-bit alphanumeric character code) the other computer machinery generating Fieldata Code (8-bit alphanumeric character code).

With an added requirement for frequent intergroup communications on the part of many users, an incompatibility develops. One solution would be to provide suitable conversion equipment at all user devices. This solution is generally infeasible from an economic standpoint. An alternate method is to provide common code-translation equipment in sufficient numbers in the switching center.

User devices, excluding large computers and machine complexes, transmit at line speeds commensurate with their own operation or input speeds. User line speeds vary with the type of user device; speeds are generally far slower than the bit-rate capability of long-haul trunks. The need for speed conversion at the message switching center is met by providing message read-in and registration at the expected speed for a given line or trunk—and readout at a predetermined speed on another line or trunk. In the interests of simplicity and economy, there have been recent efforts at standardizing a minimum number of useful line and trunk speeds. Some agreement has been reached on the use of bit rates fitting the formula $75 \times 2^n, n = 0,1, \ldots$.

THE MESSAGE-SWITCHING CENTER

The design and internal configuration of the message switching center will largely depend upon the following basic user requirements: 1) the need for one-way non-real-time message transmission, 2) timing of the transmission, 3) the need for multi-address communications, and 4) the need for communications in certain languages and at certain speeds.

Other requirements by contrast have a bearing on the engineering of the center and the system, i.e., the number and kinds of circuits for each center, the number and locations of centers in the system and the number of trunks between centers.

Equipment Considerations

Functional building blocks of a message switching center are *read-in*, *storage*, and *read-out*. Modern data-handling systems are made to cope with relatively high-speed digital streams and effect store-and-forward communications between business card machines, magnetic tapes, high-speed printers, and other computer-type devices. Message switching center circuit components and functional units in new designs are principally electronic to provide speed of operation and versatility.

The recent RCA AutoData Automatic Message Switching System[2,3] includes a read-in or input section having line buffers, buffer commutator, code converter, and input store. Line buffers accept message data at line speed and are scanned periodically by the high-speed buffer commutator to detect complete receipt of a character. Parallel transfer of the character bits then takes place. The character, subject to table look-up code conversion, is relayed to the high-speed input core store. At appropriate intervals the translated characters in the input store are transferred to the cross office section. The cross office section consists of short-term core store, communication data processor and in-transit drum store. The data processor uses logic to determine routing from the message header and effect switching. The output section consists of output store, code converter, buffer commutator and line buffers.

COMBINED LINE-MESSAGE SWITCHING

Several system designs using circuit and message switching have emerged from recent communication system planning. One suggested arrangement is shown in Fig. 6. It is assumed here that the system is extensive, serving many users and that some of the communications must be on a real-time basis (others require recording or may suffer delay).

Application of Circuit Switching

In an extensive system with some requirement for real-time communications, the application of circuit switching is indicated. Fig. 6, therefore, shows a network constructed about a group of tandem circuit switching centers providing real-time connections within and between separated areas in the over-all system. The interconnecting transmission links are arranged to provide multi-alternate routing and, thus, system reliability and flexibility.

Since the tandem line-switching centers are located within user areas, the need for additional local switching centers can be minimized if combined local-tandem service is provided. In Fig. 6, user lines appear at the tandem switching centers. Locations of the tandem circuit-switching centers will be based upon: 1) the locations of aggregates of users, 2) the terrain affecting transmission routing, and 3) the possibility of creating redundancy in the network.

Application of Message Switching

Assuming the need for a complete assortment of data communications, one would expect to find a demand for multi-address message transmission, much of which could suffer some delay in delivery. This requirement, with the need for record hard-copy at multi-points, postulates need for message switching.

Since the real-time requirement prescribed the need for circuit-switching, message switching might be considered subservient to the circuit switching function, with both arranged for coordinated operation. Unless the circuit switching requirements were so minimal in the system that a simple order-wire arrangement would suffice, the system should be basically circuit switched as in Fig. 6; message switching centers provided in minimal numbers are shown homing on some tandem circuit switching centers.

Consistent with requirements, effort should be directed at minimizing the number of message-switching locations. Fewer large centers can be more economically implemented and more efficiently operated than many small centers, since common control and power are required in any event. In fewer larger centers, problems of maintenance, supply and repair are simplified. A system design with more widely distributed circuit than message-switching is fortuitous, since circuit switching too is more economical.

The function of message switching in the system can be enhanced and extended with the application of circuit switching for concentration. Local switching centers can be installed in areas remote from the main lines of the tandem network to channel the messages from numbers of lines to less heavily loaded or more efficiently used trunks.

Combined Operation

With co-located message and circuit switching centers, arrangements should be made to assign trunks in the intervening media directly between message switching centers for handling large volumes of store-and-forward traffic. Where trunks are used between switching center sites for both line and message traffic. messages may be transmitted during non-peak levels of line traffic to fill the transmission medium efficiently. The traffic leveling effect obtained is shown in Fig. 7. When line traffic on a group of total trunks, N_G, occupies N_M trunks or more, message traffic is delayed to maintain desired grade of line traffic service. Release of a large block of held over message traffic is shown by the large shaded area at the right.

CONCLUSION

It has been shown that used singly in communications systems, circuit switching has the advantage of providing user-to-user contact with no storage cost or responsibility for message delivery. Message switching, by contrast, provides queuing and a more efficient use of transmission subsystems; it also facilitates multi-address handling.

Used together, circuit-and-message-switching systems can provide still greater flexibility and efficiency in communications operations. The present trend is to combine the two in a single entity with common control and memory facilities, a new degree of sophistication in the communications art.

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ComLogNet
AUTOMATIC STORE-AND-FORWARD MESSAGE-SWITCHING CENTERS

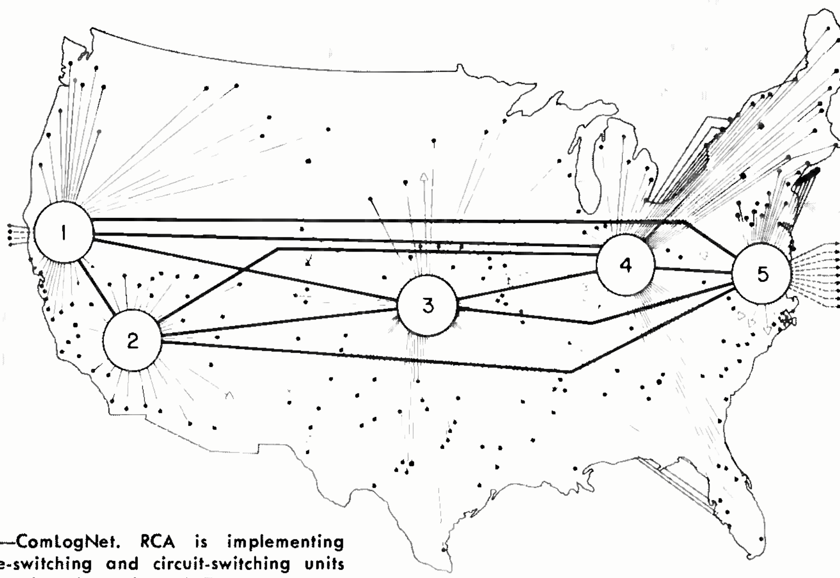

Fig. 1—ComLogNet. RCA is implementing message-switching and circuit-switching units at the numbered locations shown, and is supplying a number of tributary magnetic tape out-stations.

ComLogNet is a large-scale application of advanced digital-computer techniques to a data transmission and switching network for U.S. Air Force logistics communications. It uses high-capacity telegraph and microwave communications to link the remote transmission stations and the automatic switching facilities. In essence, it allows computer centers to communicate with each other, in spite of differences in native codes, formats, speeds, controls, and operational requirements.

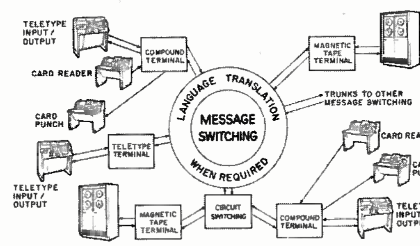

Fig. 2—Input-output devices.

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THE ELECTRONIC COMPUTER, at first thought by many to have applications only in the scientific field, has since found enthusiastic acceptance in business data processing and analysis. Now, two new areas for computer application are industrial controls and communications. One such application is a large-scale system, the *Data Communication System, Phase 1*, being implemented at several U.S. Air Force Bases, for which the Western Union Telegraph Company has been appointed systems manager. It is known in short as COMLOGNET (Fig. 1) and is an extension of modern computer technology and automatic data-transmission techniques to *logistic data handling* — an operation which today includes a vast amount of procurement, inventory, and other types of communications traffic.

The major digital data handling equipment, which includes a circuit-switching unit and automatic electronic switching centers, is being designed, manufactured, and installed for Western Union by RCA.

COMLOGNET is a high-speed data-transmission and switching network involving high-capacity telegraph and microwave communications to link remote transmission stations *(tributary stations)* to automatic switching facilities *(automatic electronic switching centers)*. The switching centers automatically handle military communications within the network by acting as clearing houses for messages on a priority basis. Subscribers can communicate with each other in spite of differences in their native codes, formats, speeds, controls, and operational requirements. This feature is achieved through the use of buffers, i.e., storage devices to compensate for differences in rates of data flow when transmitting information from one computer device to another. In addition, each switching center can be supplied with tape-station converters to permit high-speed data exchange with local computers by means of magnetic tape.

Initially, COMLOGNET channels will operate at 75, 150, 1200, or 2400 bauds. (*Bauds* is the number of code elements, pulses and spaces, per second.) Both user-to-user circuit-switching units (CSU) and store-and-forward message-switching units (MSU) are provided. A CSU can be expanded to service 200 subscribers, while an MSU can provide message flow on either 50 or 100 full-duplex channels. The CSU subscribers can avail themselves of the MSU facilities. The communication data processor can handle daily 7 million punched cards or their equivalent in information. Fig. 2 illustrates that punched cards, how-

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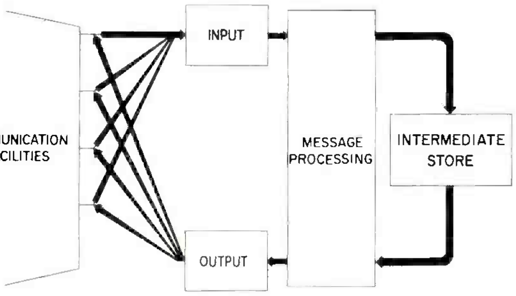


Fig. 3—Simplified diagram of an automatic electronic switching center.

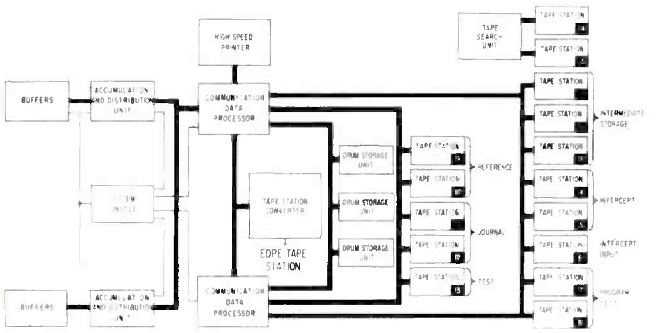
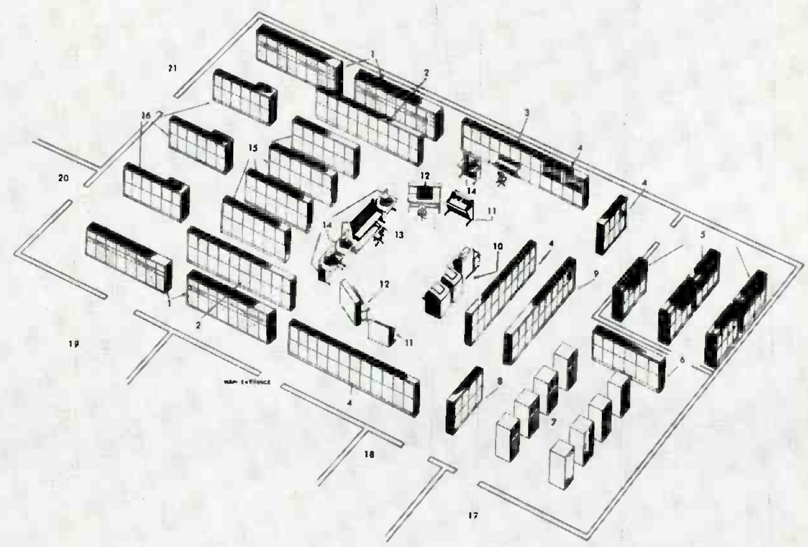


Fig. 4—Equipment in the automatic electronic switching center.

Fig. 5—Typical floor plan for a 50-line automatic electronic switching center.

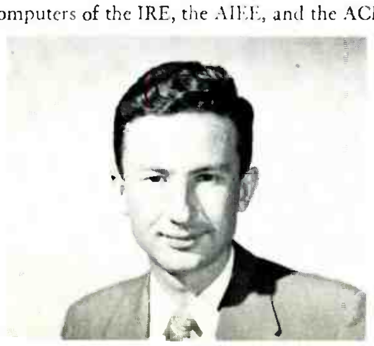


1—communication data processor
2—accumulation and distribution unit
3—tape search unit
4—tape stations
5—power regulating and control units
6—circuit switching
7—EDPE tape stations
8—power station converter
9—power distributing cabinets
10—card teletype station
11—paper tape reader
12—operator's console
13—system console
14—monitor printer
15—buffers and power supplies
16—drum storage units
17—maintenance center
18—tape vault
19—modulation-demodulation
20—technical control
21—crypto room

ever, are but one of the information-media used in ComLogNet. Other media include magnetic tape, teletypewriter, and punched paper tape.

The basic concept of the system is depicted in Fig. 3, with the equipment complement of a 50-line switching center shown in Fig. 4. Some key operating features appear in Table I.

HOWARD P. GUERBER received his BSEE degree in 1947 and his MS degree in 1954 from the University of Colorado. From 1948 to 1950, he worked on the development of analog computers for fire control, and guided-missile applications at Westinghouse Electric Corp. In 1950, he joined the RCA Advanced Development Section in participating in an initial computer system feasibility study leading to the development of the Bizmac system. Mr. Guerber was promoted to Leader, Systems Engineering, in 1959. Responsibilities include the definition of customer requirements, development of procedural techniques and general hardware organization for the ComLogNet message switching center equipment. Mr. Guerber is a member of the Professional Group on Electronic Computers of the IRE, the AIEE, and the ACM.



MECHANIZATION OF THE AUTOMATIC ELECTRONIC SWITCHING CENTER

ComLogNet message-switching hardware is based upon RCA AutoData equipment[1]. A general idea of the overall size of the system may be obtained from Fig. 5. A typical automatic electronic switching center consists of 120 racks which contain 155,000 transistors, 620,000 resistors, 155,000 capacitors and 780,000 diodes mounted on printed-circuit boards. Three types of buffers (teletype, low-speed, and high-speed) are packaged in modular form, are mounted ten buffers per rack, and can be supplied to meet the requirements of a particular switching center.

Data storage includes magnetic drums and tape stations as well as a high-speed memory of 1.5-μsec access time associated with each communication data processor (CDP). A tape station con-

TABLE I — OPERATING FEATURES OF THE SWITCHING CENTER

Journal

Provides a general traffic record on magnetic tape of the system's activity. Included are times of arrival and dispatching of messages.

Statistical Data

Allows a switching center to collect and print out useful housekeeping data including the number of messages awaiting transmission, channel utilization and errors detected in transmission and other statistical information regarding the performance of the system.

Reference

Provides a permanent copy of all messages handled by the center. Each received message is recorded on reference magnetic tape.

Ledger Balance

Provides an up-to-date record of the current activity within the switching center, showing at any given time the status of all input and output channels and tapes.

Alternate Routing

Permits traffic from a particular switching center to be distributed over one of several paths to another switching center according to the established trunk routing plan. The established routing plan may be changed by manual insertion of the desired program change.

Categorization

Each record of a message addressed to this service may be "broken-out" into one of ten separate categories, to be sent to the relevant station which is to receive this category of information.

Precedence and Priority-Interrupt

Establishes relative order in which messages are handled.

Messages are transmitted in order of precedence of which there are six in ComLogNet. Message of precedence levels 1 and 2 are released upon collection of a complete message even if this requires interruption of messages of precedence 3 or lower.

Virtual Cut-Through

Provides a virtual user-to-user connection for message switching subscribers. Messages granted this service are transferred directly from input to output, thus bypassing intermediate storage.

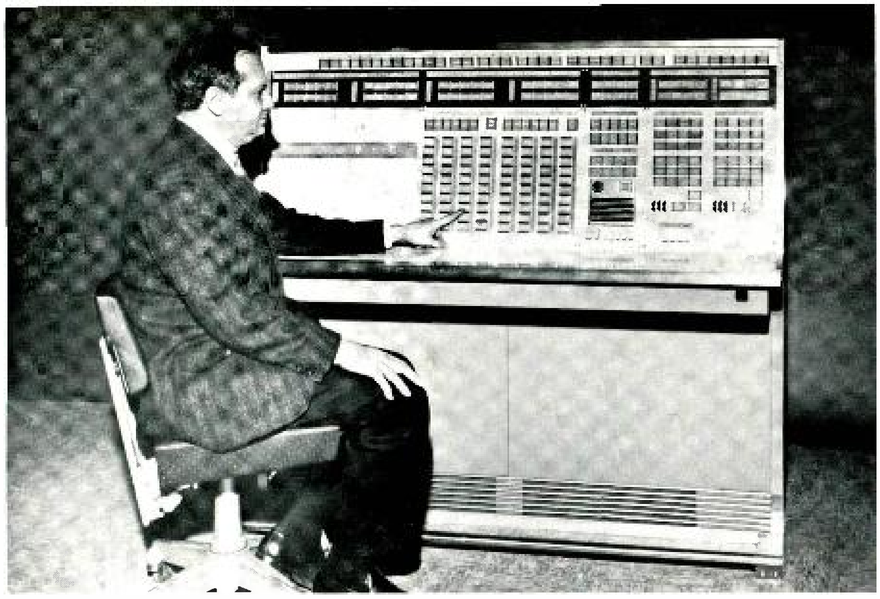


Fig. 6—ComLogNet 50-channel system console with co-author Bob Segal.

verter permits high-speed communication with local electronic-data-processing centers via magnetic tape. A supervisor's console (Fig. 6) permits monitoring and control of the switching center. A typical system complement has two accumulation and distribution units (ADU) and two CDP's, all four of which are electronic computers.

The ADU is a special-purpose digital computer utilizing both wired- and stored-program techniques to coordinate channel operation in conjunction with the CDP. It will accommodate up to 25 full-duplex (simultaneous receiving and transmitting) channels or 50 one-way channels, or any mix of these services within the maximums stated.

Its functions are: channel coordination with tributary stations; storage for input and output lines; code conversion between the transmission code and the common language code of the CDP, and vice versa; and finally, high-speed communication with the CDP. A system with 50 full-duplex channels requires two ADU's per switching center, while a system with 100 full-duplex channels will have four ADU's per switching center.

The CDP is a solid-state high-speed digital computer. One CDP handles the communications traffic, while the other performs test and auxiliary "housekeeping" functions. The reason for two CDP's is reliability. In the event of CDP trouble when handling traffic, control is automatically transferred to the alternate CDP without loss of data.

The CDP (Figs. 7, 8, 9) consists of the *basic processing unit, high-speed memory, consoles, input-output transfer channels,* and *input-output switches.* A typical input-output complement for the CDP includes three drum storage units, two accumulation and distribution units, 13 magnetic tape units, and an on-line high-speed printer. Tape-station converters are available which will permit communication between the ComLogNet switching center and local electronic-data-processing installations.

The functions of the CDP are illustrated in Fig. 8. The CDP serves as the master in the store-and-forward service performed by ComLogNet. Its high speed permits the servicing of up to four ADU's. Categorization, accuracy checking, message protection, and records of all messages handled are additional functions of the CDP. Information brought into the CDP memory is stored there only long enough to have pertinent data extracted from its heading; it is then forwarded to *intermediate drum store* until it is ready to be transmitted to its destination or destinations. The time in intermediate storage is determined by traffic conditions and message priority. Under normal traffic conditions, all data is recorded on magnetic drums. If traffic increases and the drum contents near capacity, low-priority messages are transferred temporarily to intermediate tape storage to alleviate the overload condition.

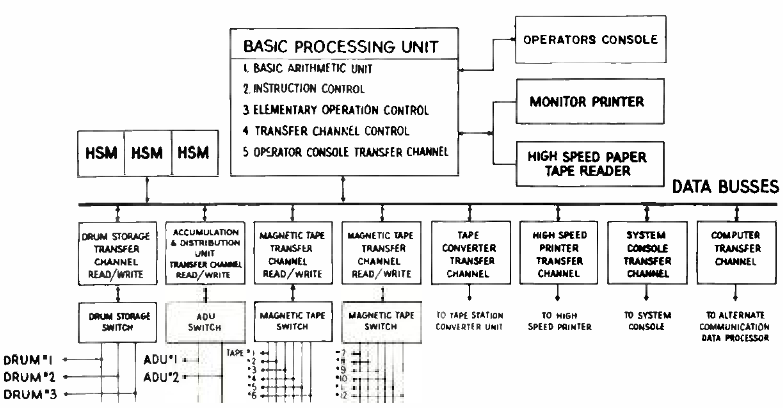


Fig. 7—Communication data processor.

All messages entering the system must have a heading specifying priority and destination. This information with the time of arrival is queued into the *bookkeeping tables* of the high-speed memory, and is also written to the *drum-store* and to the *ledger tape.* The latter two records are used for accuracy control to insure that no message is lost or remains in storage longer than its priority permits. A print-out is made automatically when any message is kept in intermediate storage too long. A permanent record of all traffic handled is kept on the *journal tape.*

The tape-search unit (TSU) is a solid-state, off-line, high-speed computer. Its equipment complement may include three magnetic tape stations, a monitor printer, and a tape search console (Fig. 10). The TSU provides the ComLogNet switching center with a facility for automatically searching a magnetic tape for messages or selected portions of messages. The criteria for search may be specified by the operator in accordance with the mode of operation selected. The TSU extracts the desired information from the tape being examined. The output data may be recorded on another magnetic tape or punched paper tape. A page-printed copy of the output may be obtained by way of the *monitor printer.*

Information is brought into or obtained from the ComLogNet message switching center via subscriber terminal stations, each of which is characterized by the type of media and devices as shown in Fig. 2. Teletype, punched cards and magnetic tape can be used interchangeably in accordance with the logistics of military communication requirements.

Teletype stations transmit data at the rate of 60, 75, or 100 words/min in a five-element start-stop code. They receive or transmit their information from Model 28 Teletype apparatus or the equivalent equipment.

Compound terminals permit transmission rates of 75, 150, 300, or 600 bauds. They receive information from punched-card or teletype equipment.

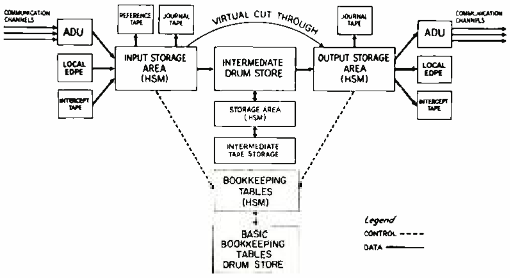


Fig. 8—Function of the communication data processor.

Magnetic tape terminals allow transmission at the rate of 1200, 2400, or 4800 bauds. Magnetic tape terminals receive their information from and transmit to magnetic tape stations included as an integral part of the terminals.

FUNCTIONS AND FEATURES

The basic functions of the message switching equipment are shown in Fig. 3: *input*, *output*, and *message switching*.

The *input function* coordinates the transfer of inbound messages. It acts as a temporary storage device between the incoming channels and the message processing function. It scans each channel cyclically, provides temporary storage for characters on a per line basis and performs code conversion, if necessary. This function will also automatically detect errors and assist in their correction.

The *output function* coordinates the transfer of outbound traffic. A limited amount of storage is provided for each outgoing channel to permit continuous transmission and electronic commutation, and to provide for automatic error detection and retransmission techniques.

The *message processing function* (Fig. 8) interprets the heading of each message and directs it to the appropriate outgoing channel or channels. As the blocks of the message are received they are transferred to the *intermediate store*; only when the message is complete does it become a candidate for transmission. As each outgoing channel becomes available, the message processing function transfers the oldest message in the highest precedence category for that output channel. A CDP is used for this function. Messages to and from local electronic data processing equipment and other high-speed input-output devices have access to the switching center by way of this message processing.

The intermediate store provides a reservoir for messages, thus permitting any subscriber to send a message without waiting for a through connection. Intermediate storage allows all output lines to be used in an optimum fashion for message traffic on a first-in, first-out basis by precedence. Furthermore, it allows top-priority traffic to automatically interrupt lower-priority messages and provides for repeat of the interrupted messages.

Magnetic drums provide rapid-access bulk storage for messages that are queued awaiting the availability of outgoing channels; magnetic tapes provide further storage for any overflow from the drums.

In certain cases, the *intercept tapes* will provide additional storage capacity. When one or more tributary or trunk channels are known to be out of service, the traffic may be routed to the intercept magnetic tape station for automatic storage until the channels are again open for service. Intercept tape may be used to store messages for channels having a heavy backlog of messages.

CONCLUSION

This brief story of how ComLogNet works from a data-handling viewpoint only implies the technical complexity of the individual equipments and ramifications of designing and manufacturing not only one of these mammoth systems, but *five in a very short period of time.* Achievement of the set goals of delivering five ComLogNet systems to the U.S. Air Force in 1962 is possible only through the diligent efforts and the hard work of engineers, production personnel, management, and all others concerned with ComLogNet. Many activities assisted RCA Electronic Data Processing in achieving these goals, including the DEP Surface Communication Division, the Semiconductor and Materials Division, the RCA Service Co., Camden Plant Manufacturing, Parts and Accessories Service, and other activities within and without RCA. Final completion and installation of the systems will provide the U.S. Air Force with a modern, computer-implemented communications system.

ACKNOWLEDGMENTS

The able assistance of T. T. Patterson, J. A. Kalz, S. F. Dierk, and others in the preparation and editing of this paper is gratefully acknowledged.

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Fig. 9—A portion of the communication data processor, showing logic and high-speed memory racks. The CDP contains 19 such racks.

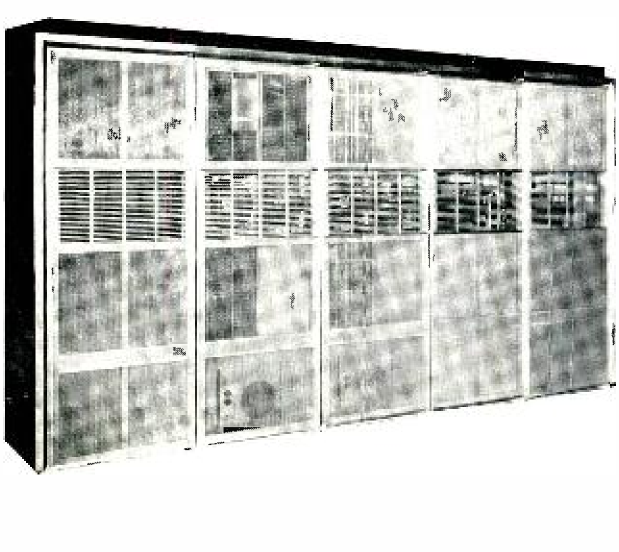

Fig. 10—Tape search unit, with Jack Figueiredo, DEP Surface Communications Div.

In commercial h-f radio service, the daily forecasting of probable signal quality is essential to efficient operations, much like the forecasting of weather conditions for airlines. In 1946, RCA Communications began h-f forecasting by observing sunspot activity and issuing regular reports. It was soon observed that study of other phenomena was needed to enhance the over-all forecasting technique. The author then investigated the relationship of certain planetary phenomena to h-f radio disturbances, and found sufficient correlation to warrant further study. Since reporting[1,2] that early work in 1951-52, additional study—reported herein—has produced substantiation for a current, more-extensive forecasting technique which considers planetary positions, as well as sunspot observations and analysis of the ionosphere.

IMPROVED DISTURBANCE FORECASTING FOR THE H-F BAND

by **J. H. NELSON**
Propagation Analyst
RCA Communications, Inc.
New York City, N.Y.

