RCA Engineer

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The international outlook

As an international company with foreign sales exceeding $600 million annually, RCA expects to benefit increasingly from the expansion of foreign markets. Barring the unlikely occurrence of a worldwide depression or a major war, we project an increase in the company's foreign business at a substantially greater rate than our domestic growth over the next five years.

I am convinced that it would be unwise not to seek expansion abroad. Except in rare instances, national economies tend to grow at different rates and fluctuate at different frequencies. In seeking sustained growth and profitability, geographical diversification can be just as important as product diversification to a company like RCA.

Moreover, there are no natural boundaries for such RCA businesses as electronics, communications, car rentals, and prepared foods. Competition is worldwide. We must face our competitors abroad as well as at home if we expect to remain a leader.

Finally, we increase our competence by operating internationally. This country is by no means the sole repository of technological skill or business capability. There is a constant exchange of ideas and experience with associates and customers abroad. We benefit from this give-and-take through greater insight to apply to our operations elsewhere, including the domestic market.

Beyond considerations of self-interest, RCA is committed to liberalized trade and international cooperation. Companies like ours can play a constructive part in furthering these objectives. They serve as vehicles for the free flow of goods and capital, the