MANY YEARS of investigation of the vagaries of radio propagation phenomena led the author in the 1940's to a study of the correlation between planetary interrelationships and h-f radio signal behavior. That early study was suggested by the results of certain investigators of planetary phenomena, whose work indicated a connection between the interrelationship of the planets and the incidence and nature of that causes a temporary change in its radiation characteristics—although the mechanism of this influence is not known, and can at best only be postulated. The ionosphere of the earth is apparently particularly sensitive to these changes and reacts accordingly. The conclusion of that early work was that the observation of planet positions as a then-new element in radio propagation analysis had netted results suffi-

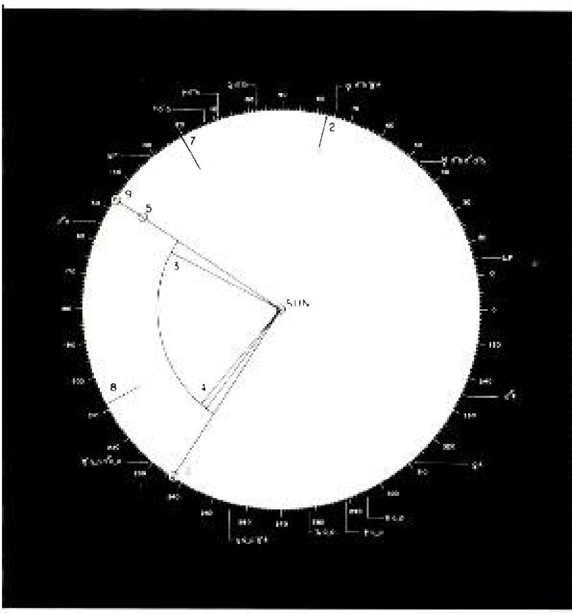

Fig. 1—Heliocentric positions of the planets, Feb. 23, 1956, when the most intense cosmic-ray shower in history was recorded. General legend and planet data:

Planet No. and Name	Planet Symbol	Mean Distance From the Sun, Earth Being Unity	Period in Days or Years	Diameter in Miles
1 Mercury	☿	0.3871	87.97d	3,000
2 Venus	♀	0.7233	224.70d	7,600
3 Earth	⊕	1.0000	365.26d	7,918
4 Mars	♂	1.5237	686.98d	4,200
5 Jupiter	♃	5.2028	11.86y	87,000
6 Saturn	♄	9.5388	29.46y	72,000
7 Uranus	♅	19.1910	84.02y	31,000
8 Neptune	♆	30.0707	164.79y	33,000
9 Pluto	♇	39.5000	248.00y	4,000?

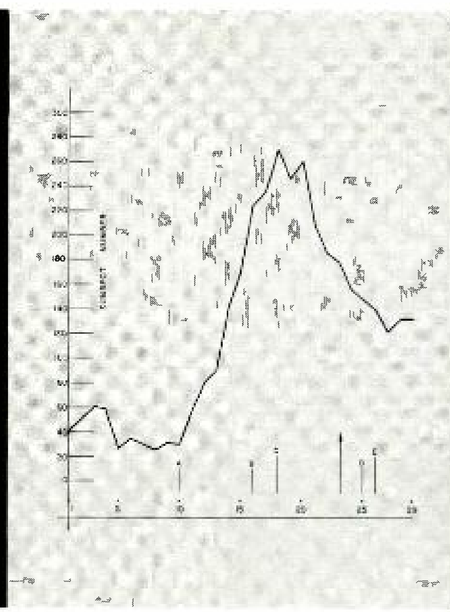

Fig. 2—Rise in number of sunspots (Zeurich) during Feb. 1956, associated with significant planetary arrangements.

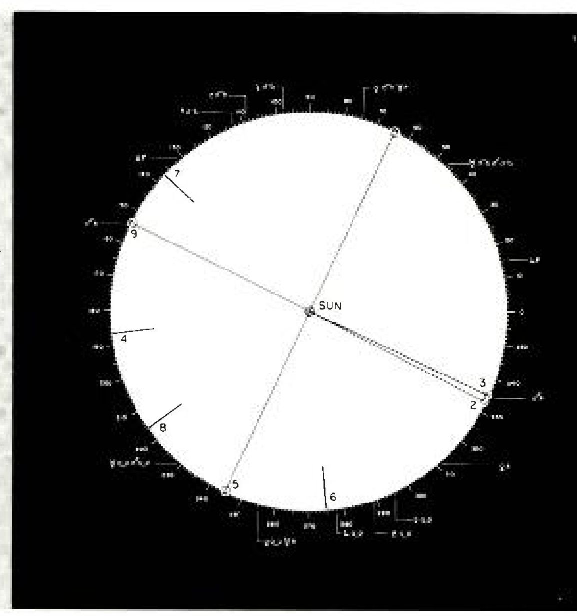

Fig. 3—A very unusual heliocentric planetary arrangement, Aug. 29, 1959, that occurred with remarkable increase in sunspot numbers.

sunspots. While validity of the planet-sunspot relationship has been debated pro and con, the question is still unsettled; however, the evidence of those who supported this connection indicated that study of the correlation of planetary phenomena and radio disturbances might reveal information of value to h-f propagation forecasters.

As was reported[1,2] in 1951-52, the author found correlation between signal degradation and certain planetary arrangements. Correlation was consistent enough to indicate that the planets possibly influence the sun in a manner

ciently encouraging to warrant further study.

During the intervening years, further information has been gathered by the author, as reported herein, which brings the records up to date and provides additional substantiation for a current technique of forecasting h-f signal qualities involving planetary positions as well as sunspot observations and analysis of ionosphere conditions.

TECHNIQUE

The technique used for the determination of the heliocentric angular separation of the planets as they circle the sun was described in detail by the author in the previous papers[1,2]; however, the fundamentals will be repeated here briefly for the guidance of new readers.

The heliocentric (Sun-center) position of each of the Sun's nine planets can be found in the *American Ephemeris and Nautical Almanac* published by the United States Government Printing Office, Washington 25, D.C. With the information given in this book, it is a simple matter to calculate the angular separation of each of the planets from any other planet.

The early papers[1,2] placed more emphasis on some angles than others and stated that separations of 0°, 90°, and 180° were associated most frequently with radio disturbances, and that 30°, 60°, and 120° separations were associated with good radio signals.

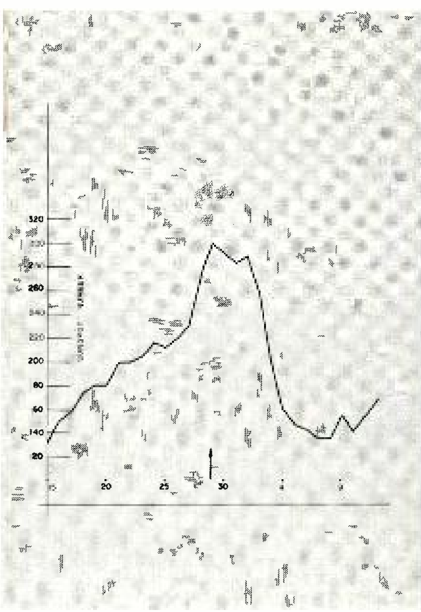

Fig. 4—Plot of the Zuerich sunspot numbers from Aug. 15 to Sept. 12, 1959; note that the peak occurs on the day of maximum stress on the sun's atmosphere.

Research soon indicated that some 0°, 90°, and 180° contacts did not coincide with a radio disturbance, some coincided with a moderate disturbance, and some with severe disturbances. Continued research showed that the failures were usually with single contacts of 0°, 90°, and 180° between two planets only, such as Mercury being 90° ahead of Jupiter.

It was further determined that the more severe disturbances occurred when two fast planets came into a 0°, 90°, and 180° arrangement with one or more slower planets— thereby creating what can be called a *multiple configuration*. An example would be Mercury 90° ahead of Jupiter, while Venus is 0° or 180° from Jupiter[2]. The fast planets are Mercury, Venus, Earth, and Mars; all planets further from the sun are considered the slow planets.

It was also found that single contacts of 0°, 90°, and 180° would be effective if there were other planets at certain harmonic angles simultaneously related to either of the two main components of a configuration.

The harmonics of the entire solar system can be found by dividing 360°, 180°, and 90° by 2, 3, 4, 5, and 6, which produces harmonics down to 18° and 15°. Under some conditions, half of 18° or 15° can also assume a role of importance. Usually, the harmonics themselves are of no importance unless there is a series of them occurring almost simultaneously—and then only when two of the planets are fast. These disturbing harmonic relationships have been narrowed down to contacts between Venus, Earth, and Mars along with one or more of the others.

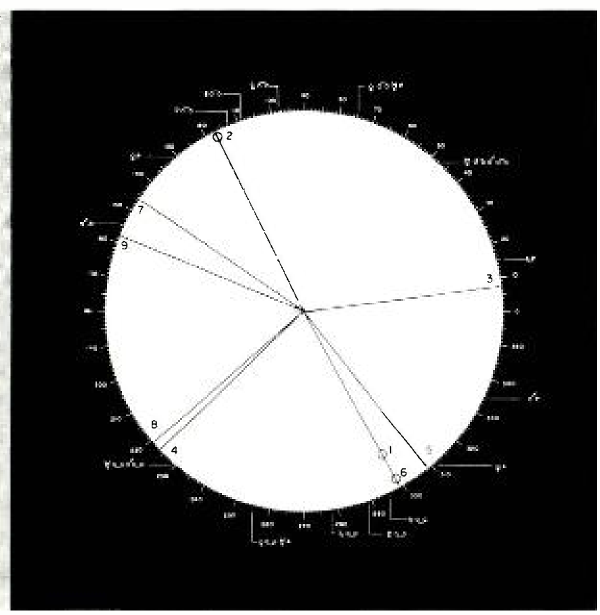

Fig. 5—Heliocentric positions of the planets on Oct. 1, 1961 showing multiple contact made by Mercury, Venus, and Saturn which coincided with a blackout and a vivid aurora.

Continued research of the 30°, 60°, and 120° contacts associated with quiet conditions has produced the information that these contacts will work best if the angles are between slow planets. Frequently, there will be a disturbance when these angles occur between Venus, Earth, and Mars—particularly if they are at the same time harmonic to other planets.

The subject is extremely complicated and difficult to produce in a statistical form, since no nine-planet combination will be reproduced by the solar system in several hundred thousands of years. A combination can occur in which Mercury is 90° ahead of Jupiter, while Jupiter is 60° from Venus and Venus is 18° from Mars. The next time Mercury is 90° from Jupiter, harmonics will not necessarily exist between Jupiter, Mars, and Venus. This applies to all multiple configurations and makes it impossible to treat the subject by standard statistics.

OPERATIONAL ASPECTS

The office of the Propagation Analyst, RCA Communications, Inc., issues a daily forecast at noon each day covering the period from 4:00 PM on the date of issue to 4:00 PM the next day. The forecast is broken down into 4-hour periods, and a separate forecast is made for each 4-hour period for signals between New York and Central Europe. This is necessary in order to match the diurnal characteristics of signals over this particular path. There are, therefore, six separate periods in each forecast. *These forecasts have maintained an accuracy of close to 90 percent for several years.* The position of the planets plays an important part in forecast construction.

In addition to the planetary arrangements, there are three other factors affecting the forecast: 1) sunspot activity as observed through a 6-inch telescope; 2) an analysis of the North Atlantic ionosphere made from radio-signal qualities and frequency behavior, derived from periodic reports made by the Riverhead receiving station technicians; and 3) an experienced forecaster.

RESEARCH BY OTHERS

For over a hundred years some astronomers and solar researchers have contended that the planets are related to sunspots. Other astronomers and researchers contend that planets cannot influence sunspot phenomena. The question has never been settled.

In research of this kind, there are so many variables beyond the researcher's control that the best approach seems to be to select the outstanding events for study. Two events very strongly supporting the theory that planetary arrangements can cause variations in the sunspot cycle are shown in Figs. 1, 2, 3, and 4.

Fig. 1 shows the heliocentric arrangement of the planets on Feb. 23, 1956; on this date, the most intense cosmic-ray shower in history was recorded at 0334 UT *(NBS Report 5596)*. Jupiter and Pluto came to a 0° relationship on Feb. 26; Jupiter was at a 90° relationship with Saturn on Feb. 18.

At the time of the cosmic-ray-shower onset, Jupiter was only 14′ of arc past the 90° position of Saturn and only 14′ of arc from the 0° position of Pluto. This, added to the close relationship of the Earth to Jupiter and Pluto, plus the close relationship of Mercury and Mars to Saturn could well cause the solar atmosphere to be placed under extreme stress.

No important transatlantic radio disturbance came until Feb. 25, when Mercury made a 0° contact with Saturn and a 90° contact with Jupiter and Pluto. In fact, in spite of the high number of sunspots for the period, the month of February was not significantly disturbed on central-European circuits except on the 25th. Nevertheless, throughout the month there were numerous *sudden ionospheric disturbances*—sudden fadeouts of all signals in the high-frequency band operating in the daylight hemisphere, averaging about 20 minutes in duration.

It is worthy to note that Jupiter and Saturn can be in this arrangement only once in 19.8 years, and Jupiter and Pluto at this arrangement only once in 12.4 years. Saturn can be 90° ahead of Pluto only once in 33.4 years. Therefore, for all three to be significantly related in such a short period of time is extremely rare.

Fig. 2 shows the number of sunspots built up as Jupiter and Saturn approached their 90° arrangement; the peak agrees perfectly with their contact date. On Feb. 10 (*A* on Fig. 2) the sunspot numbers started their rise with a multiple contact by Venus to Jupiter, Saturn, and Pluto. On Feb. 16 *(B)* the Earth also made a multiple contact with Jupiter, Saturn, and Pluto. Point *C* is the Jupiter-Saturn contact, point *D* is the Mercury contact, and point *E* is the Jupiter-Pluto contact. The solar flare is represented by the vertical arrow.

Fig. 3 shows a second very unusual planetary arrangement that occurred in 1959 with a remarkable rise in sunspot numbers. This case is particularly interesting because this considerable rise in the sunspot number was officially predicted in a special forecast sent out on July 14 with copies to the U.S. Bureau of Standards. Again, Jupiter and Pluto take a major part in the configuration, but Jupiter is about 1° past the point of 90° with Pluto. It is obvious from Fig. 3 what angles were present at this date and in this period. The four-element square is the *only* such case found by the author in his records.

Signals during this remarkable burst of sunspot activity, similar to the burst in Feb. 1956, were not disturbed except for several sudden ionosphere disturbances. The North Atlantic Radio Warning Service of the U.S. Bureau of Standards stated in their weekly forecast discussion paragraph in *CRPL-J1207*, issued on Sept. 2, that a considerable increase in solar activity was observed during the past week and that sixteen major solar flares occurred.

The author has found that bursts of sunspots frequently will be associated with good radio signals instead of bad because of the very excessive ionization in the upper atmosphere caused by the ultraviolet radiation from the sunspots. The resultant strong ionosphere can resist disturbance.

Fig. 4 shows that the peak of the sunspot numbers came precisely on the day of maximum stress upon the sun's atmosphere. The daily sunspot numbers for both of these graphs were extracted from Part B of *Solar-Geophysical Data* books issued by the U.S. Bureau of Standards.

A more recent episode shows that multiple configurations are still effective. Fig. 5 depicts the arrangement of the planets on Oct. 1, 1961. On Sept. 30, Mercury made a 180° contact with Venus about 1000 GMT. On Oct. 1, at about 0500 GMT, Mercury came into a 0° contact with Saturn, and at 0500 GMT Oct. 2, Venus was at 180° from Saturn.

Radio signals became very severely disturbed at 4:30 P.M. on Sept. 30 and were useless until 8:00 A.M. Oct. 1. That day, frequencies were fairly good until 4:00 P.M., when they again became severely disturbed and were mostly useless until 8:00 A.M. Oct. 2, when the disturbance ended as abruptly as it began. A vivid aurora accompanied this blackout. (Data source, Riverhead receiving station Daily Log).

CONCLUSION

There is no physical law in nature known to the author than can explain how the planets cause changes in the solar atmosphere. It seems valid to rule out gravitation as a primary cause since the most distant planets Uranus, Neptune, and Pluto play an important part in this approach to forecasting. The planets Mercury (at perihelion), Venus, and Jupiter do, however, have a pronounced gravitational pull on the Sun.

It is the author's belief that the cause may possibly be related to electromagnetism. The planets spinning on their axis in electrified space could conceivably develop a high static charge; under certain planetary interrelationships, a discharge into the sun would result. This could cause instability in the highly electrified solar atmosphere which we now know extends beyond the Earth.

Also, Figs. 2 and 4, representing the two most significant bursts of sunspot activity in the current cycle, lend considerate support to the theory that there is a connection between planets and sunspots.

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2. J. H. Nelson, "Planetary Position Effects on Shortwave Signal Quality," *Electrical Engineering*, May 1952.

JOHN H. NELSON was born in Gloucester, Mass., on December 10, 1903. In October 1923 he joined RCA Communications after three years service with the Commercial Cable Co. as a student and cable operator. Between 1923 and 1946 he successively held the RCAC positions of operator, chief operator, traffic chief, and supervisor. In 1946 he was transferred to Solar and Ionospheric research due to his ardent interest in Astronomy and Science. Since that time his chief duties at RCA Communications, Inc. have been research, frequency predictions, and forecasting. Mr. Nelson is a Commander in the United States Naval Reserve.

RCA Communications, Inc., provides a public service—the handling of intelligence from point to point by electrical means. The function of the engineer in the Company is mainly to determine what facilities will best perform accurately, expeditiously, and economically over the media available, to specify the performance characteristics of equipment, and to see that equipment to meet such requirements is provided. A previous article in this journal[1] explained generally the spread of our engineering attention over the entire range of communications techniques; this paper covers h-f transmission alone—the principal long-distance media used by the Company.

H-F RADIO COMMUNICATIONS FOR INTERNATIONAL COMMERCIAL SERVICE

by **D. S. RAU, Vice President**
Engineering
RCA Communications, Inc.
New York, N.Y.

The basic method of long distance communications used by RCA Communications, Inc., is h-f radio transmission in the r-f spectrum between 3 and 30 Mc. In the early years, vlf frequencies between 16 and 25 kc were used, and in fact, the development of the Alexanderson alternator and the multiple tuned antenna which operated on such frequencies were factors which led to the creation of RCA.

Development of h-f communication in the early 1930's made vlf obsolete for general communications, and by the mid-1940's, vlf was completely out of the picture in this Company. In more recent years, transoceanic coaxial cables have become an important means for long-distance communications, but because of economic considerations there are relatively few in existence and planned. Planning is now underway for long-distance microwave links by means of satellite relays, which will be important elements in the communications art. Satellite communications[9-11] will supplement the coaxial cable type of service for bulk transmission, carrying heavy traffic loads between major business or political centers. Satellites will also serve low-volume points. The main virtue of h-f radio communication is its ability to *directly* connect any point on the earth with another with facilities which may be relatively simple and inexpensive if the demand for service is not great.

Despite the installation of transoceanic cables and establishment of satellite communications networks, it is generally believed that many communication requirements between points on the earth will continue to be served by h-f radio transmission.

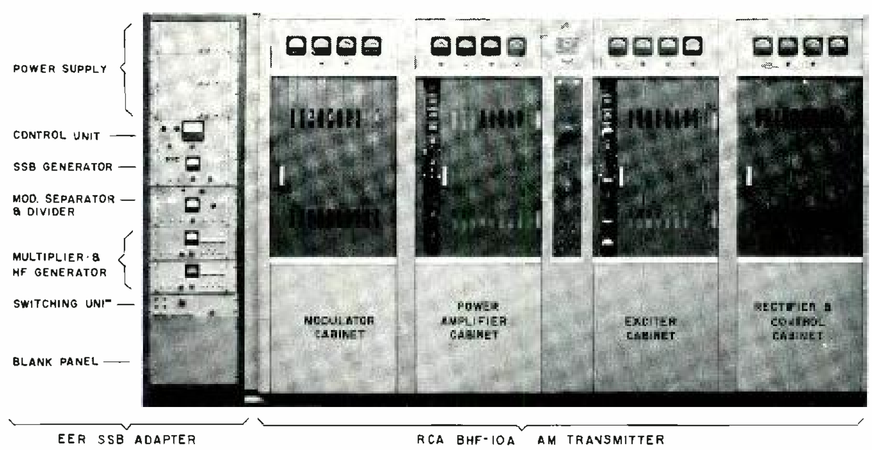
H-F TRANSMITTERS

Because of the congestion in the h-f spectrum which exists today, single-sideband (SSB) operation has just about become mandatory in important circuits. With SSB, it is possible to compress the greatest number of discrete signal channels into minimum bandwidth.

On light traffic circuits, one voice band (nominally 3 kc wide) will provide up to sixteen 100-baud telegraph channels by frequency division. By application of time division, two 50-baud teleprinter channels may be accommodated on each tone channel[2]. Several techniques are available for application of error-correction on the channels thus derived, including two-channel or four-channel MUX/ARQ utilizing the RCA transistorized MUX/ARQ equipment.[3]

For heavier traffic routes, the SSB facility may be operated with two-voice

Fig. 2—Envelope-elimination-and-restoration SSB adaptor with the BH-10-A Transmitter.



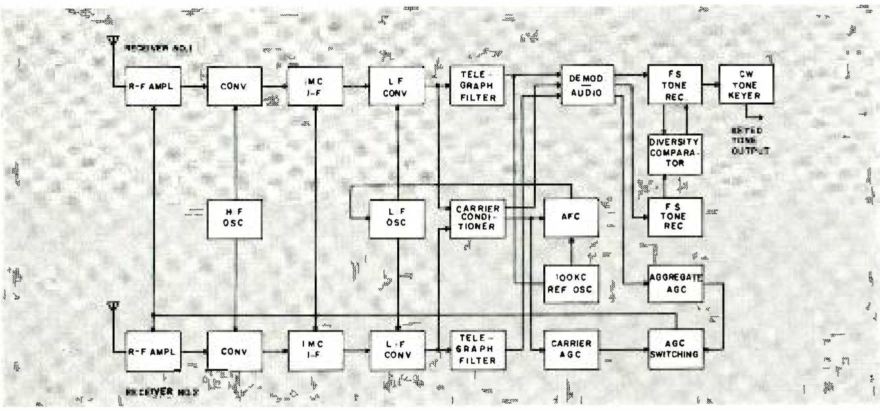


Fig. 3—Simplified block diagram, SSB-R3 Dual Diversity receiver, telegraph service.

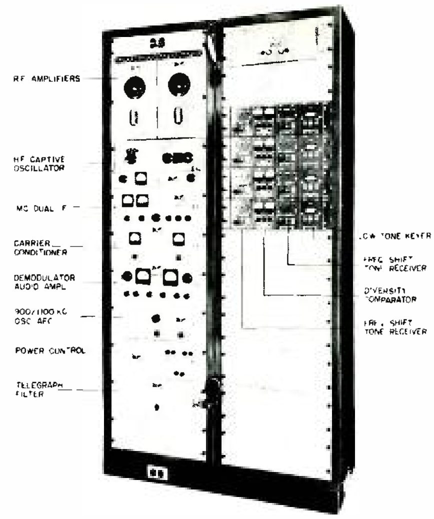


Fig. 4—SSB-R3 Dual Diversity Receiver, telegraph service.

channels on each side of the carrier (which may be reduced) thereby doubling or quadrupling the number of channels obtainable. This of course results in utilization of proportionately greater bandwidth[1] and requires proportionately greater power.

Several years ago, RCA Laboratories developed for RCA Communications, Inc. (and for the RCA International Division for world-wide sale), the transmitter designated as SSB-T3[5]. Rated at 20 kw—PEP and selling at an attractive price, it became a most useful piece of equipment in the RCA Communications plant. Many of these transmitters were obtained and installed. RCA Communications, Inc. engineers contributed their operating experience into the development of this transmitter and this proved to be an important factor in the successful design.

An operating company has the ability to contribute significantly in the development of practical designs of equipment for it has the day-by-day experience in having to use the equipment. The expansion of engineering in recent years into the field of human engineering and value engineering has been in part due to the need to apply the principles established by operating requirements. By the very nature of their jobs, operating company engineers have to be well versed in both human engineering and value engineering.

Because of its limitation in power, the SSB-T3 linear-amplifier transmitter has been unable to cope with some of the circuit requirements of RCA Communications, Inc. Where many channels must be transmitted over the more difficult radio paths, a substantial increase of power output is necessary. Because of the unavailability of high-power linear-amplifier transmitters at reasonable cost, the Company has found it advisable to resort to the "envelope elimination and restoration" method of SSB transmission[6]. This method, development of which was sponsored by RCA Communications, Inc., has been found to be particularly suitable for multichannel radio-telegraph operation. The special equipment required for this system, packaged within the limits of a standard cabinet rack, may be used with any good amplitude-modulated transmitters of any output rating.

Channeling methods are constantly being reviewed. Although most ideas in this area turn out to require transmission bandwidth beyond the allowed limitations of h-f communication, an occasional method comes up which shows possibilities of interest. At time of this writing, consideration is being given to a so-called "block-ARQ" system which, it is claimed, will provide less deterioration from multipath delay distortion and two orders of improved error-correction.

H-F RECEIVERS

In the history of RCA Communications, Inc., there have been items of equipment peculiar to itself which have contributed to the outstanding position the Company has maintained in the industry. The first was, of course, the Alexanderson Alternator. Since the advent of h-f communications, a major unit of equipment has been the RCA diversity receiver. The RCA Deluxe Diversity became a byword for reliable long distance reception over the world and for military as well as commercial communications.[7]

It was originally designed as a three-set space diversity unit, each of the three being connected to its own antenna. The Deluxe Diversity, later designated as the M-1005, successfully overcame signal fading, the result of the multipath characteristic of long-distance h-f transmission. Later, as frequency-shift-keying (FSK) techniques were adopted, the advantages of three-set diversity over two-set diversity were not considered sufficient to warrant the additional equipment and antennas, so the two-set diversity became standard. The two-set–design receiver, the M-1202, is now in regular use throughout the RCA system for FSK reception. A modernized version, the M-1076, was designed by RCA Laboratories for more recent requirements.

As explained above for transmitters, SSB operation became important. The RCA Laboratories, at its Riverhead branch, developed a diversity SSB receiver, and as with the SSB-T3 transmitter, engineers of RCA Commu-

DAVID S. RAU, after serving as student engineer and station engineer at transmitting and receiving stations of RCA and RCA Communications, Inc., was assigned to work on systems and installation design in the headquarters Engineering Department. His responsibilities included engineering a nation-wide domestic h-f radiotelegraph system supplemented by RCA's first vhf system between New York City and Philadelphia, and its first uhf circuits for keying control of transmitting stations. After serving with the Navy during the war, he was assigned to engineering-management duties in RCA Communications, Inc., advancing to Vice President and Chief Engineer, and then to Vice President, Engineering. His activities in IRE included membership on many committees, including the Transmitters and Antennas Technical Committees, and Administrative and other Committees of the Professional Group on Communications Systems. He received the award of *Fellow* of IRE in 1960.

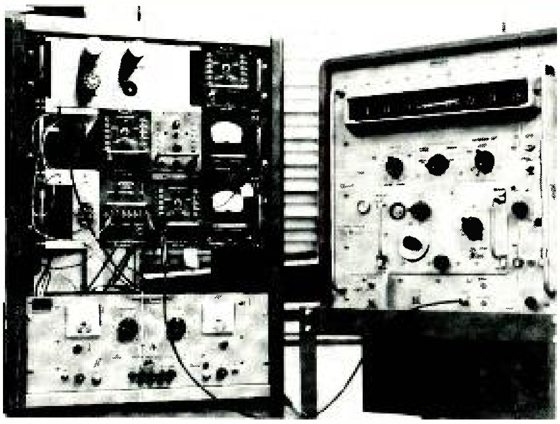


Fig. 5—Prototype of signal-quality assessor designed by the receiver laboratory.

nications, Inc., contributed operating experience toward the design. This development has been described elsewhere[5] but it may be well to repeat that certain innovations were incorporated in the design, particularly in the techniques of diversity combining which overcame difficulties heretofore experienced in obtaining acceptable diversity action in SSB receivers. In this development, diversity is provided separately for each audio sub-carrier in the receiver output.

The initial SSB-R3 assembly utilized vacuum-tube circuitry throughout. RCA Communications engineers had been investigating transistorized circuitry for control-line frequency-division channeling equipment and came up with what appeared to be suitable audio-frequency telegraph channeling units for SSB receiver application. A suitable *diversity comparator* was developed to tie this transistorized equipment into the basic r-f section of the SSB receiver. Trial of the combined assembly proved successful, and consequently RCA Communications adopted as its standard the RCA Laboratories' developed r-f unit assembly combined with the new transistorized audio-frequency combining and channeling units. In addition, RCA Communications' engineers investigated and have developed a transistorized version of the basic "captive-type" h-f oscillator for the SSB-R3, as well as the demodulator-audio amplifier. RCA Communications and RCA International Division also sponsored a new approach in diversity phone combining, which has resulted in the great improvement in telephone and program diversity reception on high-frequency SSB circuits.

Multipath propagation with selective fading is one of the major causes for degradation of quality and intelligibility on long-distance h-f circuits. Effects of selective fading are reduced when the audio spectrum is divided into several narrow frequency segments. Each individual segment is then continuously compared with its counterpart in the other receiving channel, with the stronger of the two segments accepted for the output and the weaker suppressed. The stronger segments, made up of the several segments from both receiving channels, are recombined to give an improved audio output signal.

This receiver system is marketed by the RCA International Division as the RCA SSB-R3 Diversity Receiver.

The need to completely transistorize the SSB receiver in order to fully realize the advantages only partially obtained with the SSB-R3 has always been an accepted fact both by RCA Communications and RCA International, the former for operational requirements and the latter for a good marketing item. Further development on high performance receivers are underway.

OTHER H-F ELEMENTS

Transmitters and receivers alone do not constitute a working communication system. They must have power supply for obvious reasons, control and monitoring facilities for efficient utilization in respect to traffic handling requirements, and antennas for coupling to the propagation medium. Engineering attention is given to all these items as time and manpower is available.

A major problem in the operation of long-distance radio communication circuits is coping with the daily *transition* — changing ionospheric conditions which require change in operating frequencies. For operation to be successful commercially, circuit interruptions due to frequency changes must be minimized or even eliminated. Spare equipment (transmitters, receivers, and antennas) are provided for this purpose. Considering that stations of RCA Communications each operate up to 40 or 50 circuits simultaneously, the organizational problem involved may be appreciated. It is in this connection that the design of an efficient and effective control and monitoring system becomes important. A study project is currently underway to cover the problems in operating and monitoring procedures concerned with the changing mode of operation from FSK to SSB. Its goal is to evaluate a system whereby all transmitting equipment can be easily and quickly monitored for trouble and interchanged to make maximum use of frequencies available. Included in the category of "troubles" is the transition problem mentioned above.

Despite the presentation of new ideas in the field of h-f antenna design, nothing has come up to equal, let alone surpass, the value of a modern rhombic antenna carefully designed to cover a specific frequency range. Its cost is moderate when compared to its gain and frequency coverage. The RCA Communications designed two-unit end-fire rhombic has the highest gain/bandwidth characteristic of any antenna in use in the h-f range. Engineering studies have been made to evaluate such developments as the *logarithmically periodic* antenna, but "pay-dirt" has not been struck. One development, which undoubtedly has merit, is the Laport double-rhomboid[8]. This design provides greater sidelobe suppression and retains most of the desirable features of conventional rhombic antennas.

CONCLUSION

In the international communication service, h-f radio transmission will continue to be used extensively. The correctness of present thinking and planning has been confirmed by proposed recommendations by a "Panel of Experts" recently convened by the International Telecommunications Union at Geneva, "for the purpose of devising ways and means of relieving the pressure on the radio spectrum between 4 and 27.5 Mc." Future planning will be guided by recommendations which will be forthcoming from this body.

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The nuvistor is a distinct innovation in tube design and production by virtue of unique structure, imaginative use of materials, and simplicity of manufacturing. With its improved performance, reliability, size, and cost, the nuvistor concept is a significant achievement in small ceramic-metal receiving tubes. The 1,000,000th nuvistor was produced in July 1961, and developmental work continues toward further applying the nuvistor concept in future receiving-tube products—smaller and even more reliable.

The NUVISTOR FAMILY

Commercial and Developmental Status

by **J. T. CIMORELLI, Mgr.**
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One of the major responsibilities of the designer of military, industrial, or entertainment equipment is to decide which of the many electron devices currently available is the most practical for his needs from a cost and performance standpoint. The nuvistor design concept, which represents substantial improvements in size, performance, reliability, and cost, is recognized by many design experts as a significant achievement in small ceramic-metal receiving tubes.

This paper briefly describes current nuvistor design, assembly, and processing and discusses some of the developmental work now directed toward furthering the nuvistor concept in smaller and even more reliable receiving-tube products. Performance data on types now commercially available are also included.

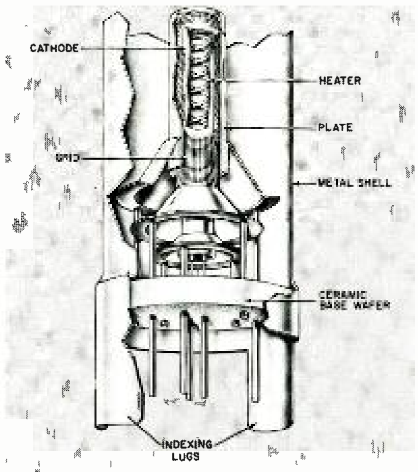


Fig. 1—Nuvistor triode.

PRESENT STATUS

Seven commercial nuvistor types have been added to RCA's product line since the nuvistor was first announced to the industry in 1959: the 7586 industrial medium-mu triode; the 7587 industrial sharp-cutoff tetrode; the 7895 industrial high-mu triode; the 8058 industrial uhf triode; and the 2CW4, 6CW4, and 6DS4 TV and FM tuner triodes. Some of the more important electrical characteristics of these nuvistor types are shown in Table I. A nuvistor triode, tetrode, and uhf triode are illustrated in Figs. 1, 2, and 3, respectively, and will be discussed later.

These types have found wide acceptance in the industry and are currently in use or are being considered for the following applications:

Communications equipment—oscillators, FM i-f stages

Telemetering equipment—ultrastable oscillators, preamplifiers

Airborne weather radar—cascode preamplifier, i-f chassis amplifiers

Satellite mass spectrometer—control oscillator

Surveillance and closed-circuit TV—preamplifier, video amplifiers

NIMBUS *satellite*—camera preamplifier

Weathersonde—blocking oscillator

Sonar—preamplifiers

Sonobuoys—preamplifier, oscillator, and transmitter stages

Test equipment—VTVM, electrometer devices, vibration analyzers, and jet-engine analyzers

vhf tuners—TV and FM

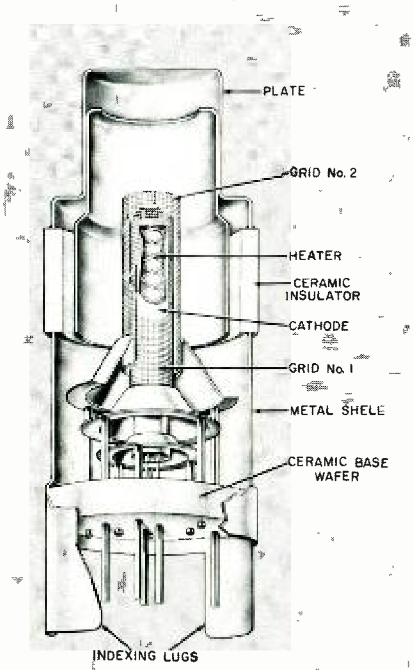


Fig. 2—Nuvistor tetrode.

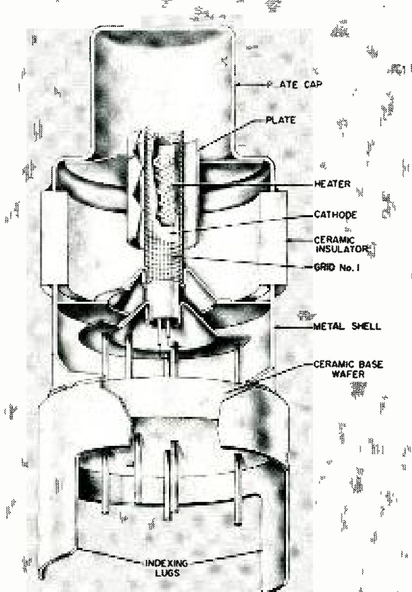


Fig. 3—Nuvistor uhf triode.

STRUCTURAL DESIGN FEATURES AND ASSEMBLY

The nuvistor is a distinct innovation in tube design and production by virtue of its unique structure, imaginative use of materials, and simple, but effective, manufacturing techniques and processes. A brief review will emphasize its distinguishing features.

In developing the nuvistor, a rugged, reliable, high-performance tube was sought which could be readily produced by automated techniques. Planar structures, cylindrical structures, ceramic-spaced stacked structures, metal-to-glass seals, metal-to-ceramic seals, and many other types of construction were carefully explored. The cylindrical concentric open-ended cantilever configuration was selected for the nuvistor because it was found to provide a mechanically sound design approach which results in improved cathode efficiency and a more uniform electric field in the active portion of the tube.

For ruggedness, a strong ceramic base wafer is used as a platform on which is erected an array of tube electrodes, each solidly held in place by a tripod-like structure (Fig. 1). With this type of construction, nuvistor electrodes are small, light cylinders which, because of their form and low mass, are well suited to withstand shock and vibration.

In the design of the nuvistor, specific requirements were established for the elimination of glass and mica, which have temperature and strength limitations that interfere with high-temperature processing. Spot-welding during assembly was also eliminated because it requires a high degree of skill and can be a source of residual strains.

All elements of the tube are accurately held in a jig and brazed together in a single simple operation at high temperatures. This technique results in a strain-free assembly, dimensional stability, and uniformity in the finished tube.

The simplicity and cylindrical symmetry of the tube parts and jigs permit maximum mechanization of the tube assembly. Individual matching of parts, which may be required in a close-spaced planar design, is not required for the nuvistor. The accuracy of control of the tube assembly permits close spacing of the tube elements and, at the same time, provides increased protection against interelectrode shorting.

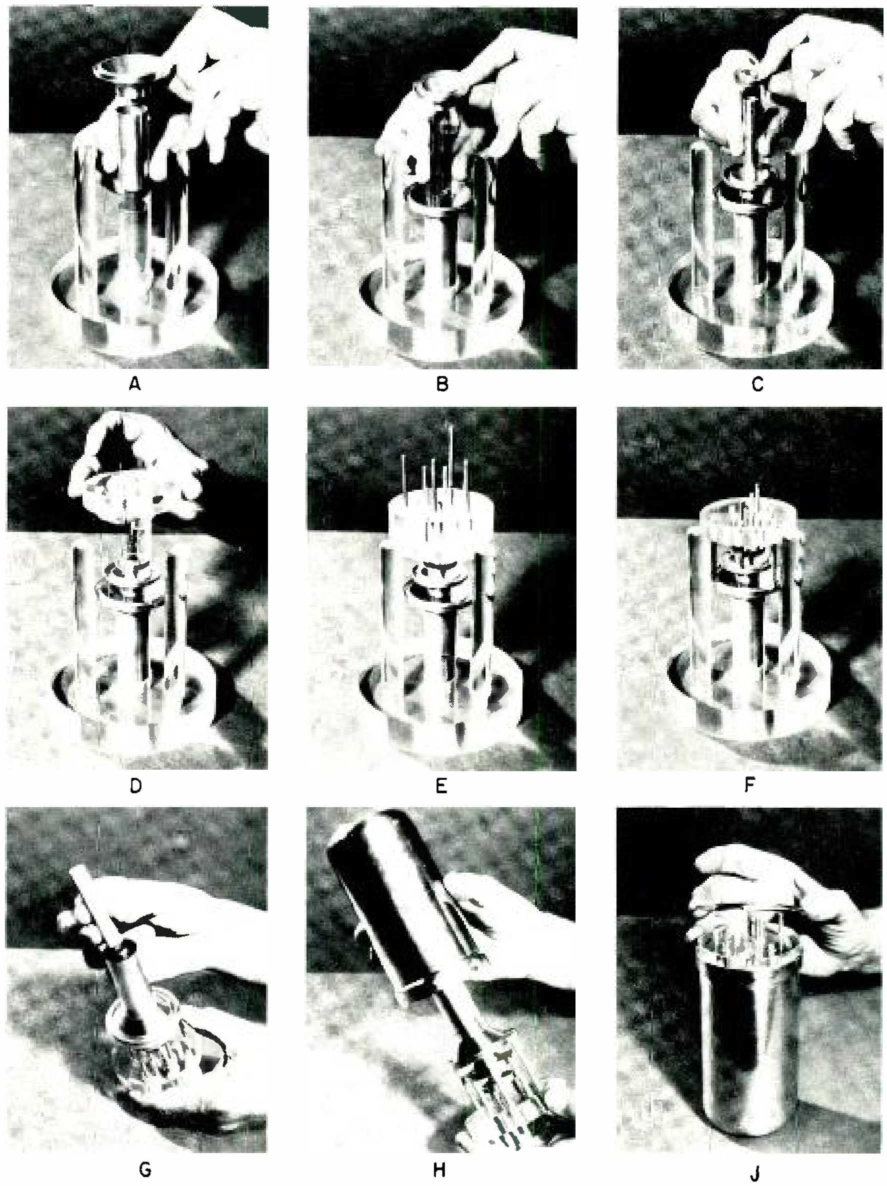


Fig. 4—The simple step-by-step assembly of a nuvistor, illustrated here using a model about ten times the size of an actual nuvistor tube. (See text for detailed description.)

The material chosen to form the basic framework of the tube structure, ceramics and metals, can be processed at high temperatures in brazing and vacuum-exhaust furnaces. High-temperature processing eliminates many of the gases and impurities that limit tube life and eventually impair tube performance.

The combination of a strong brazed structural assembly, all-ceramic-metal construction, and high-temperature processing has resulted in a tube that operates well under difficult environmental conditions such as thermal or mechanical shock and continuous vibration.

Fig. 4 shows the simple step-by-step assembly of a nuvistor display model having dimensions approximately ten times those of the actual tube. The parts are loaded on a simple jig upside down; that is, plate and plate flange are placed on the jig first (A), followed by the grid and grid flange (B). The cathode sleeve and cathode flange are then added (C), and the heater and base wafer are placed on the jig simultaneously (D). Finally, a lead-loading jig drops the leads into

TABLE I—Nuvistor Characteristics

	Plate Volts	Amplification Factor	Transconductance, μmhos	Plate Current, ma	Interelectrode Capacitances, pf		
					C_{gp}	C_{in}	C_{out}
7586	75	35	11,500	10.5	2.2	4.2	1.6
7587	125	—	10,600	10.0	.01	6.5	1.4
7895	110	64	9,400	7.0	.9	4.2	1.7
8058	110	70	12,400	10.0	1.3	6.0	1.3
2CW4 / 6CW4 / 6DS4*	70	68	12,500	8.0	.92	4.1	1.7

* Grid voltage required to reduce the plate current to 10 μa is −6.8 volts for the 6DS4, as compared to −4.0 volts for the 2CW4 and 6CW4.

position in the base wafer (E). The assembled mount is then ready for the brazing furnace (F). In actual operation, the critical spacings between tube elements are maintained by special alloy spacers which are integral parts of the brazing jig. The electrodes are joined together in one operation at high temperature by copper brazing in a hydrogen atmosphere. The coated cathode cup is assembled over the cathode sleeve after the mount brazing operation (G). The remaining operations include inserting the tube mount into the tube envelope (H) and adding the mainseal brazing ring prior to exhaust and final seal (J). The final vacuum-seal braze is made with a brazing alloy which has a melting point sufficiently below that of copper to prevent the remelting of the copper-brazed electrode junctions.

In the unique fabrication of the ceramic base wafer, which is made of forsterite (a magnesia-alumina-silicate compound), the wafer is solution-metallized and fired in hydrogen to reduce the solution to a strongly adherent metal. A light grinding operation removes the metal from the top and bottom surfaces and leaves the metal layer on the edge of the wafer and lining the lead-wire holes.

JOSEPH T. CIMORELLI graduated from MIT with the BSEE in 1932 and the MSEE in 1933. In 1935 Mr. Cimorelli joined RCA in Harrison, N. J. where he worked on tube-application problems. In 1940, he was transferred to the company's Chicago office. Here he worked as the field engineer of the tube application section, assisting local receiver manufacturers in their design problems. In 1942 Mr. Cimorelli returned to the Harrison laboratories to continue field engineering work with government agencies, and laboratories. In 1944 he was appointed Manager of the Receiving Tube Application Engineering Laboratory of the Tube Department at Harrison. Mr. Cimorelli transferred to Camden in 1953 as Assistant to the Vice President and Director of Engineering, RCA Victor Division and later became Administrative Engineer on the Staff of the Vice President, Product Engineering. On September 1, 1956, he returned to Harrison to assume his present position as Manager, Engineering, Receiving Tube Operations, Tube Division. Mr. Cimorelli, who has served on several committees of I.R.E., was Secretary-Treasurer of the New York Section in 1945, and Chairman in 1946. He became a Senior Member in 1945, and a member of the Professional Group on Engineering Management in 1952. He is also a member of the Radio Club of America.

Fig. 2 shows a cutaway view of the RCA nuvistor tetrode. The nuvistor tetrode design assures good performance and low power drain in a tube of very small size and weight. The drawing clearly shows the extension of the basic nuvistor concept to a multigrid tube.

NUVISTOR TRIODES—TYPES 2CW4, 6CW4, and 6DS4

The high transconductance and low interelectrode capacitances make the 2CW4 and 6CW4 types particularly suitable for use as r-f amplifiers at very high frequencies in neutralized grid-drive amplifier circuits and in turret- and switch-type tuners. The interelectrode capacitances of these tubes are comparable to those of conventional tubes. Therefore, the changeover to take advantage of nuvistor performance capabilities is relatively easy and requires little equipment design effort. Short-circuit input-impedance measurements indicate that the nuvistor has higher input resistance than other receiving tubes having equivalent input capacitance and transconductance. Because of the nuvistor metal enclosure, tube shielding at high frequencies is unnecessary. The average noise and gain performance of the 6CW4 in turret- and switch-type tuners on Channel 13 is compared with that of conventional miniature types in the same circuit in Table II. The recently announced type 6DS4 is a remote-cutoff version of the 6CW4 which has improved cross-modulation characteristics in TV tuner applications.

INDUSTRIAL NUVISTOR TRIODES—TYPES 7586 and 7895

As an r-f amplifier at 160 Mc. the 7586 is capable of producing useful power output of 650 mw with an input of 1 watt at a plate voltage of 120 volts. At 160 Mc. the 7586 has efficiency of 65 percent as a straight-through r-f amplifier, 50 percent as an oscillator, and 35 percent as a doubler. The design characteristics of the 7586 are such that internal losses do not affect performance until a frequency of approximately 300 Mc is reached. As a local oscillator for mixer application, the 7586 has been employed up to 1000 Mc.

Because of its high input impedance and low microphonics, the 7586 is also used as a high-gain amplifier in preamplifiers and in special-purpose test equipment.

Type 7895 is a high-mu version of the 7586. The 7895 has an amplification factor of 64 and is employed in a wide variety of applications, such as resistance-coupled amplifiers, *on-off* control circuits, r-f and i-f stages, and as oscillators ranging from vlf audio to uhf.

INDUSTRIAL NUVISTOR TETRODE—TYPE 7587

High transconductance at low plate current, low interelectrode capacitances, and high input impedance make the nuvistor tetrode, type 7587, particularly suitable for use in a wide variety of amplifiers. Because of the high gain-bandwidth product attainable, and the excellent gain stability over a wide frequency range, the nuvistor tetrode is being used in radar-beacon i-f-amplifier strips and in a number of industrial and military applications.

The gain-bandwidth figure of merit of the nuvistor tetrode indicates that this tube compares favorably with conventional tubes for broad-band amplifier applications. To demonstrate the capabilities of the 7587, a simple five-stage 60-Mc i-f amplifier with a bandwidth of 8 Mc was designed and built. The first stage consisted of two nuvistor triodes, type 7586, placed in cascode arrangement to take advantage of the low noise figure obtainable with this type of input. The cascode amplifier was followed by four 7587 nuvistor tetrodes which were single-tuned and staggered and by a diode-connected 7586 triode for use as a detector. The gain-bandpass characteristics for this particular amplifier for gains of 705, 11,100, and 104,000 are shown in Fig. 5. Because of the uniformity of nuvistor characteristics from tube to tube, a minimum amount of adjustment was necessary to maintain proper bandpass characteristics when tubes were interchanged. The small size of the 7587 and the double-ended feature simplified the circuit layout by allowing the chassis to be used as a physical and electrical barrier between input and output. With due consideration to bypassing and decoupling, high packaging density was achieved with no instability problem.

INDUSTRIAL NUVISTOR UHF TRIODE—TYPE 8058

Initial measurements of the recently announced uhf triode, type 8058, for small-signal grounded-grid amplifiers indicate performance equal to that of many of the available planar disk-seal and pencil tubes. Although the 8058 is directed toward applications in military and industrial equipments, some initial measurements were made in the TV uhf band for convenience.

Present uhf TV tuners use a crystal mixer and have a noise factor ranging from 10.5 db at 470 Mc to 12 db at 890 Mc. As with properly selected planar disk-seal or pencil triodes, the nuvistor uhf triode is capable of noise figures of 6 db at the low end and 10 db at the high end of the uhf band. The power

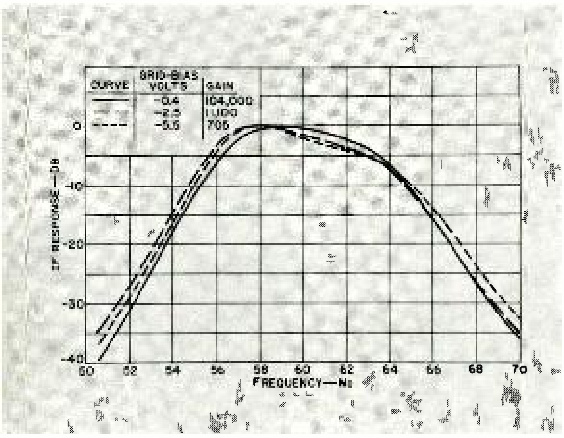


Fig. 5—Nuvistor tetrode, Type 7587, gain-bandpass characteristics.

gain for the nuvistor r-f stage is in the order of 14 db. Fig. 6 shows the noise figure, gain, and bandwidth capabilities of the nuvistor uhf triode in a test cavity over the uhf frequency range. In the test circuit, external stubs and line sections were used to tune the cathode circuit over the uhf range covered.

Fig. 3 shows the cross section of the double-ended uhf nuvistor triode. Externally, the triode is similar physically to the nuvistor tetrode. In the triode design, low reactance between the grid and ground element is obtained, to insure stability, by connecting the grid of the tube on a flange which makes contact to the metal shell around the full circumference. The input loading associated with cathode lead inductance is reduced by the use of three cathode stem leads. The tube is designed with a sufficiently high amplification factor to obtain high gain and low feedback in a grounded-grid amplifier. The transconductance of the tube and the input and output capacitances are optimized to allow for the development of circuits with high gain and wide bandwidths. A flexible connector to the plate and a conventional nuvistor socket to the remaining elements greatly simplify the tube mounting problem and reduce the costs usually associated with uhf tubes.

NEW DEVELOPMENTS

Additional work has been carried on to extend the nuvistor concept, particularly

TABLE II—Comparison of Nuvistor and Conventional Miniature Tube Performance in TV Tuners for Channel 13

Tube Type	*Noise Factor, db*	*Tuner Voltage Gain, db*
Conventional		
6BN4A	8.5	38.0
6FH5	7.5	41.0
6ER5	7.5	41.0
6GK5	6.5	44.5
Nuvistor:		
2CW4, 6CW4, 6DS4	5.5	45.0

toward the goals of reduced size and improved over-all characteristics. A reduced-size nuvistor triode requiring a heater power of only ½ watt is presently being developed for general purpose r-f amplifier applications. (This project is being supported in part by the Department of the Navy, Bureau of Ships.) The external configuration of this tube is approximately half the size of the present nuvistor prototype. Developmental tubes of this type have been made and are currently being evaluated.

Some work on the application of nuvistors to satisfy critical military requirements is in progress. The results of recent radiation tests have shown that the nuvistor performance in pulsed radiation environments is better than many conventional devices. Shell-firing tests resulted in the recommendation that the nuvistor be considered for utilization in future equipment applications involving high mechanical excitation. The nuvistor is presently being critically evaluated for linear acceleration, vibration, fatigue vibration, and thermal shock in various RCA laboratories and in several other industrial and military laboratories.

The development of a new uhf oscillator and a nuvistor for low-voltage operation described below represents just two of the nuvistor designs being developed and evaluated for new equipment designs.

DEVELOPMENTAL UHF NUVISTOR OSCILLATOR

The RCA developmental nuvistor triode oscillator, RCA Dev.No.A-15239-G, shows definite improved performance over conventional tubes in uhf oscillator applications for television receivers. For uhf TV tuners, the oscillator is normally designed to have an effective tuning range from approximately 505 to 950 Mc. The low heater current, input power, internal capacitances, and lead inductances make this tube highly efficient and suitable for uhf operation. The tube features a basing change which provides for double-grid and double-plate lead connections to reduce reactive coupling and loading effects. The amplification factor of the tube has been optimized to obtain the proper feedback-capacitance ratio, and the internal structure has been modified to minimize the total effective capacitances. Losses in transit-time loading are compensated to some extent by a multi-siderod cylindrical grid structure which results in more uniform internal electrical field than in conventional uhf tubes. Low input power minimizes temperature changes, and low interelectrode capacitances reduce the capacitance effect that

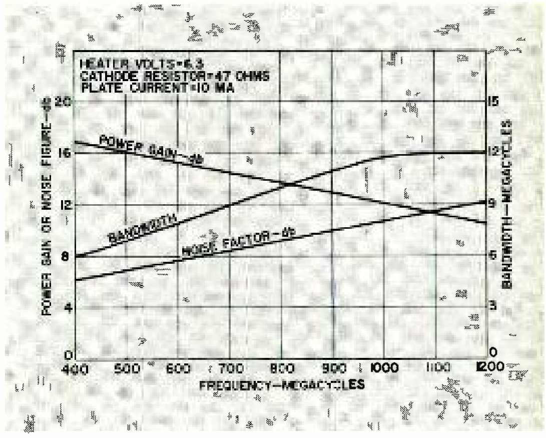


Fig. 6—Nuvistor uhf triode, Type 8058, characteristics.

uhf tubes usually create on the external resonating circuits during warmup. As a result, the tubes are subject to less frequency drift than experienced with conventional tube types.

DEVELOPMENTAL LOW-VOLTAGE NUVISTOR

Recent trends in the design of military equipment have created a need for electron tubes operating from low-voltage power sources. The developmental industrial triode, RCA Dev.No.A-15247-A, is specifically designed to operate from 12-to-24-volt low-voltage power supplies. This tube, which is insensitive to ambient-temperature variations, will eliminate the problems associated with the design of high-impedance circuits for critical control applications. It has a specially designed grid to optimize the characteristics for low-voltage operation while maintaining freedom from microphonics through an unusually high mechanical resonant frequency.

CONCLUSION

In July of 1961, the 1,000,000th nuvistor was produced at the Harrison Tube Plant. During the fourth quarter of 1961, the first step toward a high degree of mechanization was taken with the delivery of automatic machines for many of the manufacturing processes and techniques described above. These machines will further improve nuvistor reliability, uniformity, and manufacturing costs.

ACKNOWLEDGMENT

The author wishes to acknowledge the outstanding job done by the Nuvistor Manufacturing organization of the Harrison plant and the invaluable contribution made by the Equipment Development Engineering group at Harrison in developing the completely new machines, tools, and fixtures required for nuvistor production.

560-KW SATELLITE SURVEILLANCE TRANSMITTER

by **J. F. ECKERT**
and J. R. SCHIETINGER*
Broadcast and Communications Products Division
Camden, New Jersey

This 560-kw transmitter is part of the U.S. Navy Space Surveillance System, a radio-detection complex along a great-circle route across the southern U. S. It detects radio reflections from space objects passing through the vertical radiation pattern of a series of c-w transmitters. Standard broadcast transmitters were adapted, thus achieving low-cost, rapid installation and ready availability of replacement parts. Called RADAL (radio detection and location), the system provides effective, reliable orbit data and satellite-position prediction.

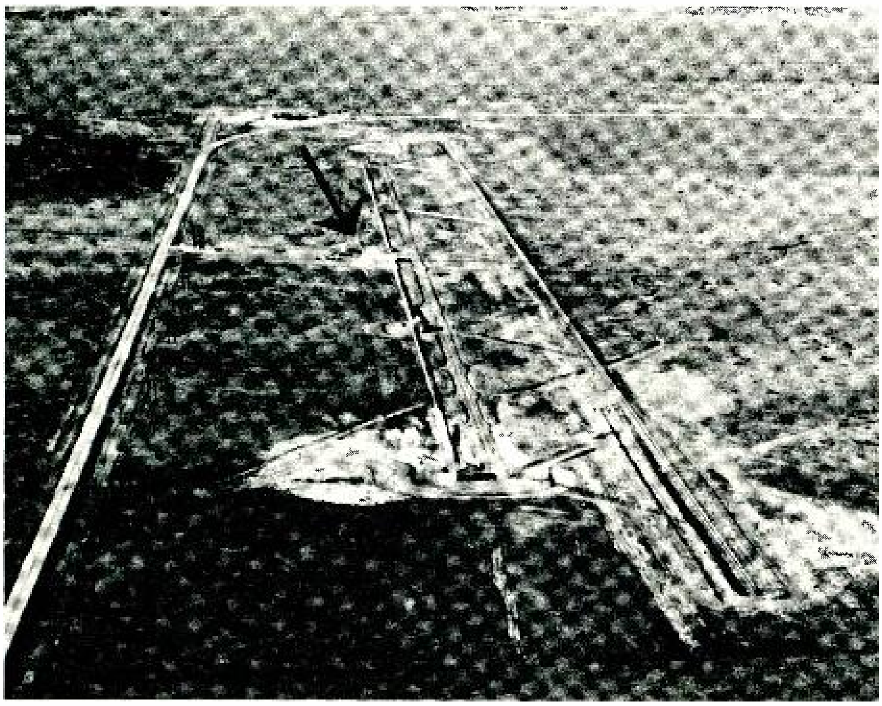


Fig. 1—Aerial view, looking north, of the Kickapoo Lake Space Surveillance Station, Texas. Arrow marks central building; the transmission lines seen running through the central building connect the field buildings, two seen on the far side and two on the near side of the central building. To the right is the mile-long antenna; a close-up of it from the far end is shown in Fig. 2.

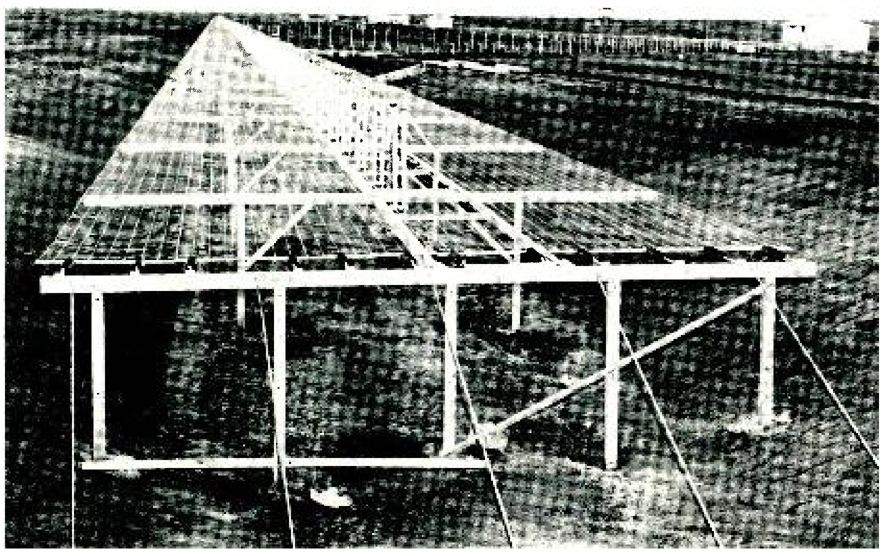


Fig. 2—View from north end of the mile-long antenna, showing also the four field buildings, central building, and interconnecting transmission lines.

AT PRESENT, the U. S. Navy Space Surveillance System complex comprises four receiving and three transmitting stations from Ft. Stewart, Ga., westward across the country. A composite 50-kw transmitter was placed in operation at Jordan Lake, Alabama, in mid-1958. A second 50-kw transmitter, an RCA TT-25 television transmitter modified for 108-Mc operation, was installed early in 1959 at Gila River, Arizona. The third — to be discussed herein — is rated at 560 kw output, and went into operation at Kickapoo Lake, Texas, in June 1961.

HOW THE SURVEILLANCE SYSTEM WORKS

All of the transmitters drive multi-element antennas (Figs. 1 and 2) with very narrow, coplanar fan patterns in a vertical east-west plane. The resultant radiation takes the form of a curtain across the southern United States.

The receiving stations operate as interferometers in which the angle of reception can be determined from the relative time of arrival of signals at two separate antennas. Comparison of data from two receiving stations locates the instantaneous position of the reflecting body in the plane of the radiation pattern.

Received information is continuously transmitted to the Space Surveillance Operations Center at the Naval Weapons Laboratory, Dalgren, Virginia. There, the high-speed Naval Ordnance Research computer calculates orbit information and maintains a catalog of all observed satellites. Among the uses of this catalog is the preparation of a timetable predicting the passage time of all known objects through the surveillance curtain. Continuous observation leads to almost immediate detection of new objects which, if unexplained, are naturally subject to considerable suspicion. For this reason, continuous operation of the equipment is considered vital. A few seconds "off the air" time may destroy the utility of the whole system.

THE 560-KW KICKAPOO LAKE TRANSMITTER

As stated above, meaningful surveillance demands *continuous* operation of the transmitter. Spare equipment or

* The authors recently transferred to Defense Electronic Products as part of the High-Power Transmitter Group.

by-pass switching facilities are provided to stay on the air (more correctly, space) even though some units may be down for maintenance or repair.

The aerial view of Fig. 1 shows the 560-kw Kickapoo Lake Transmitter Station with its five buildings and 648-element, mile-long antenna. The central building (arrow), used as the central control point, also contains two driver chains, one of which supplies grid drive to the field-building power amplifiers through a system of power splitters and transmission lines. The other drive chain feeds the center bay of the antenna, but it may be rapidly switched to substitute for the normal driver in case of failure.

Each of the four field buildings houses two power amplifiers with common power supplies and control units. They are in line with the separation between antenna bays to form symmetrical feeds from the two power amplifiers in each building to two adjoining sections of the antenna. The antenna (Fig. 2) is divided into nine bays, each driven by a separate power amplifier having an output of 62.5 kw.

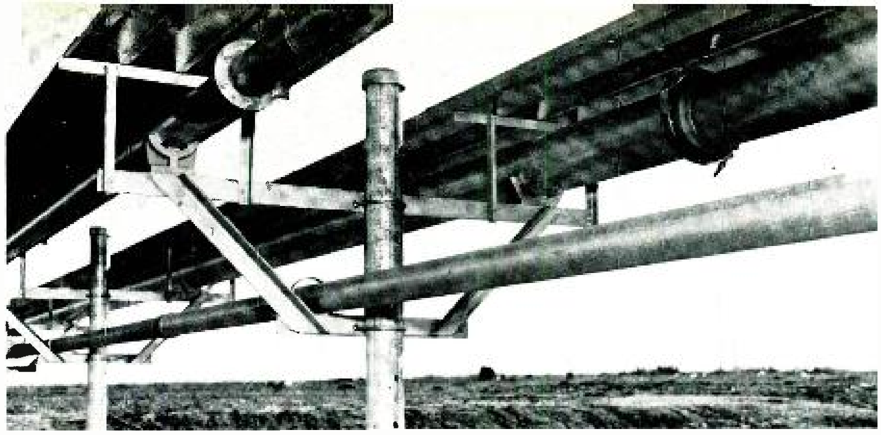


Fig. 4—Transmission lines, 3 ⅛-inch on left and 6 ⅛-inch on right, which connect central and field buildings, are supported by the frame structures shown here. Aluminum sun shields and conduit for interconnecting signal cables are also shown.

Frequency Control

The functional block diagram of Fig. 3 shows that the frequency control for the transmitter is derived from two 1-Mc frequency standards of the type developed originally to stabilize co-channel television stations for offset carrier operation. These units will have a variation not exceeding 6 parts in 10^{11} over a 30-day period. Each crystal oscillator has a separate 100-kc locked-oscillator divider and a clock unit for long-period frequency measurements. A five-channel, crystal-controlled receiver provides 1-second time ticks from the National Bureau of Standards Station, *WWV*, which are compared with 1-second ticks from the clock by means of an oscilloscope. The long-period drift of the clock output as related to the *WWV* standard time gives a precision measurement of the local oscillator stability. Polaroid cameras may be used on the oscilloscopes for logging reference.

Each crystal oscillator also drives a harmonic multiplier chain to give a 6-Mc output to drive the frequency multiplier of a modified RCA BTE-10B FM exciter to an output of 108-Mc. Selection of either frequency-control chain is accomplished by a manually controlled coaxial relay.

Drivers

Two separate drivers are provided for the system. The two low power drivers are RCA BTF-10C, 10-kw FM transmitters operating essentially without modification. Excitation at 108 Mc for the low-power drivers is obtained from the common exciter through a coaxial transformer power splitter. The common excitation is necessary to hold the phase stability of the system within the specification.

Each BTF-10C unit drives a modified TT-50AH power amplifier used as a high-power driver with an output of 62.5 kw. One high-power driver normally drives the eight power amplifiers in the field buildings through an r-f distribution system and the other is used to energize the central antenna bay.

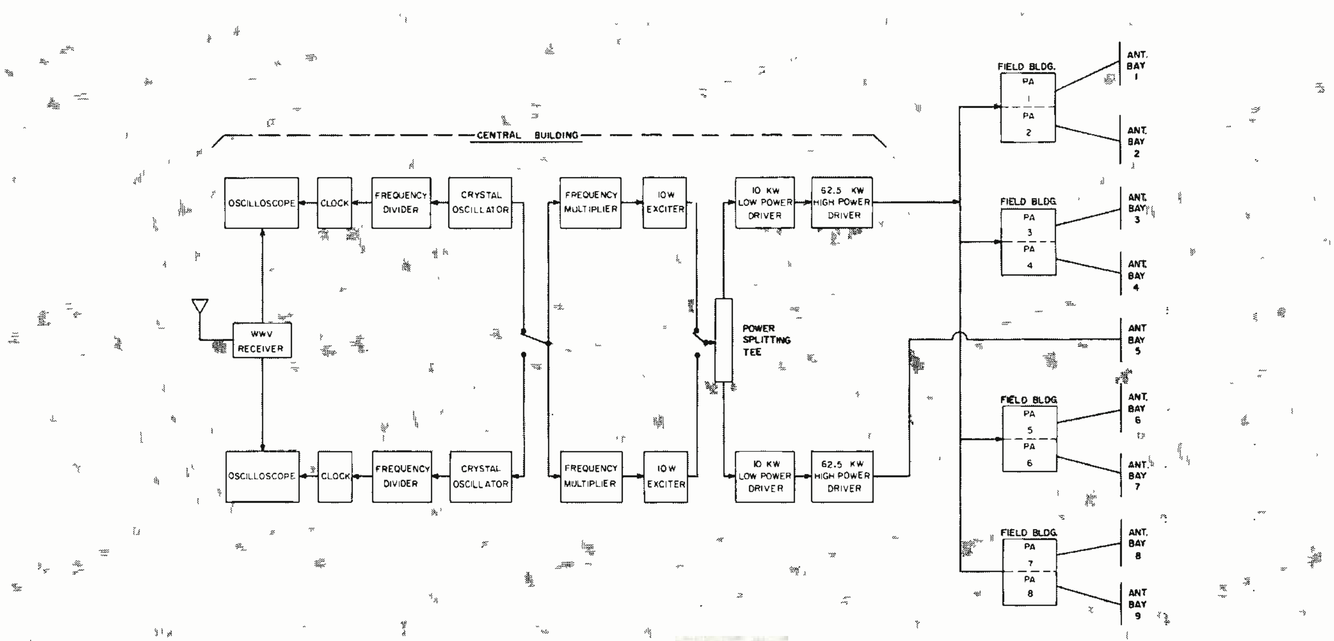
Interconnected coaxial patch panels are provided in the output lines of the low-power and the high-power drivers for the connection of a test load. One 50-kw load unit thus serves for all four drivers.

Transmission Lines

Drive for the power amplifiers is transmitted from the central building through rigid, air-dielectric, coaxial transmission lines (Fig. 4). The exterior transmission line is dry-air pressurized and uses aluminum outer and copper inner conductors. This construction, while less efficient than all copper, saves considerable initial cost without sacrificing system power output because of the ample drive power available. The lower weight also simplifies support-structure requirements.

Steatite insulators are used, and the center conductor of the transmission line is anchored at one end of each section with an expansion connector at the

Fig. 3—Kickapoo Lake Space Surveillance System diagram.



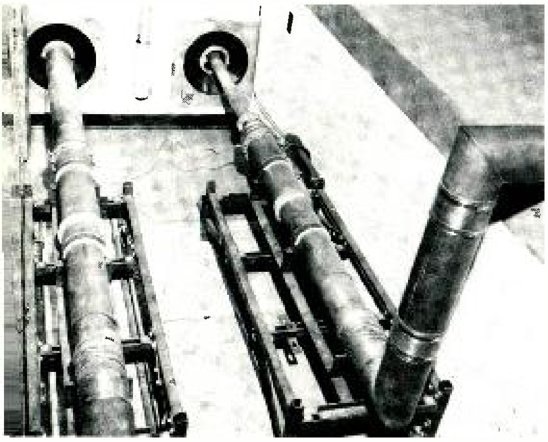


Fig. 5—Expansion units which provide constant impedance to the transmission-line runs by compensating for length change over the ambient temperature range.

opposite end to compensate for the differential expansion between the copper inner and the aluminum outer conductor.

Clamp-type connections are made between sections. The construction is similar to that employed in the RCA universal-type transmission line in which male and female flanges are *O*-ring sealed and connected with a Marman-type clamp.

The individual sections of the transmission line are an odd number of quarter wavelengths long to compensate for the possible cumulative joint mismatch resulting from the large number of connections in the system.

Corrugated aluminum awnings are positioned over the entire length of the exterior drive lines as sun shields to reduce the radiant heating. Galvanized pipe and steel angle supports carry the line on nylon glides spaced every ten feet to allow free expansion movement without snaking (Fig. 4).

The 900-foot lines to the near field buildings are 3⅛ inches in diameter, and the 2,000-foot lines to the far buildings are 6⅛ inches in diameter. Use of 6⅛-inch-diameter line, with lower loss, compensates for the difference in length so that approximately equal drive is available at each field building. Each line operates with a transmission efficiency of about 75 percent.

Phase shift due to expansion of the transmission lines is minimized by termination in constant-impedance expansion sections (Fig. 5). In this installation, the lines to the near buildings are anchored at the field building and allowed to expand into expansion sections in the central building. The longer lines, to the far buildings, are anchored in the center and allowed to expand into expansion sections at each end. This results in an almost constant electrical length over the range of ambient temperature variation.

Central Control

Normal operation of the transmitter is from the main control position in the central building (Fig. 6). For effective control, all of the important power-amplifier metering and control functions are remoted to this location. Separate switches are provided for the motorized tuning controls in each power-amplifier, amplifier-transfer, and plate-power control function. Individual meters are used for the input and output reflectometers, main-power-supply d-c voltage and current, and total power-amplifier cathode and screen currents. Plate control of each building may also be transferred to a separate panel in the master rack.

In addition to the *Master Plate Control* panel, the master rack contains an *R-F Switching Control and Status* panel, a *Building Ready* panel, a *Low-Power Driver and Frequency Control* panel and a *Dummy Load Pump Control* panel.

The R-F Switching Control and Status panel is a graphic display with illuminated pushbutton switches and indicator lights showing the flow pattern of all r-f switching in the system.

In the central building, motorized coaxial switches are used to allow diversion of driver power from any field building into 25-kw dummy loads. Other motorized coaxial switches can cross-connect the spare driver into the diplexer distribution system, and a third set of switches can be used to parallel the low-power drivers into a combining diplexer and then into the r-f distribution system in case of a common failure of both high-power drivers. All of the motorized coaxial switches are controlled in functional groups by pushbuttons on the status panel. The motorized switches must transfer "cold," and r-f is removed automatically. The push-button interrupts driver power, cycles the motorized coaxial switch, and returns drive power upon completion of the transfer cycle in less than 2 seconds.

The status of the power-amplifier-drive coaxial vacuum relays is also shown on the switching panel, but no control is provided. Operation of these relays is normally automatic, with the individual drive diverted to a dummy load whenever plate power is interrupted. Manual control at the field buildings is available for testing. As the vacuum relays are switched "hot", no interruption of drive to the rest of the system results when a power amplifier is cut in or out.

The Building Ready panel provides a safety circuit protecting the field-building diplexer-reject load and the two grid-drive dummy loads in the event of loss of cooling water flow, and removes drive from dead power-amplifier grids should there be a failure of field-building power. The panel receives dummy load over-temperature and a-c line under-voltage information from each field building. When set for automatic operation, indication of an unsafe condition received from any field building will energize the motorized coaxial switch for that building's drive line and divert r-f drive power to the central building dummy load.

Associated with the Building Ready function is the Dummy Load Pump Control panel. This panel controls the intermediate coolant circulating pumps on the 25-kw drive-line dummy loads (Fig. 7). Normally, the loads may be de-energized for a long time, and there is no need for coolant circulation during such standby periods. The Pump Control panel, when in automatic operation, provides circuitry to start the required dummy load pump as soon as the associated motorized switch starts to cycle.

The driver control panel in the master rack provides indication and control for the BTF-10C low-power drivers and selection of the exciting-frequency source.

Telephone-type and shielded cables carry all control functions and metering circuits between the control building and the field buildings, and are enclosed in conduit supported on the same structure as the transmission lines. Expansion joints and pull boxes are alternated every 150 feet (Fig. 4).

Fig. 6—Views of left and the right portion of a room in the central building containing operating positions, array of control racks, and driver units.

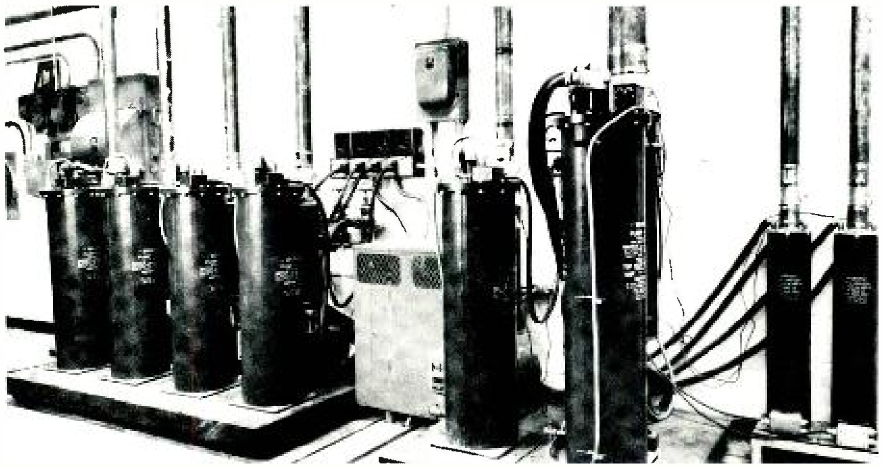


Fig. 7—The r-f load units in central building, one 50-kw, five 25-kw, and two 7.5 kw loads.

POWER AMPLIFIER BUILDING

Each field building contains a modified version of an RCA TT-50AH television transmitter, complete, except for driver units. The power amplifiers are identical to the high-power drivers located in the central building.

Power Amplifiers

The TT-50AH television transmitter has two similar but separate power amplifier units for the aural and visual channels, and six auxiliary cabinets containing control and power supply circuits. Four additional driver cabinets normally used for separate aural and visual channels in a television transmitter are omitted in this installation, since an external drive source is utilized..

The amplifiers originally covered a tuning range of from 174 to 216 Mc for broadband operation on television channels 7 to 13 inclusive. Each amplifier used five paralleled type-6166 air-cooled tetrodes in a grounded-grid, grounded-screen circuit. The aural channel was rated at 30 kw and the visual at 50 kw, peak.

The visual bias and screen regulators were eliminated and the circuits converted to the combination of grid leak and cathode bias used in the aural channel. The higher-frequency broadband circuitry was converted to 108 Mc and a new 211-kva plate transformer was provided to raise the rectifier output from 5800 to 7200 volts. These changes and the direct substitution of the new higher-rating RCA type 6166A/7007 tubes now give each amplifier a c-w output capability of 62.5 kw.

R-F Equipment

The r-f drive, received in each field building through a single coaxial transmission line, is divided two ways in a bridge diplexer to give equal drive for the two power amplifiers.

Two coaxial vacuum relays switch the outputs of the diplexer to the power-amplifier grids or divert the drive to two 7.5-kw dummy loads as required. This arrangement allows one amplifier to be driven while the other is down for maintenance. Diplexers are used, rather than simple transformer-type power splitters, to minimize tuning interaction and switching surges between amplifiers and into the r-f distribution system.

Phase-control equipment is inserted into each drive line between the coaxial relay and the power amplifier input in the form of a servo-motor-driven, half-wave, common-case, trombone-type phase shifter and a fixed line section initially adjusted in length to balance phase in the system. The phase shifter is normally controlled by the automatic-phase-control equipment in the central building with manual over-ride controls available both at the central building and the associated field building.

Reflectometers are installed in the input and output transmission lines of each power amplifier with independent metering circuits for field-building and central-building monitoring. *Carrier off* monitor units sample the reflectometer signals and compare the r-f input and output of each amplifier. Any appreciable deviation from an established ratio indicates an internal r-f fault in the amplifier and trips the overload circuit. The monitor circuit allows operation of the power amplifier down to approximately 30 percent of the full power level without readjustment. This is in contrast to a simple output detector circuit using a fixed reference which would require readjustment whenever the output power was changed.

A filter in each amplifier output provides harmonic attenuation up to the fifth harmonic and a coaxial patch panel gives facility to divert the output of either amplifier to a 50-kw test load.

Control

The TT-50AH transmitter originally allowed transfer of either the aural or the visual power amplifiers "off the air" with the remaining amplifier maintaining partial service. In this system it is necessary to provide remote control of the transfer function, as well as automatic transfer in case of amplifier failure. When the existing manual rotary switch proved unsuitable for motorized operation, multi-contact, mechanical latching relays were substituted and pushbutton switches were used for local and remote control.

The overload circuits have been modified so that in addition to the normal shutdown and indication functions, they now automatically transfer the faulty

J. F. ECKERT received his BSEE from the Drexel Institute of Technology in 1953. He joined RCA in 1936, being first employed in Radio Manufacturing of the Special Apparatus section. With the advent of commercial television in 1947 Mr. Eckert transferred to the Consumer Products Division of the RCA Service Company where he worked as a technician in both field and home office engineering groups. Upon his graduation in 1953 he became an Engineering member of the Industrial, Theatre and Sound section, working on product design and system applications, and later became part of the Television Systems group. In 1957 Mr. Eckert transferred to the IEP High Power and Nucleonics Department where he participated in engineering design for Project Matterhorn and the NRL space surveillance transmitter until his reassignment to DEP in 1961. He is presently working on a space project at the DEP Astro-Electronics Division at Princeton, N. J.

J. R. SCHIETINGER received his BSME from the Carnegie Institute of Technology and also attended classes in physics at the Johns Hopkins University, where he was appointed Assistant Professor in the Engineering College. He began his engineering career with the Western Electric Co. Joining RCA in 1952, Mr. Schietinger has participated in the design and development of antenna-pedestals such as the AN/TPS-10D as well as coordinating the mechanical design review program on the TALOS Project for the DEP Missile and Surface Radar Division. In 1957 he became a member of the Broadcast Transmitting Equipment Engineering group of IEP and shared in the mechanical design of high-power equipment on the C-Stellarator Project for the Princeton Physics Laboratory. As mechanical project engineer he was responsible for the integration of the RADAL System described in the article. Mr. Schietinger holds several U.S. Patents and is a Member of Pi Tau Sigma.

amplifier out of the system, reset the trip circuit, and return the remaining amplifier "on the air."

Grid drive is automatically diverted from an amplifier into a dummy load whenever plate power is interrupted or transferred.

Metering

Operation of the individual power amplifiers is normally unattended, making necessary the remote metering of the more important circuits. It was possible to arrange all of the required remote metering circuits at ground potential with the exception of the amplifier screen current. Because a common power supply is used for the two amplifiers, the individual screen current had to be measured at a point 1100 volts positive. Isolation of this circuit was accomplished through the use of a *transductor*, a highly refined variation of the saturable reactor, in which the d-c control current causes a change in impedance of a separately excited a-c winding. Rectification of the a-c output gives a d-c signal for the meter circuit which may be conveniently operated at ground potential.

Auxiliaries

The power amplifiers are forced air-cooled by individual 7½-hp blowers located in a totally enclosed subfloor blower tunnel. Outside air intake is through a large filtered opening in one wall. Air is directed into the amplifiers through floor trenches and exhausted to the outside through roof stacks, with provision to deflect heating air into the room during periods of cold weather.

Since the power amplifiers are entirely air-cooled, the only water requirement is for the dummy loads. However, no cooling water is required during normal operation when the only dissipation is a very small loss due to diplexer unbalance power in the reject load. The other extreme would occur during test periods when one grid drive may divert 5 kw to a dummy load and the other amplifier may feed 50 kw into the test load.

All water must be trucked into this location. Conservation of the water thereby dictates a closed system. Circulating pump life is extended through the use of water-saver control circuitry, so that the pumps operate only when cooling water is required.

The equipment installed in each building consists of a 100-gallon storage tank and a cooling tower with a circulating pump that starts only on demand from the thermostats in the load units. The water is returned directly to the tank if the temperature is below 80°F and is diverted through the cooling tower if the water exceeds that temperature. The tower fan is turned on automatically if the flow is diverted to the tower when the circulating pump is operating.

AUTOMATIC PHASE CONTROLS

By specification, the relative phase between any of the nine antenna feed points must be maintained within two electrical degrees. This requirement originated from the need to minimize random variation of antenna performance resulting from phase shifts between antenna feed points mainly due to differential expansion of the transmission lines. Many other secondary sources of phase shift, such as amplifier and frequency multiplier tuning, variations in equipment temperature, and changes due to power-supply variation, are also present in an installation of this size.

In the system employed, a 200-watt sample of the antenna-feed forward power is extracted by a directional coupler located at the feed point. The directivity of the coupler discriminates against any spurious reverse power component which might result from antenna mismatch or adjacent bay coupling.

Approximately 2600 feet of Habirlene-jacketed ½-inch-diameter Styroflex cable is used to transmit the sample signal from each directional coupler to the phase detection equipment in the central building. This is the length needed to reach the end bays with about a 23-db power loss resulting in a 1-watt sample at the phase-detector–equipment input. All the sampling cables are made the same length to eliminate differential phase variation due to temperature changes. In addition, each cable is inserted in an individual 2-inch-diameter plastic pipe with circulating water and buried 3 feet underground to assure equal temperature throughout the sampling cable system.

Approximately 9400 feet of excess cable, beyond that necessary to reach from the sampling points to the central building, is coiled and immersed in the reservoir from which the circulating water is pumped.

The load ends of the individual Styroflex sampling cables are terminated in manually adjustable line stretchers to allow convenient setting of the electrical length in order to meet a ½° equality specification. The equalized cables each connect to an input of a hybrid network which splits the signal two ways. One output of the hybrid is passed through a second manual line stretcher and a 10-db pad into the input of a phase detector hybrid. The other output is connected to a coaxial switching system which allows selection of one of the nine samples as a reference. The selected reference is divided nine ways by means of cascaded three-way power dividers and fed into the reference input of each of the nine detector hybrids. Matched silicon diode detectors develop a d-c output voltage in which polarity and amplitude are proportional to phase difference between the reference and the sample. The filtered output of the detector is connected to the control winding of the servo system magnetic modulator and to a zero-center meter calibrated directly in degrees of phase deviation. The output of each magnetic modulator is transmitted to the associated field building where it is processed and amplified in a servo amplifier and applied to the control winding of the servo motor driving the power-amplifier grid-line stretcher.

CONCLUSION

The rapid installation of both the early, low-power transmitters at Gila River, Arizona, and Jordan Lake, Ala., and the high-power one described herein were made possible through the adaptation of standard broadcast equipment. Obvious advantages of such practice are lower cost and greater speed of installation as well as ready availability of replacement parts.

The operational RADAL (radio detection and location) system, has resulted in effective and reliable satellite orbit calculation and position prediction.

ACKNOWLEDGEMENT

A number of people were naturally associated with the authors in the engineering design and construction of this transmitter. Those most closely concerned, under the general direction of C. J. Starner, were R. N. Clark and W. A. Hargrave, who designed the power-amplifier conversion, and J. F. Coyle and W. D. Lindley who participated in the general equipment design.

The whole Space Surveillance System was developed by the Naval Research Laboratory under the sponsorship of the ARPA, DOD. This work was under ONR Contr. No. NONR-3264(00)X. Buildings were constructed under BuDocks supervision. All stations are operated by Bendix Radio Div. for the Navy.

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NEW MM&SR SIGNAL PROCESSING SKILL CENTER

The June-July 1961 RCA ENGINEER (p. 35) described a new Antenna Skill Center at the DEP Moorestown Missile and Surface Radar Division. Now, another such activity—the new **Signal Processing Skill Center**—has evolved from a carefully planned program to establish an integrated group in this field with increased emphasis on both business and engineering aspects. These and the other new Skill Centers at Moorestown (see chart) create a total organizational capability to meet the challenge of increasingly complex radar projects.

TODAY'S RADAR SYSTEMS are complex information-gathering devices working in conjunction with computers and data processing equipment. The precision and amount of information required have increased immeasurably over the past few years, placing stringent specifications upon radar design and producing a complicated signal-processing art.

This new *Signal Processing Skill Center* (SIPROSC) pulls together under one manager, P. Selvaggi, a logical coalition of the Receiver, Signal-Processing, and Range-Tracking design groups, and a Mechanical Engineering Support activity. The new Center now provides Moorestown with an integrated design force capable of more efficiently coping with the complex problems arising from the expanding signal-processing art in radar design.

SIPROSC consists of 107 engineers and supervisors with approximately 7.0 years of average experience per engineer in radar design, accumulated from major programs such as TALOS, DIRAM, BMEWS, TRADEX, and MIPIR. This experience covers the study and determination of specifications as well as the circuit design and construction phases of engineering. No small part of their experience and skill is their understanding and familiarity with system philosophy and operation, and with the factors that effect and determine the radar parameters. Their skills cover analog and digital design techniques, instrument servo design, monopulse receiver, range and doppler tracking, complex signal processing, and master timing subsystems. A wide variety of techniques such as signal storage, sorting and weighting are utilized as well as integration, identification, and translation devices. Signal storage and integration have led to the development of precision electromagnetic devices such as drums, disks, and tape mechanisms.

The new SIPROSC is now involved in space-technology efforts as well as in basic product-improvement programs. Examples of the former are the development of satellite surveillance systems, c-w doppler systems, and electronic scanning antenna systems. Efforts on product improvement include modularization of existing equipment and the development of a standard line of transistor modules for receiver circuits. Further effort is concerned with improving a multichannel wideband tape machine and a magnetic disk-storage device for use in information-retrieval storage systems.

RECEIVER UNIT

The design of pulse and c-w signal receivers and exciters is the responsibility of the Receiver Design Group. Equipment concerned with the generation of local oscillator signals, amplification and signal level control, filtering, shaping and coding of transmitter excitation is considered as part of the unit's activity. Also included is the consideration of designing hardware which utilizes such techniques as frequency and phase-locked loop design and frequency synthesis. All of these techniques are used for producing receiving equipment used in frequency acquisition and c-w doppler tracking of high speed targets.

SIGNAL ESTIMATION & TRACKING UNIT

This group concerns itself with the timing in synchronizing systems, analog and digital range tracking, target detection and acquisition, signal-hit radar signal estimators and sequential signal processing, track-while-scan systems and target simulators. One of the outstanding achievements of this group was the development of a single-hit processing system capable of generating precise range angle and doppler information from a single radar return.

SIGNAL PROCESSING & RANGING UNIT

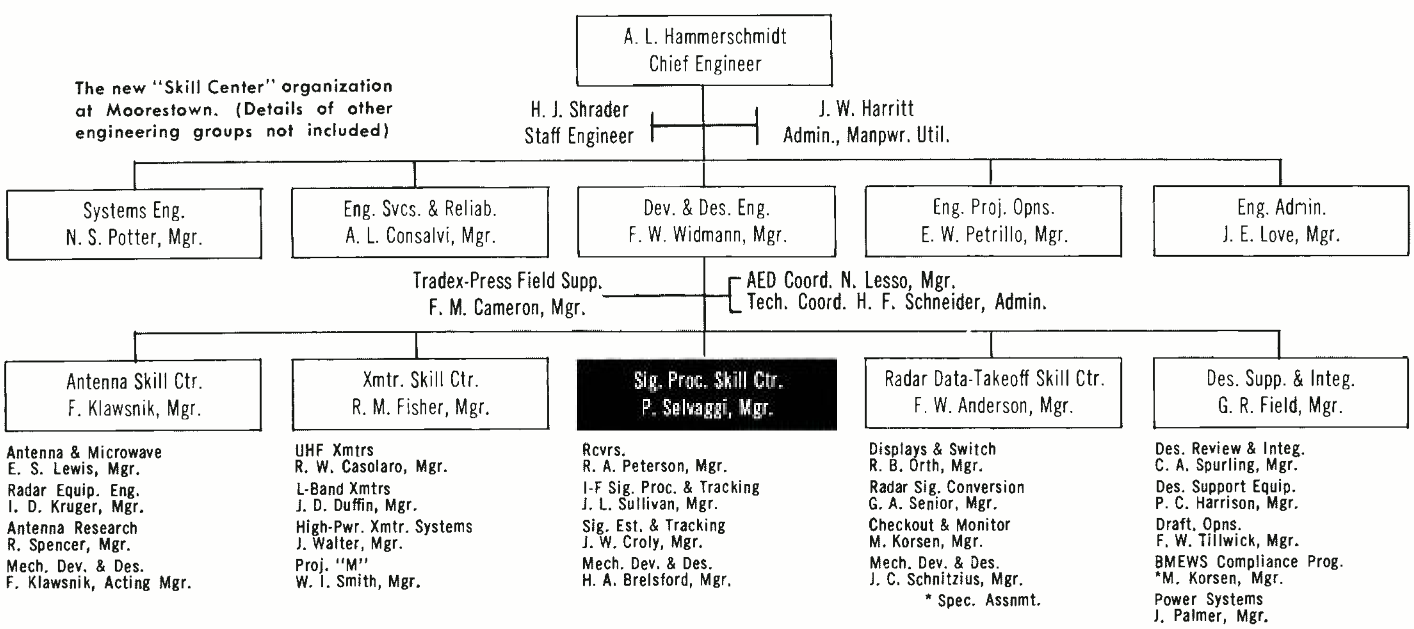
Concerned mainly with such items as signal sorting, storage and weighting, this group attempts to optimize and enhance the information extraction process. Extensive use is made of digital and analog techniques as well as modulation, demodulation, and filtering techniques. This group has done outstanding work in the application of electromechanical devices such as tape mechanisms, and magnetic drums and disks which have been used in fine-line doppler tracking systems, as well as in data-storage and spectral-analysis equipment.

The use of i-f tape recording equipment permits the storage of target information before any irreversible signal alteration is entered, thus permitting the maximum analysis of radar returns during off-line operation. The devices developed utilize techniques which permit maximum dynamic signal range with minimum distortion, thus enhancing resolution in multiple target environments.

MECHANICAL UNIT

The mechanical activity associated with SIPROSC is responsible for the design of all model and production hardware, including development of packaging techniques to house the equipment in an optimum physical configuration. In addition to electronic packaging for receiver, digital, and other types of electronic equipment, printed-circuit modules are being developed for high volumetric efficiency. A high-speed tape-transport system has recently been completed together with the development of magnetic memory storage disks for various equipments and a multiple-channel drum for others. New approaches to air bearings and air-driven high-speed turbines are being investigated.

Credit is due Harlin Brelsford, Mgr. Mechanical Development and Design at SIPROSC, for supplying this information.—The Editors



The new "Skill Center" organization at Moorestown. (Details of other engineering groups not included)

A VERSATILE MAN-COMPUTER COMMUNICATION CONSOLE FOR INFORMATION-PROCESSING SYSTEMS

by **P. B. LAZOVICK, A. W. REICKORD, and J. C. TROST**

Astro-Electronics Division
DEP, Princeton, N. J.

This unique console allows individuals not trained in machine language to use a computer directly, through English-language formulations of business, industrial, and scientific problems. Translating and machine-language editing are completely controlled by the console, and the time differential between a man's actions and a computer's responses are automatically buffered. The console can be used in a wide variety of information-processing applications, although it was originally developed as part of Project ACSI-MATIC (see Prologue).

It became obvious during the development of the Acsi-Matic system[1,2] that no adequate communication and buffering console existed to meet the requirements of untrained, non–computer-oriented personnel who would have to deal with a complex information-processing system. Thus, RCA developed an experimental prototype of such a console for the purpose of testing and evaluating different communication and buffering schemes. The resulting console, called Pac, for *Prototype Analyst Console*, has proven to be a powerful and interesting solution to the problem of providing man-machine communication and time buffering. RCA is now in the process of evaluating this prototype for the purpose of making more-specialized consoles for the Acsi-Matic system. Meanwhile, other applications for the Pac have been examined and tested; results demonstrate the versatility of the original concept.

GENERAL OPERATION

Figs. 1 and 2 show Pac's operating position, which includes a CRT display circuit, a core memory, operator panels, control circuits, and power supplies. The soft-copy (CRT) display uses a 21-inch tonotron storage-display tube. Careful design provides an extremely legible display with minimum circuitry. The actual function of each control depends upon computer programming and the restrictions the user wishes for the operator.

The types of console modes and operator identification requirements may be completely changed with no affect whatsoever on other Pac circuits. The *interrogate* switch, for example, could just as simply be labelled *integrate*, or the *security classification* indication could be changed to *business affiliation*. The only change would be in the labelling of the indicators and in the type of program read onto a tape associated with the console. This tape is called the *format tape*, and it contains the form of all allowable inputs to the computer. These forms are written on the format tape as soon as computer programs are established to process them. Each format contains both the machine designations required to indicate the program to the computer and a statement—*in written English*—which indicates the format to the console operator. When the operator selects a particular format, Pac reads the entire format into its internal core memory and then displays the written statement on the CRT. It then indicates the type of parameter which the operator must insert to compose a message.

The operator inserts his parameters in the format by operating a standard typewriter keyboard. The parameter is typed in English and displayed beside the format statement on the CRT. Each parameter is read into a composing core memory where it is grouped with the machine language from the format.

When the operator verifies the last required item in the message, the Pac reads out the data of the composing memory and sends it to the paper-tape punch. The punch control then edits the message and removes all data except the header indicating the program, an operator identification (*ID*), the characters used to separate items, and the operator's parameters.

When the message has been punched on tape, Pac signals the computer that a message is available. The computer may then read the message at its leisure, placing an answer on the magnetic *operator tape*. The answer may be retrieved by the operator just as simply as format was selected. Messages on the answer tape are preceded by a three-character header which indicates the operator and the question answered. When Pac locates the desired item on

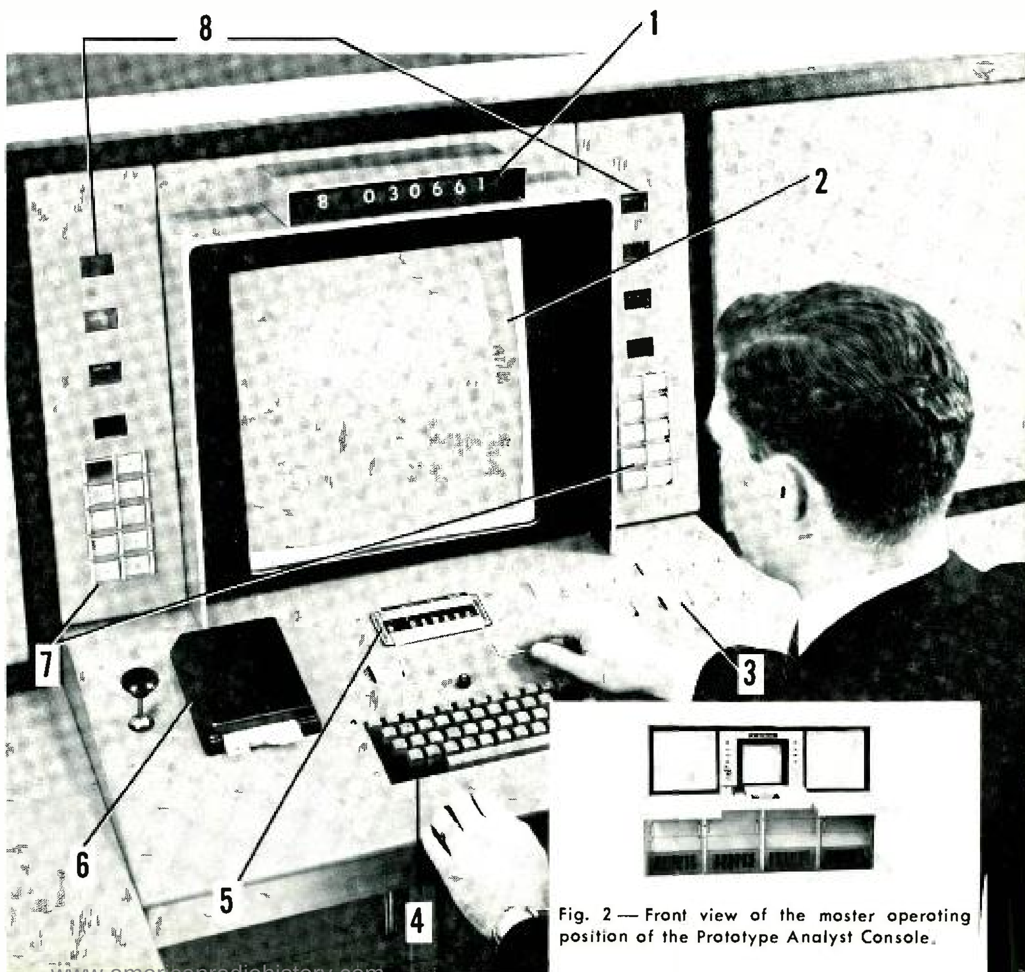


Fig. 1 — Closeup view showing the operator's manual controls. The functions of the various controls are: 1) date and identification indicator; 2) CRT visual display; 3) indicator and control switches; 4) typewriter keyboard; 5) date and identification switch; 6) card reader; 7) signaling indicators; 8) status indicators.

Fig. 2 — Front view of the master operating position of the Prototype Analyst Console.

Prologue . . . PAC and ACSI-MATIC

PAC was developed as part of the ACSI-MATIC program, a major study by RCA of the potential uses of modern data-processing equipment and procedures in certain military intelligence operations of the U.S. Army. (Under contract with the Dept. of the Army, Office of the Assistant Chief of Staff for Intelligence—hence the acronym *ACSI*, combined with auto*MATIC*.)

ACSI-MATIC is concerned with advanced concepts of man-machine information processing. It is a *natural-language* (non-numerical) system characterized by *1*) a high input rate of information, *2*) a great variety of input, and *3*) capability not only for interpretation, storage, and retrieval of the input information, but also for the logical selection, processing, correlation, and combination of stored data to develop a *different body of information* for output and analysis. Moreover, this system, though designed with one particular application in mind, has characteristics that make it adaptable to other activities, as shown in this article by the versatility of PAC—an important element of the system.

The ACSI-MATIC computer information-processing subsystem builds up files of information on particular subjects. These files handle both formal data—limited relations between certain classes of items—as well as background information expressed in a relatively free style. The input information not only helps fill out the formal parts of the files, but also can change the file data. The inputs in most cases are fragmentary in nature, and the machine programs help fill in the formal categories by piecing together and associating new and previously received information. Thus, this is *not* a system for document storage and retrieval.

Men play an important part in the analysis and decision-making required with respect to the information being processed. The system communicates desired information in useful formats (i.e., natural language, not a computer code) to the user—both automatically and upon request. Moreover, man-machine communications allow for manual control over processing and file maintenance when desired. PAC, then, is the important means for bringing directly together the actual *user* of the information and the sophisticated computer-implemented information-processing system. [This information was extracted from Ref. 1.—*The Editors.*]

the tape, it is read into the core memory and then displayed in the first manuscript page on the CRT. The operator then has his choice of printing that page and displaying the next, erasing that page and displaying the next, or printing the entire message. He has identical options for each page displayed.

Security requirements (essential to the ACSI-MATIC application) for the PAC are met by providing each operator with an identification card upon which is encoded an *ID* number. Before operating the console, the operator must set the control panel *ID* switches to his number and then insert his card. If the encoded number and the number selected do not agree, a security alarm sounds, and the PAC is inoperative until a security officer takes necessary action. The machine inputs to and outputs from the PAC are standard computer words comprising 7 digits in parallel. Since the PAC is only a communications device, it may be used for *any system* using similar word construction. The only basic change involved would be to place the new formats on the format tape. In addition, straightforward circuit changes can be made in PAC to allow operation with computer words of any number of digits.

OPERATOR MANUAL CONTROLS

The card reader (Fig. 1) provides an introduction between the operator and the computer, including an identification *(ID)* number, the operator's security clearance, (for classified-information applications) and his particular area of interest or specialization. The seven 10-digit switches indicate the *month*, *day*, and *year*, the operator *ID*, and any other routine information desired. The indicator switches determine the various modes of operation of the console. The typewriter keyboard is similar to a conventional typewriter keyboard. A *verify* character is added to this keyboard. When the operator is required to supply information, the indicator lamp above the keyboard is lighted. After typing the requested information displayed on the visual CRT display, character-by-character, the operator verifies that he has not made a typing mistake by pressing the *verify* character.

THEORY OF OPERATION

Fig. 3 shows a simplified block diagram of the circuits and components of the PAC. The *master sequencing control* and nine *operating routine* blocks contain the most important functions from the standpoint of understanding PAC's theory of operation. A brief description is given here of the remainder of the Fig. 3 blocks; the numbers in the lower right-hand corners of the blocks indicate the physical bay in which the circuits are located within PAC.

Bay 1—The Core Memory

The *core memory* facilitates message composition and enables printing one page of data while displaying another. It is therefore divided into two separate storage units, each with a capacity of 2,048 characters (the maximum number of characters per page) and is also used as a composing and a format section. The *computer drive* accepts the data output of the paper-tape reader and ensures that the data is exactly matched to the requirements of the particular computer with which PAC is used.

Bay 2—The Keyboard Register

The *keyboard register* translates the keyboard data into digital character codes required for the *information register* and the *comparator*. The information register accepts and routes all data. A combination of gates at the input of the information register reads the incoming 7-bit codes into a storage register of 7 flip-flops, which control gates that apply data pulses to the core memory, the comparator, the paper-tape punch, the CRT control, the printer control, or combinations of these circuits, depending upon the operation required. An arrangement of gates also check for odd parity, which, if not present, stop operation and light the *restart* indicator. The *comparator and comparison register* stores the 3-character codes used by PAC to search for parameters on the format prior for comparison with the characters read from tape. If they do not compare, a signal is sent to the *memory addressing and control* to clear the memory and prevent further read-ins. The memory addressing and control monitors the read-in and read-out of core memory data, adding or extracting the data from the required positions in the core matrix. Fixed data readout upon command pulses the *step switch* to read the operator identification data through the information register.

Bays 3 and 4—The CRT Display

The CRT *display*, which consists of the CRT and the circuits that actually write the data on the screen, accepts the 7-bit character codes from the information register. The inner face of the CRT is divided into independent areas by a fine mesh, and PAC divides the usable portion of the mesh into 4000 separate scanning areas, each a 5-by-7 matrix of 35 dots. The 7-bit characters applied to the CRT display are decoded by an array of 46 *and* gates, each causing a specific series of *or* gates to be activated, with each *or* gate corresponding to a dot on the matrix, according to the particular character being written. As the CRT beam scans a particular area, the activated *or* gates cause their associated portion of the screen to brighten, which allows a variety of characters to be presented on the face of the screen. The number of characters written per line is counted, and when the number reaches 80 the trace automatically moves back to the beginning of the next line. After an individual matrix has been scanned, the trace moves to the next matrix position. When the space signal is received, nothing is written because the decoder activates no matrix gates. When a carriage return is decoded, the gate drives the trace to begin the next line.

Bay 7—The Master Sequencing Control

The *master sequencing control* is the control logic for the over-all operation of PAC; its functions are described in the following sections covering Bays 8 and 9, and under *Operating Control*. It contains the *Nine Operating Routines* described later.

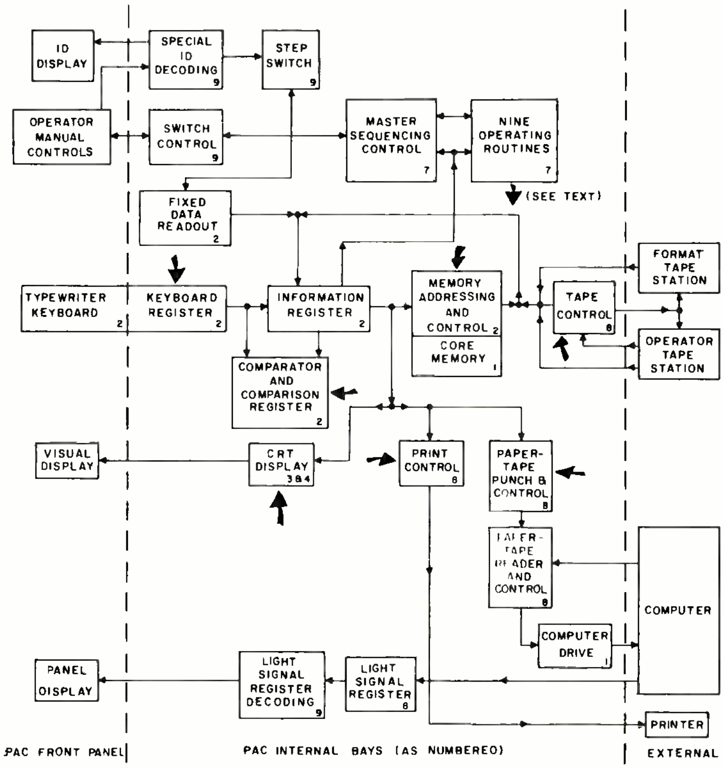


Fig. 3 — Simplified block diagram showing the functions and operation of PAC.

Bay 8—The Tape Control

The *tape control* is the interface between the computer and the *operator* and *format* tape stations. Both of these tape stations are located with the computer system. Upon command, the tape control attempts to switch the output of either tape to the information register, driving the tape forward in search of the information or of the end-tape symbol; this continues until a *stop* command is given. At end-tape symbol, the tape control automatically rewinds the tape and searches again. If the end-tape symbol is read a second time, the tape control stops the tape and lights the *request not on tape* indicator. Status signals indicate when the computer is using the tape.

The *print control* operates the hard-copy printing device used with PAC. Upon command from the master sequencing control (when one of the *print* switches is operated), the print control activates the printer and provides the pulses which operate the keys.

The *paper-tape punch and control* translates output of the information register into voltage levels capable of driving the paper-tape punch. Upon command from the master sequencing control, the punch control applies an enabling signal to the paper-tape punch.

The *paper-tape reader and control* contains circuits which read punched paper tape to develop data signals for transmission to the computer. A counter in this reader counts the number of messages punched. When the computer senses that there is a message on the paper tape, an enabling signal is applied to the tape readers; thus, the transport mechanism is started and the entire message is read from the tape into the computer drive circuit. As each message is read, a count is substracted from the message counter. The *light signal register* accepts the status and alarm indications from the computer and translates them into signals for lighting the appropriate indicators.

Bay 9—The Operator and Date Decoding Circuit

The *special ID* decoding circuit is a set of relays which are operated or released in accordance with the settings of the control-panel digital switches and the information read by the card reader. This, then, provides the fixed data through the *step switch* for transmission with the input messages. This circuit also checks the operator identification number against the number set on the *ID* switch, and if it agrees, it closes a path which enables the power to be applied to the PAC control panel. The step switch is a rotary switch which samples the output of the relay circuits in the operator and date decoding circuit. It is driven by the *fixed data readout* through a series of 11 positions for the purpose of reading out the information. The switch and light control translates the operation of the switches into electronic signals for driving the master sequencing control. The light signal register decoding controls the lighting of the indicators on the display panel.

OPERATING CONTROL

When the operator depresses any of the input mode switches (in the case of PAC utilized with the ACSI-MATIC, system, these modes are *int*errogation, *order* to change files, *hyp*othesis, and *new message* input, marked with the capital letters on switches on the front of PAC) it closes a relay in the switch control which pulses the master sequencing control. This places the machine in the particular mode designated. Note that the modes are arbitrarily defined by the programming of the computer for any particular application of PAC. The different formats available for any particular mode are given 3-character *item* codes, and if the analyst knows the format he is going to use, he depresses the *item* switch on the front panel and types in the *item* code on the keyboard. This immediately displays the format on the CRT for his use. If he does not know the *item* code, the operator presses the *index* switch, and a list of all of the formats available to him for any particular mode of operation is displayed on the CRT for his reference. He can note the *item* code of the desired format and then proceed to press the *item* switch as before for selection of any format.

Fig. 4 indicates a typical format for an *int*errogation mode with the parameters which might be typed in by an operator for a personnel information retrieval application of PAC. The < symbol is the *begin message* symbol and the > symbol is the *end message* symbol. The ◇ symbol is the item separator. The first line indicates interrogation item number (*A06*), and the identification of the operator (*2386100635*). Next is the actual format for the operator to use, with the unknown parameters in parentheses. The first parameter which the operator must insert is displayed on the next line; the operator types and verifies the word *manager*, representing his desire for information about managers. After the operator has typed in the first parameter and verified it, the second parameter appears on the CRT, namely *plant designation*. Then, *west coast central* is typed and verified.

The final line helps the operator identify the interrogation. *Index* is requested

< A06 ◇ 2386100635 ◇

HOW MANY (Personnel Category) AT (Plant Designation)

(Personnel Category) MANAGERS ◇

(Plant Designation) WEST COAST CENTRAL ◇

(Index) 15 ◇ >

Fig. 4 — Typical format for a personnel retrieval application of PAC.

after the operator has typed and verified the *plant designation*. The operator enters *15* as the index for the particular interrogation; this index is used as the search parameter when the operator wishes to inspect the computer response. Batching of inputs is at the operator's discretion.

After the message(s) have been compared, PAC forwards data to the paper-tape station for punching and storage on tape until the computer can read the information. When the computer has read the information and processed it, the response is written onto the answer tape; then, an *operator indicator* is lighted on the display panel, showing that information is available for the operator. The operator can select the *inspect* output mode to observe the computer response with the following options: 1) viewing the information on the CRT, 2) printing the first page and viewing the rest, or 3) printing the entire response from the computer. The storage persistence of the CRT is such that each page can remain for 10 minutes.

NINE OPERATING ROUTINES

The logic of PAC performs its operations through the master sequencing control and the following nine operating routines. Fig. 3 indicates by broad arrowheads where these routines are applied throughout the circuits of the PAC.

1) The *setup routine* is the sequence by which the operator informs PAC of the item requested; loading the comparator with the search parameters, either automatically when the *index* is requested, or manually when the operator types the *item*.

2) The *tape search* routine controls the comparator and tape circuits to find the message identified by the 3-character header which is loaded in the comparator.

3) The *load memory from tape* routine controls the insertion of data into PAC core memory from either the *operator* or *format* tape.

4) The *display memory* routine works with the soft-copy CRT display; it displays the computer responses or it redisplays the input information after a character or parameter has been erased. This allows the operator to correct a mistake in erasure.

5) The *read fixed control* routine controls the reading of the operator identification and other fixed data from the stepping switch into the core memory.

6) The *rotate format memory* (into assembly memory) routine controls the reading of the format message into the composing half of the core memory from the format half.

7) The *load from keyboard* routine controls the operation of the keyboard and the storage and display of keyboard-inserted information.

8) The *correct mistake* routine reads zeros into core memory to replace either the last character typed or characters following the last parameter category. It is controlled by the *erase char* or *erase par* switches.

9) The *print* or *punch* routine controls the reading of information out of core memory for duplication on a hard-copy printer or on the paper-tape punch.

CONCLUSIONS

The console described in this paper has been in operation with an RCA 501 computing system and has proven to be a successful man-computer communication device which could readily be understood and used by individuals with no computer experience in a very short time. PAC has checks built in to prevent mistakes from being entered into the computer and taking important time from processing. It presents a calm atmosphere for operation remote from the actual computer installation if desired, and it can operate simultaneous with other similar devices at the same or other locations.

PAC is an invaluable tool both from the standpoint of developing the final operational console to be used in the ACSI-MATIC system, and of demonstrating the potentialities of a computer to specialists whose interest is not in computer problems and jargon, but in realistic results.

ACKNOWLEDGEMENT

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P. B. Lazovick

A. W. Reickord

J. C. Trost

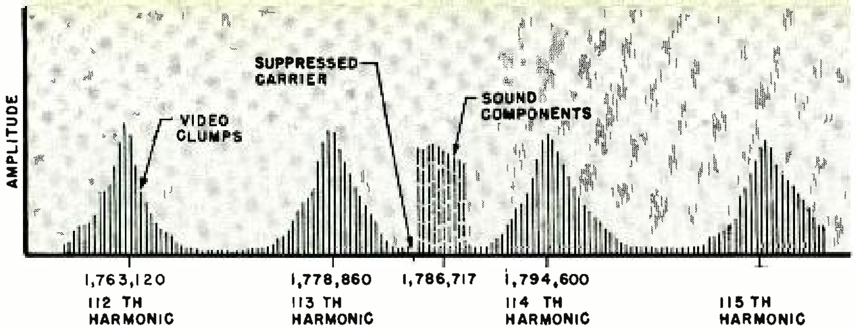


Fig. 1—Waveforms showing the video energy clumps and interleaved sound waves.

INTERLEAVED SOUND

. . . Standby Audio and TV Picture Transmission Over A Single Video Circuit

TV networks are troubled by occasional failures of interconnecting common-carrier circuits, even though advanced, well-maintained equipment is used. This unique emergency network system of interleaved sound, wherein video and the special emergency audio are transmitted over a single video circuit, avoids loss of sound to the TV viewer should the normal audio circuits fail.

by **J. L. HATHAWAY, Staff Engineer**
Engineering Department
National Broadcasting Co., Inc.
New York City, N.Y.

ALTHOUGH TELEVISION SOUND failures attributable to the common-carriers have become less frequent in recent years, a tabulation for 1960 on NBC circuits shows many hundred interruptions lasting longer than 30 seconds. As an example, one interruption resulted from a switching error in which CBS audio was routed on Bob Hope's video over NBC—several minutes of sound were lost and front-page newspaper coverage resulted.

Picture and sound circuits are normally carried over intercity facilities which are different in types of apparatus and in routings. One major difference is that video circuits are one-way only, while audio is reversible by means of a series of relays operating in tandem at the many repeaters along the route. Actuation of these relays is sometimes adversely affected by spurious voltages developing along one or more of the many lengths. This and many other factors have caused television sound outages, but it is noteworthy that these have seldom occurred simultaneously with picture circuit failures.

EARLY CONSIDERATIONS

The need for economical emergency sound facilities has long been recognized by broadcasting networks in fulfilling their mission of public service. Several years ago consideration was given to development of a system similar to that employed in microwave relaying, wherein an FM channel is multiplexed above the video frequencies. This seemed expedient and might have provided a high-quality circuit if the common-carrier bandwidth had been slightly greater, or if the video spectrum had been slightly curtailed. However, it would not have functioned on circuits which did not transmit the multiplexed channel properly. The decision to avoid using the extremely high end of the video spectrum proved wise, since broadcasters now use somewhat narrower intercity facilities in the interest of economy.

JARRETT L. HATHAWAY graduated from the University of Colorado in 1929 with a B.S.E.E. and that year joined the Development Engineering Group of the National Broadcasting Company. On a leave of absence from 1941-1944, Mr. Hathaway served on faculty appointment at Harvard University where he participated in development of new systems of underwater sound detection and missile guidance. Returning to NBC in 1944, he participated in a government sponsored project on high-altitude night photography including development, flight testing and consultation. Appointed NBC Staff Engineer in 1947, position currently held, Mr. Hathaway has been involved in nearly all phases of the company's television and radio engineering. Several years were devoted part-time to patent litigation consultation. Mr. Hathaway has been granted 33 U.S. Patents in various fields of electronics. He is a Senior Member of IRE, and a Member of Eta Kappa Nu.

PRESENT INTERLEAVED SOUND SYSTEM

A system of *interleaved sound* has now been developed to a state of practical utility, wherein *video* and *emergency audio* are transmitted over a single video circuit. In this system, the sound is interleaved within the picture components as a sheet of paper might be slipped between two of the many pages of a book, keeping the book intact. This means that the band requirement is no greater than that required for video alone. It also means that no added hardships are imposed in handling the video and the audio.

The system of interleaving the sound is possible because of the nature of television signals. Many years ago it was found, experimentally and mathematically, that television scanning of a picture produces concentrations (or "clumps") of energy distributed throughout the video spectrum at harmonics of the horizontal-line scanning frequency; each energy clump or harmonic has sideband components at multiples of the field-scanning frequency. Between these clumps, there is little video energy—it is into one of these "gaps" that sound is inserted. A few of the energy clumps are represented in Fig. 1, together with audio signals interleaved between two selected clumps; in this instance, the audio is between the 113th and the 114th harmonics of the line scanning frequency. The gap is rather narrow, especially for pictures including considerable high-contrast, finely detailed material; for this reason, single-sideband suppressed-carrier transmission is used for the sound. Any other gap in the same general portion of the spectrum could have been used just as well as the space between the 113th and 114th harmonics. Tests showed, however, that video interference between the clumps increases at lower frequencies. In the direction of higher frequencies the interference would have been much lower if the gaps were not occupied by chromiance components during the transmission of color.

TRANSMITTER AND RECEIVER

A single-sideband sound generator and a sound recovery unit were constructed in 1958 for evaluating the principle of interleaved sound. Fig. 2 diagrams these units in block form. Both the transmitter and receiver are "filter" types employing unsymmetrical crystal filters: thus, only the upper sideband is passed and sharp attenuation of the frequencies near and below the suppressed carrier frequency is provided. The filters have identical characteristics, with measured frequency response shown in Fig. 3.

The pass range of the crystal filters is *centered* between the 113th and 114th harmonics of the *average* frequency of horizontal scanning. This centering results in minimum interference from video into the audio and vice versa. Monochrome television horizontal frequency in the USA averages 15,750 cps; slight variations are caused by changes in the 60-cps power-line frequency generally used to control the synchronizing generators.

Color television employs a horizontal frequency 0.1 percent lower than that of monochrome television. The center frequency for the audio energy is determined by multiplying one-half the average horizontal frequency by an odd integer. Sound is placed between the harmonics previously mentioned when this integer is 227. Thus, center frequency is:

$$f = \tfrac{1}{2}\ (15{,}750 - 0.05\%) \times 227$$
$$= 1{,}786{,}731 \text{ cps}$$

The carrier should be located approximately 1000 cps lower in frequency, or at 1,785,700 cps.

Temperature-regulated quartz-crystal oscillators are used in the transmitter and receiver, and a means of readily checking frequency of the receiver against the transmitter is provided. These frequencies must match within about 4 cps; otherwise, the recovered sound would be offset in frequency enough to implant a slightly unnatural characteristic to certain voices and other program content.

Operationally, the frequency check and adjustment may be accomplished whenever the emergency circuit is not in use. A switch at the transmitter applies a 120-cps modulation derived from the 60-cps power frequency. When the audio output exceeds the limits of 120 ± 1 cps at the distant recovery unit, the local oscillator should be trimmed. Extreme accuracy is possible in this checking by connecting an oscilloscope to the receiver output and sweeping the trace with the local 60-cps power frequency. In metropolitan areas, power frequency is generally maintained within 0.1 cps. Under typical operating conditions. Interleaved Sound apparatus and companion equipment are turned on 24 hours daily. Stability of the oscillators is such as to require a frequency check and readjustment on a weekly basis. The crystal filters and all other components are sufficiently stable to make balancing and gain readjustments unnecessary over long periods of time.

PRELIMINARY RESULTS

Laboratory testing of the system was first conducted by adding the sound signal to the picture signal and recovering the sound components without any long interconnecting circuit. Results were good enough to warrant trials over actual video circuits, so a test was conducted from Radio City to Brooklyn and return. Results were equally good. Next, a circuit of over 2000 miles from New York to St. Louis to Chicago and return was tried; again, results were equally good. Finally, as a check on transmission over extreme distances, tests were made on a coast-to-coast-and-return common-carrier circuit of more than 7000 miles total. Here again results were good; there was no significant degradation of sound when compared with the original laboratory bench tests conducted without any intercity circuitry. Furthermore, the video signals suffered only the normal degradation associated with such long-distance transmission.

Control of the level of the interleaved sound signals is extremely important, since an excessive level creates interference patterns on the picture whereas insufficient level causes objectionable buzzing in the recovered sound. For these performance tests, the normal level of sound transmission produced a peak-to-peak voltage measuring one percent of the peak-to-peak television signal voltage; Fig. 4 depicts a video waveform with and without the added sound signals. Under this condition of transmission, no trace of sound interference could be seen on the picture, even on closeup viewing of large high-quality monitors. At this transmission level, the recovered sound was highly intelligible and adequate for use during short periods of interruption of the regular audio circuit. For prolonged listening however, an improved signal-to-noise ratio was highly desirable; thus, the receiving end of the circuit was arranged to initiate a telephone call to the transmitting end as soon as possible after an interruption occurred and the emergency circuit had been placed in use. The call would bring about a fourfold increase of transmitted sound level and a 4:1 drop in receiver sensitivity. This resulted in a recovered sound signal-to-noise ratio improvement of 12 db. Although this caused 4-percent modulation of the television signal by the sound, interference with the reproduced picture was insignificant and unnoticeable in ordinary television viewing.

A 30-day test was conducted with FCC authorization in the fall of 1960 from New York, with a sound recovery unit located at Washington, D.C. Sound signals were added to all programs originating in or passing through the Radio City New York control center. Normally a 1-percent level prevailed but on many occasions the 4-percent level was used to simulate emergency conditions. American Telephone and Telegraph long-lines personnel as well as those in all NBC affiliated stations were alerted prior to the tests; some days after inauguration, reports indicated that many not only failed to see any sign of interference to the pictures, but they were wondering why the test had not started as scheduled! During the entire month there was not one com-

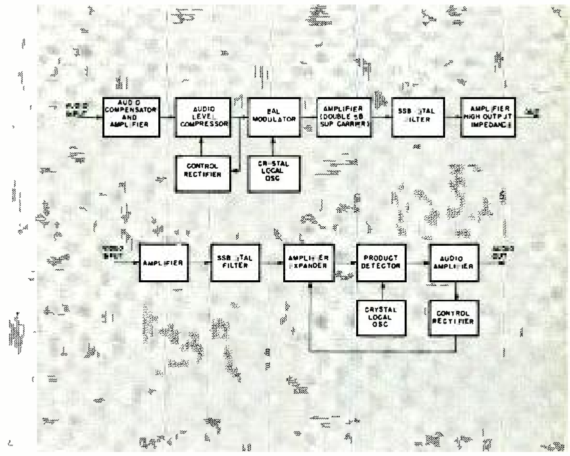


Fig. 2—Emergency-sound generator (top) and receiver (bottom).

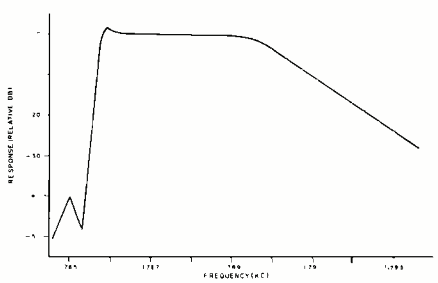
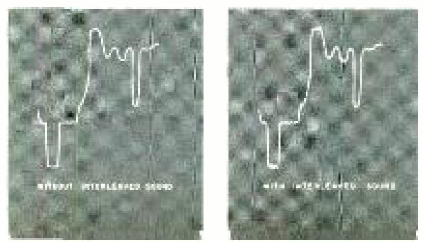


Fig. 3—Crystal filter response characteristic.

Fig. 4—Video waveforms showing the almost negligible effects of adding interleaved sound.



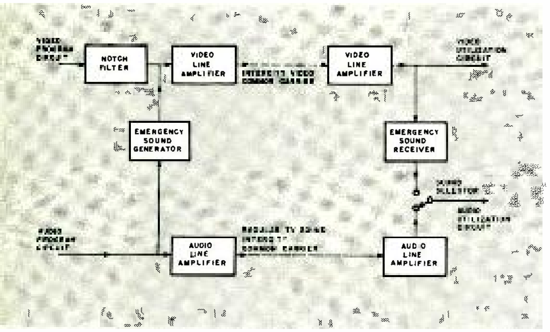


Fig. 5—Addition of the notch filter and interleaved sound to the transmitting and receiving video system.

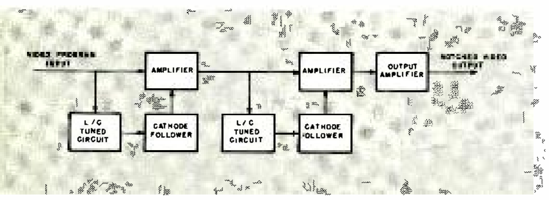


Fig. 6—Utilization of the unity-gain notch filter.

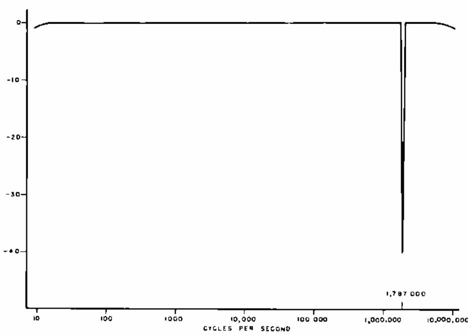
ment from the public which could in any way be related to possible interference from the added sound signal; furthermore, the network affiliates reported no interference. A demonstration was given to FCC members and staff on the final day of testing.

IMPROVED SYSTEM

Success of the 1960 test lead to the trial of another development and improvement. This has proven well worthwhile and results in three major advantages over the earlier system:

1) The signal-to-noise ratio of the received signal is always satisfactory for prolonged emergency network use and the level need not be increased above the normal 1-percent value.
2) Satisfactory signal-to-noise ratio is obtained at lower sound-transmission level so there is never the slightest vestige of interference to the picture.
3) The level change formerly required whenever a sound interruption occurred at a distant city has been eliminated; this simplifies and improves network operation compared with the two-level system.

Fig. 7—Frequency response curve showing the interleaved-sound notch-filter characteristic.

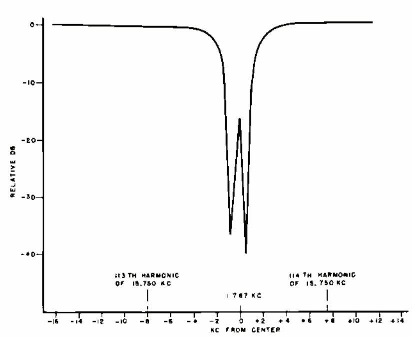


The only change apparatus-wise in realizing these advantages is the addition of a special filter to clear the channel for the subsequent injection of the interleaved sound signals. A double-notch filter eliminates most of the video signal components which would ordinarily occur at relatively low levels between two adjacent clumps of video energy. In the early system, practically all of the adverse noise in the recovered sound was created by video crossover; therefore, a reduction of these crossover components reduces the noise to a degree dependent upon the attenuation ability of the filter throughout the channel. A block diagram of the over-all transmitting and receiving system for video, regular audio, and emergency audio is given in Fig. 5.

NOTCH ATTENUATION FILTER

A suitable filter must be sufficiently selective to reject the desired band of frequencies without material attenuation or phase shift at the frequencies of the adjacent video clumps. In the filter employed, these criteria are met by using LC tuned circuits arranged to cancel video at two frequencies. The over-all filter, with isolation amplifier for over-all unity gain in a 75-ohm circuit is shown in Fig. 6. The LC tuned circuits has a Q of around 150 at the tuned frequency of approximately 1.78 Mc. Each circuit is provided with an amplitude and phase control (as well as tuning control) so that after passing through a cathode follower, cancellation of the video circuit signal may be achieved at the resonant frequency. The two LC circuits are slightly staggered in tuning to provide the response shown in Fig. 7. This response curve is plotted with greatly expanded scale of frequencies around the sound channel shown in Fig. 8. Although the unit does not represent the ultimate in performance in this application, it has proven relatively stable and easily controlled. Furthermore, it provides for a subjective improvement of at least 12 db in the recovered sound signal-to-noise.

Fig. 8—Expanded-scale frequency response curve of the notch filter of Fig. 7.



A preferred filter design would utilize a number of crystals in order to obtain at least 4 rejection points. Such a filter should provide at least 20 db of attenuation over a band of frequencies wider than that of Fig. 8, but having no significant attenuation or phase shift over a narrower band. This would result in a further increase of recovered sound signal-to-noise ratio without introduction of video "ringing."

SYSTEM PERFORMANCE AND STATUS

The over-all system described and presently in use as an emergency sound circuit covers the audio frequency band from 100 cps through 4300 cps, flat within ± 2 db. Harmonic distortion is below 3-percent RMS. Signal-to-noise of the recovered sound is a changing factor, depending on the nature of the video. In general, measured RMS noise is between 27 db and 45 db below RMS program; average video produces a figure approximately 36 db. So far, there is no indication that this is materially different on coast-to-coast circuits as compared to much shorter circuits.

The combined effects of interleaved sound transmitted at the specified level and radiated by a broadcaster produces no detectable change or deterioration of received picture quality and no co-channel or adjacent-channel interference. Furthermore, the level of transmission is so low that the sound signal added to video is far below the system noise limit specified by the FCC. Thus, the broadcaster's service to the public is never deteriorated by the existence of the emergency sound, whereas service is improved whenever a failure occurs in the regular audio circuits.

An agreement was negotiated giving the common carrier ownership of the experimental equipment, which the network operates over the New York to Hollywood, California circuit. This operation has been authorized by the FCC for a period of one year. Presently, American Telephone and Telegraph Company is testing other systems of transmitting sound together with video over a single circuit. They hope to evaluate the various possible systems and to complete development of the most practical one.

ACKNOWLEDGMENT

The author acknowledges the help and encouragement from Messrs A. L. Hammerschmidt, T. Kuron, G. M. Nixon, W. H. Trevarthen, and J. L. Wilson which made this development possible.

ANGLE CALIBRATION BY USE OF THE STARS

Calibration of precise measuring instruments that involve large angle excursions is a complex problem. The technique described herein, using precise star angles as a calibration standard, has been applied to the specific requirements of the AN/FPS-16 instrumentation radar, but is also feasible for other angle-measurement calibration problems.

by **D. R. BILLETTER**

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INHERENT in any precise measurement device is *calibration*. Angle-measuring devices may be calibrated readily over relatively small excursions by employing highly accurate optical devices such as theodolites and autocollimators. Where these devices do not prove adequate, angles may be precisely defined by establishing their trigonometric functions, usually the tangent or sine. As the excursion over which the device must be calibrated increases, so does the magnitude of the problem.

The problem is particularly severe for instruments such as tracking radars, ballistic cameras, and theodolites, which simultaneously measure angles in two planes and provide hemispheric coverage. For a radar, the problem is additionally complicated in that the various propagation errors must be taken into account.

The problem of calibrating a radar may be divided into two parts: 1) calibrating the data outputs relative to the optical axis of a telescope mounted on the antenna, and 2) the normal boresighting procedure of defining the axis of the radiated energy relative to the optical axis. The latter is generally accomplished by sighting on a distant target identifiable by both the radar and the telescope. However, boresighting provides only a portion of the required information; such calibration is valid only at a particular angle, since mechanical errors (e.g., antenna and feed horn droop) and gearing and data-device nonlinearities are not completely defined. It is the first part of the solution which evaluates these nonlinearities and a portion of the mechanical deflections; yet, this is not usually a part of the normal radar calibration because of the difficulties involved.

BASIC APPROACH

The major difficulty in such an undertaking is to establish a set of reference points precisely located on the inner surface of a hemisphere centered at the radar and sufficient in number to provide the desired precision of calibration. The stars provide a ready solution to this problem in that their positions are precisely known and they are readily observable over a hemisphere.

In June 1959 the DEP Missile and Surface Radar Division at Moorestown, N. J. was awarded a contract (DA-36-039-SC-78311) by the U. S. Army Signal Research and Development Laboratory, Fort Monmouth, N. J. to study and evaluate the performance of the AN/FPS-16 radar installed there. A part of the study was the calibration of the angle data outputs of the radar with respect to the telescope mounted on the elevation shaft to an absolute accuracy of 10 seconds of arc or better. Other phases of the program were to relate the optical axis of the telescope to the radio-frequency axis of the radar.

The techniques developed were to be suitable for calibrating other instruments. These same techniques, when used in conjunction with radio stars, will also provide a means of directly calibrating the radio-frequency axis of the radar with the angle-data outputs, thus eliminating the intermediary step of calibrating to the optical axis of the telescope.

The calibration of the angle-data output devices, in this instance 17-bit digital encoders, requires that a relationship be developed between the known true angles of reference points and the angles measured by the digital encoders when the points are observed through the telescope. This relationship is directly influenced by the inaccuracies inherent in the encoders and the data-device gearing. Other factors which play an influencing role are optical and mechanical misalignment of the telescope and pedestal axes, and mechanical deflections of the pedestal. While the AN/FPS-16 holds claim to being the most accurate radar made, some errors do exist that limit the benefits of employing data takeoffs with finer granularity than presently used (9.9 seconds of arc).

The calibration technique allows gains to be realized from the use of transducers with finer granularity, achieved by employing a new transducer or by increasing the gear ratio of the present transducer (the latter introduces additional gearing errors). In either instance, the increase in precision will be eclipsed by the inherent inaccuracies, and a calibration is mandatory if the benefits of the finer granularity are to be realized.

To calibrate a radar pedestal capable of observation over a complete hemisphere requires that reference points with known angles be available over a hemisphere. The creation of such a reference system is a formidable problem, to say the least, and a system of natural references like the stars is much more desirable. Fortunately, the positions of the stars have been noted and cataloged since the time when the earth was considered to be flat, and very accurate tabulations are now available.[1,2] Unfortunately, the radar pedestal measures angles in horizontal and vertical planes, while the positions of the stars are defined in a different co-ordinate system. The astronomic coordinates must, therefore, be converted to the azimuth and elevation angles which the radar will measure. This conversion requires a precise knowledge of the time of observation, the location of the point of observation, and the behavior of the stars. An understanding of the language of astronomy also proves to be useful.

THE STAR COORDINATE SYSTEM

For the purpose of location and description, the stars may be considered to be fixed on the inner surface of a *celestial*

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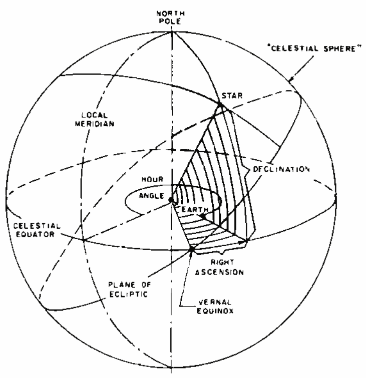

Fig. 1—Celestial coordinate system.

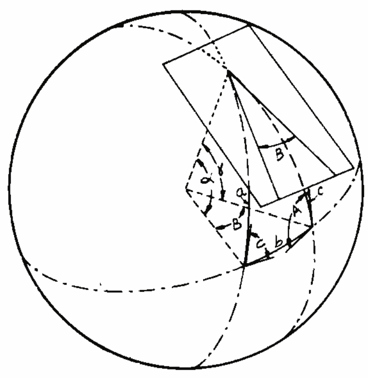

Fig. 2—Spherical angle definitions.

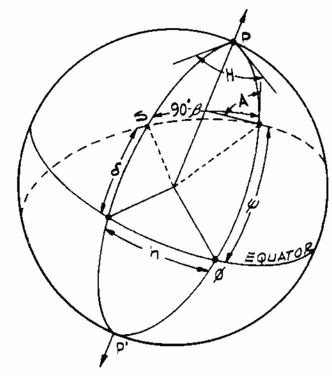

Fig. 3—Celestial angles.

sphere whose axis is coincident with the earth's axis of rotation. The sun, moon, and planets appear to move along the surface of this sphere just as, in reality, they move among the stars in the heavens. A coordinate system is established on this sphere much as is done on earth (Fig. 1). The *celestial poles* are colinear with the earth's poles, and the *celestial equator* is coplanar with the earth's equator. The location of a star on the sphere is defined in much the same manner as a point is defined on earth. The minor circles, or almuncators, of *declination* on the celestial sphere correspond to circles of terrestrial latitude. The great circles on the celestial sphere which correspond to circles of longitude on earth, are termed circles of *right ascension*. The prime meridian of right ascension passes through the *vernal equinox*, the point where the sun traveling northward along its path, the *ecliptic*, crosses the celestial equator on or about June 20th. Right ascension is measured counterclockwise, or in an easterly direction, from this point. An additional coordinate very closely related to right ascension is *hour angle*. The differences between the two are that the zero reference for hour angle is the observer's meridian, as opposed to the meridian passing through the vernal equinox, and that they are measured in opposite directions.

CALCULATING STAR ANGLES

The coordinate system just described is based on an ideal earth located at the center of the sphere and corrections are required to attain the true coordinates of a star. The *parallax* correction, usually negligible, accounts for the earth not truly being at the center of the sphere. The *precession* correction is for the long-term wobble of the earth's axis, and the *nutation* correction is for the monthly wobble created by the moon's gravitational attraction. The coordinates must also be corrected for *aberration*—actually an observational error, but it may be compensated for prior to the observation, since it is unaffected by observational conditions[3].

The astronomer also uses a different system of time in that he measures time in *sidereal* rather than solar units. Sidereal time is based on the apparent motion of the stars, rather than the sun, and provides the relationship between right ascension and hour angle. (One sidereal day consists of 23 hours, 56 minutes and 4.09 seconds of solar time.) It is this time difference that accounts for the seasonal change in the heavens.

Before the observed angles of a star may be calculated, the terrestrial coordinates of the point of observation and the local north direction must be determined. The coordinates should preferably be determined from the stars in the manner prescribed in the many books on surveying and navigation.[1] By using astronomically determined coordinates rather than those obtainable from a map or geodetic survey, corrections for gravity anomaly and the shape of the earth are not required. In this manner, any factors due to gravity anomaly and the shape of the earth will be included in both the determination of the location of the point of observation and the observed position of the stars. The effect of these errors on the end product—the angle calibration—is therefore insignificant. It was found that the astronomic coordinates, including the true north direction, can be determined with a probable error of less than 0.2 second of arc with relative ease if a first-order theodolite is utilized with adequate care. This corresponds to a probable error of approximately 20 feet in defining the location of the radar. Once the coordinates of the site are known, it is possible to calculate the observed angles of a star in any desired coordinate system, azimuth and elevation in this case, from the star's right ascension and declination, and the time of the observation.

Describing the heavens in terms of the celestial sphere is convenient in that it allows the principles of spherical trigonometry to be applied. The cosine formula of spherical trigonometry states:

$$\cos a = \cos b \cos c + \sin b \sin c \cos A$$

(The angles are defined in Fig. 2.) The celestial sphere may be drawn as in Fig. 3 where POP' is the meridian of an observer located at point O as projected on the celestial sphere. The star of interest is at S. Also, δ = declination of the star, h = star's hour angle, ψ = projected latitude of the observed, ϕ = projected longitude of the observer, and β = observed elevation of the star. Solving the triangle $E_1 PE_2$ yields:

$$\cos h = \cos 90° \cos 90° + \sin 90° \cos H$$

$$\cos h = \cos H$$

Solving the triangle SPO yields:

$$\cos (90° - \beta) = \cos (90° - \psi) \cos (90 - \delta) + \sin (90° - \psi) \sin (90 - \delta) \cos H$$

Since $\cos h = \cos H$, then:

$$\beta = \sin^{-1} (\sin \psi \sin \delta + \cos \psi \cos \delta \cos h)$$

And, similarly solving another triangle yields the expression for the observed azimuth angle θ:

$$\theta = \cos^{-1}\left(\frac{\sin \delta}{\cos \rho \cos \psi} - \tan \beta \tan \phi\right)$$

Or, in an alternate form:

$$\theta = \sin^{-1} \frac{\cos \delta \sin h}{\cos \beta}$$

The first equation is best employed for values of θ near $\pi/2$ radians or odd multiples thereof. The second equation is best employed for values of θ near 0 or multiples of π radians. This is because of the steepness of the sine and cosine curves about the respective points.

The values of declination and right ascension for this computation may be obtained from catalogs[1,2]; they must then be corrected for diurnal aberration. Most of the listings of stars include corrections for nutation and annual aberration; parallax may be ignored except in the most precise determinations.

USING STAR ANGLES IN THE CALIBRATION

Now that the angles to a star may be precisely calculated, all that remains is to obtain the angles as defined by the radar's data devices and compare these values with the calculated values. Obtaining these measured angles is not in itself a simple task, since the accuracy of the calibration is directly dependent on the accuracy of these measurements. The U.S. Bureau of Standards' time signal broadcasts on WWV (or WWVH) may be used to satisfy the requirement of accurate time determination.

It was found that the best way to make the measurements is to position the pedestal so that the selected star is visible in the center of the field of view of the telescope and moving towards the reticle, and to note the time when the star is coincident with the cross-hairs in the telescope reticle. A further refinement is to make multiple-exposure photographs through the telescope showing the star both before and after it crosses the appropriate hair-line. The time of making each exposure is noted by connecting the flash synchronizer on the camera in such a way as to make a mark on a recorder that is recording WWV signals. It is then a simple matter of interpolation to precisely determine the instant of coincidence, without relying so heavily on human judgement, by plotting a curve of distance of the star from the hair-line versus time. The relationship of the linear and angular displacements between the star and the hair-line in the multiple exposures need not be determined, since only the time of coincidence is of interest. The measured data is best obtained by selecting a star and taking consecutive readings as the star travels across the sky until a sufficient number of observations have been made in a given angular interval. Another star is then chosen and the process repeated. Both the precision and the accuracy of the calibration are dependent upon the number of observations made.

In addition to the statistical increase in accuracy obtained through numerous readings and the large number of readings required to provide full coverage of a hemisphere, there are other reasons for taking a large quantity of readings. The refraction correction is based on a standard atmosphere which is rarely realized. Numerous readings should therefore be taken even at the same angular positions over a time span of several days to average out the deviations in the atmosphere and thus obtain a good refraction correction. Since the accuracy of the tabulated data on the stars varies for different stars and the accuracy of a specific set of data is not readily determinable, various stars should be employed within any angular interval unless the star being used is known to be accurately defined. Also, stars with high values of declination, those near the pole, are undesirable in that their rate of movement across the sky is low. It is therefore very difficult to precisely define the instant of coincidence of these stars and the telescope reticle.

The observed data must be modified to eliminate the effects of atmospheric refraction and the residual error in leveling the pedestal. If the proper care has been exercised, the difference between the calculated and the corrected observed angles is the error in the pedestal.

CALIBRATION RESULTS ON THE AN/FPS-16

Figs. 4 and 5 show the results of the calibration of the AN/FPS-16 radar at Moorestown. It will be noted that the elevation error (Fig. 4) has the characteristics of a high-frequency sine wave superimposed on the lower-frequency sine wave. The long period error may be attributed to mechanical deflections, the large bull gear, and misalignment of the axes. The shorter period terms are due to the higher-speed gearing and the transducer. Actually, there should be a separate sine wave for each gear mesh, but the granularity and volume of the data could not resolve this detail. The azimuth curve (Fig. 5) shows only a single sine wave. The lack of higher-frequency terms is due to the limited amount of data available which had to encompass four times the elevation angular coverage. As can be seen from the plotted points, there are higher-frequency terms present, although they were not resolved into their respective sine waves.

This specific radar pedestal now, by the use of these curves, has an accuracy compatible with the granularity of the data devices. Should this radar be moved or parts of it be changed the calibration will no longer be valid, and the process must be repeated. It must be remembered that this accuracy is dependent upon correcting the leveling errors and refraction effects.

CONCLUSION

The techniques used in this study may be applied to the calibration of any angle-measuring instrument. The only requirement is that it be possible to mount a telescope on the device to be calibrated. The detailed procedures and step-by-step calculation forms developed for this program, including those required to determine the coordinates of a point on earth, are available for future studies; with only minor modification they may be used for any instrument.

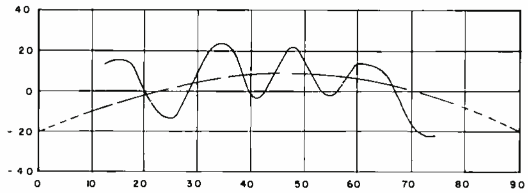

Fig. 4—Elevation error.

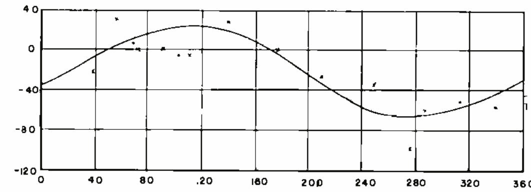

Fig. 5—Azimuth error.

If the stars employed in the calibration procedure emit radio-frequency signals that the radar can receive, the same calibration procedures may be used to calibrate the axis of the radiated beam relative to the optical axis of the telescope. In this instance, a different refraction correction which also involves the moisture content of the air must be employed, along with other propagation corrections.

ACKNOWLEDGEMENTS

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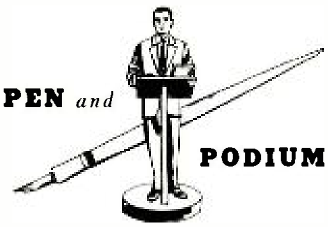

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DATES and DEADLINES

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Mar. 8-9, 1962: Middle Atlantic Conf., American Soc. for Quality Control, Statler Hilton Hotel, Washington, D. C.

Mar. 14-16, 1962: Electric Propulsion, Am. Rocket Soc., Hotel Claremont, Berkeley, Cal. *Prog. Info.:* R. Hohl, ARS, 500 Fifth Ave., New York 36, N. Y.

Mar. 26-29, 1962: American Physical Soc., Baltimore, Md. *Prog. Info.:* K. K. Darrow, 538 W. 120 St., New York 27, N. Y.

Mar. 26-29, 1962: 1962 IRE Intl. Conv., Waldorf Astoria and N. Y. Coliseum, NYC. *Prog. Info.:* Dr. D. B. Sinclair, IRE Inc., 1 E. 79 St., New York 21, N. Y.

Mar. 28-29, 1962: Engineering Aspects of Magnetohydrodynamics Symp., IRE-PGNS, U. of Rochester, AIEE, IAS; Univ. of Rochester, Rochester, N. Y. *Prog. Info.:* G. W. Sutton, MIT, Rm. 3-254, Cambridge 39, Mass.

Apr. 10-12, 1962: 2nd Symp. on the Plasma Sheath—Its Effect upon Re-Entry Communication and Detection, Air Force Cambridge Research Labs; New England Mutual Hall, Boston, Mass. *Registration Forms:* Miss A. Cahill, Symp. Secy., Air Force Cambridge Research Labs., L. G. Hanscom Field, Bedford, Mass.

Apr. 11-13, 1962: SWIRECo (Southwest IRE Conf. & Electronics Show), Rice Hotel, Houston, Tex. *Prog. Info.:* Prof. M. Graham, Rice Univ., Computer Project, Houston 1, Tex.

Apr. 23-26, 1962: American Physical Soc., Washington, D. C. *Prog. Info.:* K. K. Darrow, 538 W. 120 St., New York 27, N. Y.

Apr. 24-26, 1962: Mathematical Theory of Automata Symp., IRE-PGEC, -PGIT, AIEE, PIB, et al; Eng. Soc. Bldg. Aud., UN Plaza, New York, N. Y. *Prog. Info.:* Symp. Committee, PIB, 55 Johnson St., Brooklyn 1, N. Y.

Apr. 29-May 4, 1962: 91st SMPTE Conv., Ambassador Hotel, Los Angeles, Calif. *Prog. Inf.:* E. P. Ancona, Jr., 3170 Lake Hollywood Dr., Hollywood 28, Calif.

May, 1962: 21st Natl. Mtg. of Operations Research Soc. of America, Washington, D. C.

May 1-3, 1962: Spring Joint Computer Conf., IRE-PGEC, AIEE, ACM; Fairmont Hotel, San Francisco, Calif. *Prog. Info.:* R. I. Tanaka, Lockheed Missile & Space Div., Dept. 58-51, Palo Alto, Calif.

May 3-4, 1962: Intl. Congress on Human Factors in Electronics, IRE-PGHFE; Lafayette Hotel, Long Beach, Calif. *Prog. Info.:* J. W. Senders, Minneapolis-Honeywell Regulator Co., 2600 Ridgeway Rd., Minneapolis 40, Minn.

May 3-4, 1962: Theoretical & Applied Mechanics, Oak Ridge Natl. Lab., Gatlinburg, Tenn. *Prog. Info.:* R. L. Maxwell, U. of Tenn., Knoxville, Tenn.

May 3-5, 1962: University Computing Ctrs., Intl. Conf., Mexico City. *For Info.:* Centro Electronico de Calculo, Universidad Nacional Autonoma de Mexico, Mexico, D. F., Mexico.

May 6-10, 1962: Optical Masers, Electrochemical Soc., Statler-Hilton Hotel, Los Angeles, Cal. *For Info.:* J. L. Birman, Gen. Tel. & Electronics Labs. Inc., 208-20 Willets Pt. Blvd., Bayside 60, N. Y.

May 8-10, 1962: Electronic Components Conf., IRE-PGCP, AIEE, EIA, WEMA, ASQC, SNT; Marriott Twin Bridges Hotel, Washington, D. C. *Prog Info.:* H. A. Stone, Bell Telephone Labs., Murray Hill, N. J.

May 14-16, 1962: NAECON (Natl. Aerospace Electronics Conf.), IRE-PGANE (Dayton Sect.); Biltmore Hotel, Dayton, O. *Prog. Info.:* G. A. Langston, 4725 Rean Meadow Dr., Dayton, O.

May 14-16, 1962: Thermionic Power Conversion Symp., IRE-PGED, DOD, AIEE, APS, AIRS, ANS; Antlers Hotel, Colorado Springs, Colo. *For Info.:* V. C. Wilson, GE, Schenectady, N. Y.

May 21-23, 1962: Natl. Symp. Aerospace Instrumentation, ISA; Marriott Twin Bridges Motel, Washington, D. C. *For Info.:* C. Creveling, Goddard Space Flight Ctr., Greenbelt, Md.

May 22-24, 1962: Natl. Microwave Theory & Techniques Symp., IRE-PGMTT, Boulder, Colorado. *Prog. Info.:* R. W. Beatty, NBS, Boulder, Colo.

May 23-25, 1962: Natl. Telemetering Conf., IRE-PGSET, AIEE, IAS, ARS, ISA; Sheraton Park Hotel, Wash., D. C. *Prog. Info.:* D. G. Mazur, Code 620, Goddard Space Flight Center, Greenbelt, Md.

May 23-25, 1962: 16th Natl. ASQC Conv., Netherlands Hilton Hotel, Cincinnati, O. *Prog. Info.:* M. J. O'Callaghan, Schick Inc., Lancaster, Pa.

May 23-26, 1962: Acoustical Soc. of America, New York, N. Y. *Prog. Info.:* W. P. Mason, Bell Telephone Labs, Murray Hill, N. J.

May 24-26, 1962: IRE 7th Region Conf. on Space Communications, Olympic Hotel, Seattle, Wash. *Prog. Info.:* T. G. Dalby, 3220-99th N. E., Bellevue, Washington.

Calls for Papers

June 19-21, 1962: American Physical Soc., Evanston, Ill. *DEADLINE:* Abstracts, **4/13/62** to K. K. Darrow, American Physical Soc., Columbia University, New York 27, N. Y.

July 16-18, 1962: Lunar Missions, Am. Rocket Soc., Pick-Carter & Statler-Hilton Hotels, Cleveland, O. *DEADLINE:* Abstracts, **3/1/62** to B. Chifos, ARS, 500 Fifth Ave., New York 36, N. Y.

Aug. 14-16, 1962: Intl. Conf. on Precision Electromagnetic Measurements, IRE-PGI, NBS, AIEE; NBS Labs, Boulder, Colo. *DEADLINE:* 500-1000 wd. summaries, **3/15/62** to Dr. G. Birnbaum, Hughes Res. Labs, Malibu, Calif.

Aug. 15-17, 1962: Nuclear Propulsion (spons'd by ARS, ANS, IAS), Naval Post-Graduate School, Monterey, Calif. *DEADLINE:* Abstracts, **3/19/62** to B. Chifos, ARS, 500 Fifth Ave., New York 36, N. Y.

Aug. 21-24, 1962: WESCON (Western Electronics Show and Conf.), IRE, WEMA; Memorial Sports Arena & Statler-Hilton Hotel, Los Angeles, Calif. *DEADLINE:* 100-200 wd. abstract and 500-1000 wd. summary; indicate in which tech. field paper falls (use IRE prof. group classification), **4/15/62**. To: Wescon Business Office, % Tech. Prog. Chairman, 1435 S. La Cienega Blvd., Los Angeles 35, Calif.

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

Aug. 29-Sept. 5, 1962: 5th Intl. Congress for Electron Microscopy, Electron Microscope Soc. of America et al; Sheraton Hotel, Phila., Pa. *DEADLINE:* 1000-wd. abstract, **5/15/62**; must be submitted on spec. forms obtainable from Electron Microscope Soc. of America, 7701 Burholme Ave., Phila. 11, Pa.

Oct. 1-3, 1962: 8th Natl. Communications Symp., IRE-PGCS, Rome-Utica Sect.; Hotel Utica & Municipal Aud., Utica, N. Y. *DEADLINE:* Approx. **6/1/62**.

Oct. 2-4, 1962: Natl. Symp. on Space Elec. & Telemetry, IRE-PGSET; Fontainebleau Hotel, Miami Beach, Fla. *DEADLINE:* Titles, **1/19/62**; abstracts, **3/1/62**; papers **4/12/62** (limited to 30-45 min.). To: Otto A. Hoberg, George C. Marshall Space Flt. Center, NASA Redstone Arsenal, Ala.

Oct. 8-10, 1962: Natl. Electronics Conf., IRE, AIEE, et al; Exposition Hall, Chicago, Ill. *DEADLINE:* Approx. **5/1/62**. To Natl. Elec. Conf., 228 N. LaSalle, Chicago, Ill.

Oct. 22-24, 1962: ECCANE (East Coast Conf. on Aerospace & Navigational Elec.), IRE-PGANE; Baltimore Sect.; Baltimore, Md. *DEADLINE:* Approx. **7/5/62**.

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

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

Nov. 12-15, 1962: 8th Ann. Conf. on Magnetism & Magnetic Materials, IRE-PGMTT, AIEE, AIP; Penn-Sheraton, Pittsburgh, Pa. *DEADLINE:* Approx. **8/18/62**.

Nov. 13-15, 1962: NEREM (Northeast Res. & Engrg. Mtg.), IRE-Region 1; Boston, Mass. *DEADLINE:* Approx. **6/15/62** to NEREM-IRE Boston Off., 313 Washington St., Newton.

Dec. 4-5, 1962: EJCC (Eastern Joint Computer Conf.), IRE-PGEC, AFIPS; Bellevue-Stratford Hotel, Phila., Pa. *DEADLINE:* Approx. **6/20/62**.

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

Sept., 1963: 2nd Congress, Intl. Fed. of Automatic Control, IRE-PGAC, IFAC, AACC; Basle, Switzerland. *DEADLINE:* **5/1/62** to Prof. Irving Lefkowitz, Case Inst. of Tech., 10900 Euclid Ave., Cleveland, O.

Be sure DEADLINES are met — consult your Technical Publications Administrator for lead time needed to obtain required RCA approvals.

Laminates, New Approach to Ceramic-Metal Manufacture: Part II. Hermetic Ceramic Package for Quartz Crystal Oscillators—H. W. Stetson and W. H. Liederbach: American Ceramic Society Electronics Division West Coast Fall Meeting, Oct. 25, 1961

Design and Application of Silicon Unipolar Transistors Made by Diffusion Techniques—W. Bosenberg, J. Olmstead, and K. Wybrands: IRE Electron Devices Meeting, Washington, D. C., Oct. 26-28, 1961

High-Cutoff-Frequency Gallium-Arsenide Diffused-Junction Varactor Diodes—M. Lamorte, A. Widmer and L. Gibbons: IRE Electron Devices Meeting, Washington, D. C., Oct. 26-28, 1961

High-Efficiency Gallium-Arsenide Solar Cells M. Lamorte, A. Gobat, G. McIver and D. Bortfeld: IRE Electron Devices Meeting, Washington, D. C., Oct. 26-28, 1961

Whither The Tunnel Diode—E. O. Johnson: IRE Electron Devices Meeting, Washington, D. C., Oct. 27, 1961

Consideration of Automobile AM/FM Receiver Design—R. A. Santilli and H. Thanos: IRE/EIA Radio Fall Meeting, Syracuse, N. Y., Oct. 31, 1961

Investigation of the Electrochemical Characteristics of Organic Compounds—VIII. Hydrazine and Hydroxylamine Compounds R. Glicksman: *Journal of Electrochemical Society*, Oct., 1961

The State of The Art for Gallium Arsenide Devices—J. Hilibrand: IRE-PGED Chapter Meeting, Boston, Mass., November 9, and Carnegie Institute of Technology, Nov. 15, 1961

A Method for the Deposition of SiO_2 at Low Temperatures—J. Klerer: *Journal of Applied Physics* (Letter), Nov., 1961

An All-Transistor Six-Meter Receiver—S. W. Daskam and A. Troiano: QST, Nov., 1961

Transistors As RF Power Amplifiers—J. B. Fisher: *RCA Ham Tips*, Dec., 1961

PRINCETON LABORATORIES

Kilomegacycle Computer Circuits and Systems—B. J. Lechner: PGMIT-IRE Meeting, Washington, D. C., Dec. 14, 1961

Mass Spectrographic Analysis of Solids—J. R. Woolston: Baltimore-Washington Section Meeting of Society for Applied Spectroscopy, Catonsville, Md., Dec. 5, 1961

Thermal Conductivity in GE-SI Alloys at High Temperature—C. D. Cody, B. Abeles, D. S. Beers: Chicago Meeting of the American Physical Society, Nov. 25, 1961

Prospects for Utilization of Advanced Computer Techniques in Organic Chemistry—S. Amarel: Organic Chemistry Seminar, Princeton University, Princeton, N. J., Dec. 6, 1961

Some Physical Properties of Deposited Nb_3Sn—J. J. Hanak, G. D. Code: International Conference on High Magnetic Fields, Boston, Mass., Nov. 4, 1961 and *Proceedings of Conference*

Sensory Aids: Implants and Endosondes—V. K. Zworykin: NEREM Meeting, Boston, Mass., Nov. 16, 1961 and *NEREM Record*

After Treatments of CdS Single Crystals Grown By The Chemical Transport Methods—J. A. Beun, R. Nitsche, H. V. Bolsterli: Meeting on Physics and Chemistry of Phosphors, East Berlin, Germany, Nov. 27, 1961

Permalloy-Sheet Transfluxor-Array Memory—G. R. Briggs, J. W. Tuska: Conference on Magnetism, Phoenix, Arizona, Nov. 12, 1961

Medical Electronics Comes of Age—H. L. Cooke: Detroit and Tri-County League for Nursing, Detroit, Michigan, Nov. 30, 1961

The Electronic Synthesis of Sound—H. L. Cooke: Washington Society of Engineers, Washington, D. C., Dec. 6, 1961 and Seminar, Nassau Academy of Medicine, Garden City, L. I., Nov. 29, 1961

The World of Electronics—H. L. Cooke: Princeton University 25-Year Club, Princeton, N. J., Dec. 21, 1961

Hydromagnetic Instabilities in Electron-Hole Plasmas—M. Glicksman, Plasma Physics Division of the American Physical Society, Colorado Springs, Colorado, Nov. 15, 1961

Diffusion in Compound Semiconductors—B. Goldstein: International Business Machine Research Laboratories, Yorktown Heights, N. Y., Nov. 29, 1961

Hexagonal Ferrites for Potential High-Frequency Applications—I. Grodon: Graduate Seminar Ceramics Department, Rutgers University, New Brunswick, N. J., Nov. 18, 1961

Metallurgy of Semiconductors—F. D. Rosi: Long Island Chapter American Society for Metals, Brookhaven National Laboratories, Upton, L. I., N. Y., Nov. 30, 1961

High Density Cesium Plasma Discharge—G. A. Swartz and L. S. Napoli: Plasma Physics Division of the American Physical Society, Colorado Springs, Colorado, Nov. 16, 1961

Spectra of Copper and Nickel Impurities in Zinc Oxide—H. A. Weakliem: National Bureau of Standards Colloquim, Washington, D. C., Dec. 20, 1961

High Temperature Susceptibility of Garnets: Exchange Interactions in YIG and LuIG—P. J. Wojtowicz: Conference on Magnetism, Phoenix, Arizona, Nov. 15, 1961

Threshold Logic and the General Synthesis Problem—R. O. Winder: Colloquim of the Harvard Computation Laboratory, Cambridge, Mass., Nov. 28, 1961

New Display Components and Techniques H. O. Hook: University of Penna., IRE Winter Session, Lecture Series I, Philadelphia, Pa., Nov. 13, 1961; and Brooklyn Polytechnic Institute, Graduate Seminar, Brooklyn, N.Y., Nov. 27, 1961

High Temperature Methods and Their Application to Single Crystal Growth of Inorganic Materials—M. Kestigan: Seminar, University of Massachusetts, Amherst, Mass., Nov. 7, 1961

Ordering and Clustering in Alloys of the Zinc Blende Structure—E. E. Loebner: Colloquim, Materials Research Laboratory of the Univ. of Pa., Philadelphia, Pa., Nov. 27, 1961

Thermodynamics of Transistion Metal Oxide Systems—A. Miller: Ceramics Department Seminar, Rutgers University, New Brunswick, N. J., Dec. 2, 1961

A Print Out System for the Automatic Recording of the Spectral Analysis of Spokan Syllables—H. F. Olson and H. Belar: Acoustical Society of America, Cincinnati, Ohio, Nov. 9, 1961

Role of Space Charge Currents in Photoconductivity—A. Rose: Research Institute of Advanced Study, Baltimore, Md., Dec. 6, 1961 and Institute of Optics, University of Rochester, Rochester, N. Y., Dec. 13, 1961

A Solution for Certain Types of Partitioning Problems—M. E. Greenblatt: *The Mathematics Teacher*, Nov., 1961

Quenching Effects and Negative Photoconductivity in Amophous Selenium—J. Dresner: *Journal of Chemical Physics*, Nov., 1961

Phonetic Typewriter III H. F. Olson and H. Belar: *Journal of the Acoustical Society*, Nov., 1961

The Enhanced-Scan Post Acceleration Kinescope—H. B. Law, L. Dayne and E. G. Ramberg: *RCA Review*, Dec., 1961

The Effect of a D-C Magnetic Field on the UHF Permeability and Losses of some Hexagonal Magnetic Compounds—R. L. Harvey, I. Gordon, and R. A. Braden: *RCA Review*, Dec., 1961

High-Speed Logic Circuits Using Common-Base Transistors and Tunnel Diodes—J. J. Amodei, W. F. Kosonocky: *RCA Review*, Dec., 1961

An Electrical Analog for Electroluminescent Layers—S. M. Thomsen: *RCA Review*, Dec., 1961

Transfluxor Frequency Memory A. G. Samusenko: *RCA Review*, Dec., 1961

A Dynamic-Capacitor Electrometer Suitable for Measuring Electro-Photographic Recording Media E. C. Giamo: *RCA Review*, Dec., 1961

Analysis of Double-Stream Interactions in the Presence of a Finite Axial Magnetic Field—B. Vural: *RCA Review*, Dec., 1961

The Non-Directional Aspect of Stereo C. J. Hirsch: *IRE Transactions on Broadcast and Television Receivers*, Nov., 1961

Degenerate Germanium II. Band Gap and Carrier Recombination—H. S. Sommers, Jr.: *Physical Review*, Nov., 1961

DEFENSE ELECTRONIC PRODUCTS

A Single Tunnel Diode Full Binary Adder B. Rabinovici and C. A. Renton: *IRE Proceedings*, July, 1961

The Future of Pulsed Radar for Missile and Space Range Instrumentation—D. K. Barton: *IRE Transactions of the Professional Group on Military Electronics*, Oct., 1961

Stability Criteria for a Tunnel Diode Amplifier—H. Boyet and D. Fleri: *IRE Proceedings*, Dec., 1961

Predicting Spurious Transmitter Signals—J. G. Arnold: *Electronics*, April 21, 1961

Amplitude Control with No D-C Variation in D-C Coupled Circuits I. Bayer: *Electronic Design*

Optimum H-F Prediction Bumiller, Krevsky, Greenberg and Curtis: Fall URSI Meeting, IRE, Oct., 1961

Error Rate Performance of Diphase Modulation over Narrow Band Telephone Lines—D. Douglas: *Masters Thesis*, Polytechnic Institute, Brooklyn, N. Y.

Time Division Closed Loop Communications—S. Flateau and J. Massari: *Masters Thesis*, University of Penna.

A Ground to Air Traffic Control Teletype: System Management of Equipment Design E. M. Alexander: *MSEE Thesis*, University of Penna.

Transient Analysis of a Transistorized Logic Gate—S. R. Gygi: *MSEE Thesis*, University of Penna.

Automatic Checkout for Aerospace Vehicles—R. J. Allen: Lecture at U.C.L.A., Oct. 18, 1961

The Logic Design of the FC-4100 Data Processing System H. S. Zieper: Eastern Joint Computer Conference, Washington, D. C., Dec. 13, 1961

Shock and Vibration of Apache Tailer—S. A. Lever: 30th Symposium on Shock, Vibration and Associated Environments in Detroit, Michigan, Oct. 12, 1961

Computer Memory Devices—R. E. Wilson: IRE Student Branch, California State Polytechnic College, San Luis Obispo, California, Nov. 2, 1961

Position and Velocity Differences Between Satelites on Adjacent Orbits—D. Winfield: *Proceedings, Eighth Annual East Coast Conference on Aerospace and Navigational Electronics*, Oct. 23, 1961

An Investigation of Sequential Decoding—D. Jones and J. Pennypacker, W. Wadden: *RCA Review*, Sept. 1961.

RCA VICTOR RECORD DIVISION

The Education of an Electroplater—Dr. A. M. Max: Indianapolis Branch of the American Electroplaters Society, Jan. 12, 1962

Trends in Packaging Costs—H. W. Hittle: *Consumer Packaging*, Dec., 1961

ELECTRONIC DATA PROCESSING

Four Advanced Computers—Key to Air Force Digital Data Communication System—R. J. Segal and H. P. Guerber: Eastern Joint Computer Conference, Washington, D. C., Dec. 14, 1961

RESEARCH AND ENGINEERING

Comments on an Electronic Highway; Some Specific Techniques and Suggestions for a Test Roadway—Dr. G. H. Brown: 41st Annual Meeting, Highway Research Board, Washington, D. C., Jan. 8-12, 1962

Better Writing for Engineers—W. O. Hadlock: Philadelphia Section, Standards Engineers Society, Engineers Club, Philadelphia, Pa., Jan. 22, 1962

The Ballistic Missile Early Warning System—G. W. K. King: West Philadelphia Radio Club, February 13, 1962 and Tom Carlyle Club, Springfield, Pa., Feb. 21, 1962

BROADCAST AND COMMUNICATIONS PRODUCTS DIVISION

New 5 KW VHF Television Transmitter Type TT-5BH—H. E. Small: *Broadcast News*, Dec., 1961

"Treasure From Trivia" Peculiar, and Often Overlooked Genius of Industrial Standardization K. M. Stoll: Standards Engineers Society, Philadelphia Section, Oct. 23, 1961

The Distributor's Contribution to Standardization—D. C. Bowen: Standards Engineers Society, Philadelphia Section, Nov. 27, 1961

New Developments in FM Stereo Techniques—A. H. Bott: IRE Meeting, Professional Group of Broadcasters in Dayton, Ohio, Dec. 6, 1961

Patents Granted

TO RCA ENGINEERS

As Reported By RCA Domestic Patents, Princeton

ELECTRON TUBE DIVISION

3,006,059—High Efficiency Automatic Assembling Apparatus, Oct. 31, 1961; H. Hermanny

3,006,069—Method of Sealing a Metal Member to a Ceramic Member, Oct. 31, 1961; J. L. Rhoads and M. Berg

3,009,510—Apparatus and Method for Corrugating Sheet Metal Strip, Nov. 21, 1961; A. M. Meshulam

3,007,760—Method of Making Electron Tubes, Nov. 7, 1961; H. V. Knauf, Jr. and G. M. Rose, Jr.

3,007,604—Electron Tube Component Dispensing Apparatus, Nov. 7, 1961; J. J. Lukawich

3,011,090—Plural Beam Tube, Nov. 28, 1961; H. C. Moodey

DEFENSE ELECTRONIC PRODUCTS

3,008,054—Signal-Responsive Circuit, Nov. 7, 1961; J. Saltz

3,007,093—Variable Capacitor, Oct. 31, 1961; L. E. Potter and E. A. Bennett

3,016,211—Automatic Flywheel Driving Mechanism, Jan. 9, 1962; J. J. Hoehn and M. E. Ecker

3,016,210—Automatic Film Transport Reversing Mechanism, Jan. 9, 1962; J. A. Liggett and M. E. Ecker

3,016,422—Reversible Code Converter, Jan. 9, 1962; F. F. Lee

ELECTRONIC DATA PROCESSING

3,008,129—Memory Systems, Nov. 7, 1961; A. Katz

3,009,145—Direct-View Electrical Storage Tube and Erasing System Therefor, Nov. 14, 1961; C. E. Reeder and H. M. Scott

3,007,137—Information Handling System, Oct. 31, 1961; J. F. Page and A. M. Spielberg

3,012,207—Controlled Phase Shift Oscillator, Dec. 5, 1961; M. Silverberg

3,014,656—Counting Circuit, Dec. 26, 1961; J. A. O'Brien

3,016,194—Digital Computing System, Jan. 9, 1962; D. L. Nettleton and L. S. Bensky

SEMICONDUCTOR AND MATERIALS DIVISION

3,006,791—Semiconductor Devices, Oct. 31, 1961; W. M. Webster, Jr.

3,009,880—Method for Preparing Nickel-Zinc Ferrites, Nov. 21, 1961; H. Lessoff

3,014,620—Fluid Dispensing Device, Dec. 26, 1961; A. M. Moore

3,017,615—Matrix Frame, Jan. 16, 1962; L. B. Smith & James D. Childress

RCA VICTOR HOME INSTRUMENTS DIVISION

3,017,099—Parallel Binary Adder, Jan. 16, 1962; G. W. Booth

3,017,504—Cabinet Structure for Small Radio Receivers and the Like, Jan. 16, 1962; R. F. Eaton

3,007,046—Transistor Radio Receivers, Oct. 31, 1961; J. B. Schultz

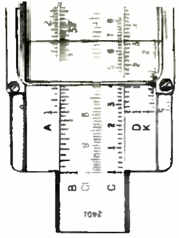
3,009,151—Stereophonic Radio Balance and Tuning Indicator System, Nov. 14, 1961; J. R. Shoaf, II

3,007,999—Phase Shifting Circuit Arrangements, Nov. 7, 1961; G. E. Kelly

3,015,069—Oscillating In-Phase Detectors, Dec. 26, 1961; R. W. Sonnenfeldt

RCA COMMUNICATIONS, INC.

3,017,461—Communication System, Jan. 16, 1962; T. H. Mitchell, J. S. Harris and D. Zekaria

Engineering  NEWS *and* HIGHLIGHTS

TEN RCA MEN AWARDED SARNOFF FELLOWSHIPS

David Sarnoff Fellowships have been awarded to ten RCA men for graduate studies for the 1962-63 academic year. The grants, announced by **Dr. Irving Wolff,** Chairman, RCA Education Committee, are worth up to $6000 each, and include full tuition and fees, book allowance, a stipend of $2400 to $4000 depending on marital status, and $1000 as an unrestricted gift to the university. Although the grants are for one year, each *Fellow* is eligible for reappointment; the first two of the ten *Fellows* below are reappointments for the second year:

W. R. Atkins, 27, Research Associate, RCA Victor Ltd., Montreal, Canada, for a PhD in EE, Imperial College, University of London, London, England.

J. A. Adolphson, 29, Production Engineer, DEP-ACC, Camden, for an MBA in Industrial Management, University of Pennsylvania.

J. W. Coleman, 33, Engineering, Broadcast, Camden, for a PhD in Physics, University of Pennsylvania.

F. P. Heiman, 23, Member Technical Staff, RCA Labs, Princeton, for a PhD in EE, Princeton University.

N. W. Hill, 36, Data Reduction Analyst, RCA Service Co., Cocoa Beach Fla., for a PhD in Applied Mathematics at either Princeton or Brown University.

J. Klapper, 31, Sr. Member, Technical Staff, DEP-SurfCom Systems Labs., New York, for a PhD in EE, Brooklyn Polytechnic Institute.

J. J. Mascony, 32, Engineering, ETD, Lancaster, for a PhD in Chemistry, University of Pennsylvania.

H. E. Davis, 26, Supervisor, General Accounting, NBC, Burbank, Calif., for an MBA in Financial Management, Columbia University.

L. J. Wilson, 27, Construction Engineer, RCA Communications, Inc., New York, for an MS in Industrial Management Engineering, Stevens Institute of Technology.

R. L. Pisor, 23, Sales Store Clerk, NBC, New York, for an MA in Journalism, Columbia University.

HOME INSTRUMENT SALES NET 11-YEAR RECORD, SPARKED BY COLOR TV

January 1962 was the biggest month in sales volume in 11 years for RCA Victor home instruments, sparked by the best single month in color TV's 7-year history. The total sales volume was surpassed for a January only in 1951—at the height of the early consumer demand for black-and-white TV receivers.

Other significant facts are: Color TV orders from distributors for February 1962 exceeded RCA production capacity for the month. January's total home instrument sales volume was 85 percent better than January 1961, and 14 percent ahead of January, 1955—the biggest boom year in black-and-white TV. Color television was ahead of the previous best month—September 1961—by 15 percent. Black-and-white TV achieved a dollar volume second only to the Januarys of 1951 and 1955.

Radios jumped 78 percent in dollar volume and 121 percent in units over last January and the best January since 1951. *Victrola* phonographs recorded best January sales mark since 1952, nearly triple that of the same month last year in dollar volume and 373 percent ahead in units. Tape recorders registered the best single month in RCA history.

RCA PACKAGING EXPERTS COP HONORS AT SYMPOSIUM

The following RCA Packaging personnel received honors in the 1961 National Packaging & Handling Competition, sponsored by the Society of Packaging & Handling Engineers in conjunction with the 7th Annual Eastern Packaging Handling Show, Baltimore, Maryland, 14th & 15th November 1961: *1st Prize, Class 7 "Military"*: **R. E. Hersey,** DEP-(M&SR), Moorestown, N.J.; *2nd Prize, Class 5 "General"*: **G. G. Zappasodi,** BCP, Camden, N.J.; *3rd Prize, Class 1 "Corrugated Fiberboard Products"*: **R. G. Ridley,** DEP-(ACC), Burlington, Mass.; and *Honorable Mention, Class 5 "General"*: **T. W. Kisor,** SC&M, Somerville, N.J.

HIGH-SCHOOL STUDENTS BEGIN ELECTRONICS COURSE AT RCA MOORESTOWN

A group of twenty outstanding students from Moorestown secondary schools started a ten-week evening course in *Fundamentals of Electronics* on January 31, 1962. Seniors from Moorestown Friends School selected for outstanding ability and interest in science will attend these Wednesday evening lectures and Saturday morning laboratory classes. The course is being sponsored by the RCA Moorestown Plant and taught by RCA engineers for the sixth successive year. While studying electronics theory each student will assemble a radio kit and test it during the laboratory sessions.—*T. G. Greene*

SHIPMENT OF MM-600-6 MICROWAVE EQUIPMENT BEGINS FOR 5,300-MILE TRANSCONTINENTAL SYSTEM

First units of RCA's new high-capacity MM-600-6 microwave equipment are being shipped to installation sites in Western Union's 5,300-mile transcontinental communications system. Produced at Camden, the broadband equipment will provide the new communications complex with 600 voice channels between Los Angeles and Boston and intermediate cities. MM-600-6 (600 channels at 6,000 Mc), will be installed in 236 relay stations. [*Editor's Note:* See Elvidge, et al., this issue, for description of an MM-600 system in Canada.]

DR. MORTON RECEIVES MAJOR IRE AWARD

Dr. George A. Morton, Director of the Electron Tube Division's Conversion Devices Laboratory at Princeton, has been named to receive the *1962 Prize Award by Vladimir K. Zworykin,* which is awarded to a member of the IRE for important technical contributions to television. The official citation is *"for his contribution to electronic television through the development of camera and imaging tubes."*

Dr. Morton received his B.S. in E.E., his M.S. in E.E., and his Ph.D. in Physics from the Massachusetts Institute of Technology. From 1933 to 1941 he was a research engineer at the RCA Manufacturing Company in Camden, and from 1942 to 1946 he was a member of the Technical Staff of RCA Laboratories in Princeton. In 1946, on leave from RCA, he was employed as a nuclear physicist at the U.S. Atomic Energy Commission in Oak Ridge. In 1947 Dr. Morton returned to RCA Laboratories as Associate Director of the Physical and Chemical Research Laboratory. During World War II and after, he served as a member of the National Defense Research Committee, AAF Scientific Advisory Board and the Research Defense Board. He is a fellow of the IRE and American Physical Society, and a member of Sigma Xi, American Association for the Advancement of Science and the AIEE.

Dr. G. A. Morton

BECKHART HONORED BY ASQC

At the Eighth National Symposium on Reliability and Quality Control held in Washington, D.C. on January 9, 10, and 11, **G. H. Beckhart** was awarded the *1961-62 ASQC Electronics Division Award.* Mr. Beckhart is Mgr., Engineering Product Assurance for the Missile and Surface Radar Division of RCA in Moorestown, New Jersey. The citation for outstanding service to the society mentioned his many contributions.—*T. G. Greene*

. . . NEW FEATURE PLANNED FOR THE RCA ENGINEER

Beginning in the June-July 1962 issue, the RCA ENGINEER will carry a new feature, entitled *Engineering and Research Notes.* Two to four pages of each issue will be devoted to this feature, which will consist of brief technical papers, 300 to 900 words in length—a length that will allow two to three *Notes* per page. Each *Note* will be by-lined, and they are intended to cover the technical material of interest that may not be appropriate for a full-length article. Examples include a unique engineering technique, a new development that can be described meaningfully in brief, an interesting method of solving an engineering problem, a design method that saves time and money, etc. Contact your Editorial Representative or the Assistant Editor for information on deadlines and approvals if you have material in mind.—*E. R. Jennings, Ass't. Editor.*

ENGINEERS IN NEW POSTS

In the Electron Tube Division, Industrial Tube Products Dept., **C. C. Simeral, Jr.,** Mgr., Microwave Tube Operations, announces his staff as: **W. E. Breen,** Mgr., Pencil Tube and Parts Manufacturing; **J. W. Caffry,** Mgr., Microwave Accounting; **H. L. Eberly,** Mgr., Special Products Manufacturing and Methods Development; **W. G. Hartzell,** Mgr., Microwave Operations Planning and Controls; **H. K. Jenny,** Mgr., Microwave Engineering; **H. M. Learner,** Mgr., Traveling Wave Tube and Magnetron Manufacturing; **A. F. Pheasant,** Mgr., Microwave Materials; **A. Rau,** Mgr., Plant Services and Equipment Construction; and **J. F. Kucera,** Mgr., Microwave Quality Control.

In Microwave Engineering, under H. K. Jenny, **M. Nowogrodski,** Mgr., Product and Equipment Engineering, Microwave Engineering, announces his staff as: **A. J. Bianculli,** Mgr., Microwave Equipment Design and Tube Development Laboratories; **C. L. Cuccia,** Mgr., West Coast Microwave Engineering Laboratory; **E. J. Homor,** Mgr., Microwave Engineering Administration and Data Systems Development; **R. G. Talpey,** Mgr., Magnetron and Pencil Tube Design and Applications; and **H. J. Wolkstein,** Mgr., Traveling Wave Tube Design and Applications.

Also in the ETD Industrial Tube Products Dept., **D. W. Epstein,** Mgr., Conversion Tube Operations, announces his staff as: **C. W. Bizal,** Mgr., Conversion Tube Development Shop; **R. W. Engstrom,** Mgr., Photo and Image Tube Engineering; **W. G. Fahnestock,** Mgr., Operations Planning and Controls, Conversion Tube; **J. K. Johnson,** Mgr., Photo Cell Engineering and Production, Mountaintop; **J. A. Molzahn,** Mgr., Quality Control, Conversion Tube Operations; **G. A. Morton,** Director, Conversion Devices Laboratory, Princeton; **M. Petrisek,** Mgr., Camera and Display Tube Engineering; **R. C. Pontz,** Mgr., Photo and Image Tube Manufacturing; **W. E. Rohland,** Mgr., Camera and Display Tube Manufacturing; and **F. S. Veith,** Staff Engineer.

In the RCA Service Co., **H. Metz,** Division Vice President, RCA Educational Services, has named **J. W. Wentworth** as Mgr., Educational Advisory Services.

In the RCA Victor Record Division, **N. Racusin,** Division Vice President and Operations Manager, has named **A. L. McClay** to the newly established position of Mgr., Manufacturing and Engineering Dept. Mr. McClay's staff in this new Department is: **L. M. Goebel,** Plant Mgr., Rockaway Record Plant; **R. A. Lynn,** Administrator, Quality; **E. D. O'Mahony,** Plant Mgr., Indianapolis Magnetic Tape Plant; **R. O. Price,** Plant Mgr., Indianapolis Record Plant; **A. A. Pulley,** Administrator, Audio Engineering Red Seal Recordings; **D. L. Richter,** Mgr., Recordings; **H. E. Roys,** Chief Engineer, Engineering; **H. H. Sheppard,** Plant Mgr., Hollywood Record Plant; and **A. Stevens,** General Plant Engineer.

In the Broadcast and Communications Products Division, **V. E. Trouant,** Chief Engineer, announces his staff as: **F. C. Blancha,** Coordinator, Mechanical Design; **D. C. Bowen,** Administrator, Standards Engineering; **R. H. Edmondson,** Administrator, Automation Program Coordination; **A. E. Garrod,** Mgr., Drafting; **W. R. Johnson,** Mgr., Engineering Services; **H. N. Kozanowski,** Mgr., TV Product Advanced Development; **D. R. Pratt,** Mgr., Technical Publications; and **G. G. Zappasodi,** Mgr., Packing Design.

Also in Broadcast, **A. F. Inglis,** Mgr., CCTV, Scientific Instruments, and Recording Products Dept., announces that **A. H. Lind** is Mgr., Scientific Instruments and Recording Products Engineering; and **A. M. Miller** is Mgr., Film Recording and West Coast Operations.

In DEP Missile and Surface Radar Division, Moorestown, **A. L. Hammerschmidt,** Chief Engineer, has named **N. S. Potter** as Mgr., Systems Engineering.

D. H. Ewing, Vice President and Technical Director, RCA, has announced that **F. Edelman** has been appointed Director, Operations Research.

RCA SPACE CENTER TO ADD LAB WING

Construction has begun on a new laboratory wing for the DEP Astro-Electronics Division. The new 23,000 square-foot facility will bring the Division's total space to 200,000 square feet, all in the Princeton area. The new one-story, air-conditioned Northeast Wing will be integrated into existing facilities. When completed by March, 1962, it will house approximately 200 employees and be used primarily for engineering activities.

Recently, AED had leased a three-story building from the Hightstown Rug Company in Hightstown, N.J., to provide additional working space for its expanding operations.

ORGANIZATIONAL CHANGES IN DEP

The DEP Major Systems Division, Moorestown, has been placed under the supervision of **W. G. Bain,** Vice President, Communications and Aerospace. Four of the six divisions in DEP now are under Mr. Bain. The others are the Surface Communications Division, the Aerospace Communications and Controls Division, and the Astro-Electronics Division.

DR. GERJUOY NAMED TO HEAD NEW DEP PLASMA AND SPACE APPLIED PHYSICS GROUP

Dr. Edward Gerjuoy, an authority in theoretical physics, has been appointed director of Plasma and Space Applied Physics for DEP. Dr. Gerjuoy had been on the staff of E. H. Plesset Associates, Los Angeles. Previously, while on leave from the staff of the University of Pittsburgh, he was a member of the research staff on the General Atomics Division of General Dynamics in San Diego, California.

The Plasma and Space Applied Physics group will be located at Princeton, N. J. in close proximity to the DEP Advanced Military Systems group, with which it will maintain close liaison.

PROFESSIONAL ACTIVITIES

DEP Applied Research, Camden: **Dr. J. Vollmer,** Leader, DEP Applied Research, was an invited speaker at the Career Conference of the Delaware Valley Engineering and Technical Societies Council. His topic was *The Meaning of Basic Science.* He spoke to 300 gifted high school students from Pennsylvania, New Jersey and Delaware. On February 2, 1962, **M. S. Corrington** was re-elected as chairman of the Sponsors' Advisory Committee of the International Solid-State Circuits Conference. He was one of the founders of this conference and has been chairman of the Sponsors' Committee since it was organized. **M. B. Herscher** of Applied Research was a panel member for an evening discussion February 14 on *Distributed Logic* at the 1962 International Solid State Circuits Conference in Philadelphia.—*M. G. Pietz*

DEP Central Engineering, Camden: **J. L. Krager,** Administrator, Military Packaging, was elected to the Board of Directors of the Society of Packaging and Handling Engineers as a Vice President for 1962-63. He is currently completing a term as an Eastern Regional Director, and Chairman of the National Packaging Competition Committee.—*F. W. Whitmore*

Broadcast, Hollywood, Calif.: **D. C. Yarnes,** is slated as a Topic Chairman for the 91st SMPTE Convention, Apr. 30—May 4, 1962, Los Angeles. He is with the CCTV and Film Recording Dept., Hollywood.

DEP M&SR, Moorestown: A special *Engineer's Week* program was held Feb. 21 at RCA Moorestown, sponsored by the Engineering Society of Southern, N. J. Theme of the Dinner Conference was *Economic Growth through Professional Engineering,* and included talks by **J. H. Sidebottom,** Vice President and General Mgr., Major Systems Division; **E. E. Roberts, Jr.,** Mgr., Space Systems Programming; **H. W. Phillips,** DEP-MSR, and Vice President of the ESSNJ, was moderator.

Typical of many activities where RCA engineers participate in programs that encourage our youth to enter engineering, are the following: On Dec. 6, 1961, **R. S. Putnam,** Ldr., Range Instrumentation Products, spoke to several hundred Delaware Township High School Students. On Nov. 3, 1961, **S. Aron** and **M. Lowe,** both of MSR Engineering, presented an audio demonstration before science classes of the Woodcrest Grammar School.
—*T. G. Greene*

DEGREES GRANTED

H. J. Ghandour, Broadcast and Communications Products Division, Camden, received his MSEE from the University of Pennsylvania.—*C. D. Kentner.*

J. C. Johnson, DEP-SurfCom Systems Lab, Tucson, received his MSEE from the University of Arizona.—*C. W. Fields.*

REGISTERED PROFESSIONAL ENGINEERS

M. J. Kozak, DEP Central Engineering	PE 12050, N.J.
D. Roda, DEP-ACCD	PE 7990E, Pa.
C. H. Musson, DEP—M&SR	PE 11606, N.J.
E. Leshner, DEP—SurfCom	PE 5804E, Pa.

T. T. Patterson

C. W. Sall

PATTERSON AND SALL NAMED AS ENGINEERING EDITORS FOR RCA ENGINEER

T. T. Patterson, Electronic Data Processing, Pennsauken, N.J., and **C. W. Sall,** RCA Laboratories, Princeton, N.J., have been named as Engineering Editors for the RCA ENGINEER. In this capacity, they will act as consulting editors for the RCA ENGINEER editorial staff and Advisory Board. Both men have distinguished professional backgrounds in engineering publications work at RCA, and both serve as Editorial Representatives and Technical Publications Administrators for their RCA activities.

T. T. Patterson, Leader, Engineering Publications, Electronic Data Processing, received his BEE (Electronics) from the University of Virginia in 1949. He first worked for the Molded Insulation Company, Philadelphia, as an engineer and then in 1950 joined the Department of Defense as a Radio Engineer on special-purpose communications equipment used by all three services. In 1952, he was with the Allen B. DuMont Labs as an Editor-Writer and in 1953, he joined Burroughs Corporation Research Center in Paoli, Pennsylvania, as a Technical Writer. In 1956 he was in charge of all publications for the Research Center. At RCA since 1956, he has been in charge of Engineering Publications for Electronic Data Processing, and now also acts as Technical Publications Administrator for EDP. He has been active in the IRE: is presently a Senior Member; was a founder of the professional group on Engineering Writing and Speech, was national program chairman (1958), Dual-National Symposium Chairman (1959), National Chairman of the Administrative Committee (1960) and a member of the committee since 1957; and is presently Editor of the *PGEWS Newsletter*. With the IRE professional group on Engineering Management, he has been Editor of the *Transactions* (1956-59), and member of the Advisory Board for the Philadelphia Chapter. He is a member of the Franklin Institute.

C. W. Sall, Technical Publications Administrator, RCA Laboratories, received his A.B. degree from DePauw University in 1935 and his A.M. degree from N.Y. State College for Teachers in 1942. From 1935 to 1943 he taught high-school science in Baldwin, L.I., N.Y. He joined RCA in 1943, and until 1958 was Technical Publications Administrator for the RCA Laboratories Industry Service Laboratory in New York City. From 1958 to 1960 he was Mgr. Technical Publications, for IEP in Camden. In 1960-1961 he was back with the RCA Laboratories as Technical Editor and Reports Coordinator for Project PANGLOSS, and in 1962 was named Technical Publications Administrator for the RCA Laboratories. Mr. Sall is a Senior Member, IRE, and has been Editor of the *Transactions* of the Professional Group on Broadcast Transmitters. Currently, he is active in the Professional Group on Engineering Writing and Speech, as National Vice Chairman, Administrative Committee, and as a member of several other subcommittees.

KNOW YOUR "TPA"
The RCA Technical Publications Administrators

The RCA system for review and approval of technical papers is designed to protect RCA commercial, legal, and technical interests, as well as to protect the author and provide an often-valuable critique of the material. It is a matter of formal RCA corporate policy, as implemented by local divisional procedures.

The men listed below are responsible for coordinating the corporate review and approval of *all technical papers for presentation and/or publication.*

Before working up your paper or presentation for a professional society, technical journal, or any other publication, be sure and check with your manager and your TPA to determine *exactly* what approval procedure is required.

And be sure to allow ample lead time: your TPA can advise how much, and of details as to how many copies of the manuscript he will require, etc. (Note that the Editorial Representatives listed on the inside back cover of every issue of the RCA ENGINEER are also available to assist in approvals, since they work closely with the TPA's.) Some important points to remember are:

1) All professional papers and presentations must have corporate approval *before* they can be submitted for consideration to a technical society or journal. This *includes the advance abstracts or summaries* that the society or journal may require well in advance of the date of presentation or publication of the full paper.
2) If your subject concerns government contract work, remember that government release is a requirement *in addition* to the corporate approval. Your Editorial Representative is the one who can arrange this for you, or check with your manager or TPA. Government contract and/or security release *often requires many weeks,* and your TPA *cannot* grant RCA corporate approval until it has been obtained in writing.

The following is a current list of Technical Publications Administrators:

RCA Victor Home Instruments, **K. A. Chittick,** 600 N. Sherman Dr., 6-2, Indianapolis, Ind.

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NBC and RCA Institutes, **W. A. Howard,** 30 Rockefeller Pl., 515W, New York 20, N.Y.

RCA Electron Tube and Semiconductor and Materials, **E. C. Hughes, Jr.,** Bldg. 51-2, 415 S. 5th St., Harrison, N.J.

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RCA Laboratories, **C. W. Sall,** Princeton, N.J.

RCA International, **L. S. Beeny,** Clark, N.J.

Defense Electronic Products, **F. D. Whitmore,** Bldg. 10-8, Camden 2, N.J.

NEW ED REPS NAMED: M. G. PIETZ IN DEP APPLIED RESEARCH; G. A. DE LONG AT ETD LANCASTER; T. G. GREENE FOR MSR, MOORESTOWN; R. N. HURST FOR BROADCAST, CAMDEN

In DEP Applied Research, Camden, **M. G. Pietz** has been named as RCA ENGINEER Editorial Representative, filling the vacancy left by **F. W. Whittier,** who recently transferred to SurfCom in Cambridge. Mr. Pietz will serve on **F. D. Whitmore's** DEP Editorial Board.

For Conversion Tube Operations, Electron Tube Division, Lancaster, Pa., **G. A. DeLong,** Project Representative, Planning and Controls, has taken over as Ed Rep from **W. G. Fahnestock,** who is now Mgr., Operations Planning and Controls at Lancaster.

In the DEP Missile and Surface Radar Division, Moorestown, **T. G. Greene,** Administrator, Technical Coordination, Engineering, Project Operations, has taken over as Ed Rep from **R. W. Howery.** Mr. Greene had been active as an Assistant Ed Rep, and will serve on **F. D. Whitmore's** DEP Editorial Board.

In the Broadcast and Communications Products Division, Camden, **R. N. Hurst** is now Ed Rep for Broadcast Studio Engineering. He replaces **J. H. Roe,** who has moved to DEP-AED.

SESSION ON "BETTER WRITING PAYS" SCHEDULED AT 1962 IRE INTERNATIONAL ON MARCH 28

At the upcoming 1962 IRE International Convention in New York City, the IRE Professional Group on Engineering Writing and Speech will present Session 36 on "Better Writing Pays" in the Sert Room, Waldorf Astoria, from 2:30 to 5:00 PM, Wednesday, March 28, 1962. **C. W. Sall,** Technical Publications Administrator, RCA Laboratories is Chairman of this session, which will be of considerable interest to RCA engineers and scientists. Four papers are scheduled, with time allowed for discussion:

36.1 *Educating Engineers to Write Effectively,* A. C. Mansfield, Atomic Power Development Associates, Inc., Detroit 26, Mich.

36.2 *Placement of Technical Papers for Maximum Effectiveness,* **C. A. Meyer,** RCA, Electron Tube Div., Harrison. N. J.

36.3 *The Engineering Report, A Rusty Tool,* R. M. Woelfle, The Bendix Corp., Mishawaka, Ind.

36.4 *The Consequences of Choice,* Thomas Farrell, Prof. of Business Communications, Michigan State Univ., East Lansing, Mich.

NEW EDITION PUBLISHED OF 4-MILLION-COPY BEST SELLER—THE RCA "RECEIVING TUBE MANUAL"

A new edition of one of the best sellers in the electronics industry, the *RCA Receiving Tube Manual,* recently came off the press. This latest printing will raise the sales of this popular reference book above the 4 million mark. Published by Commercial Engineering, Electron Tube Division, Harrison, N.J., the new *RC-21* edition contains 480 pages and has technical data on more than 900 receiving tubes, including nuvistor and novar, as well as data on over 100 black-and-white and color kinescopes.

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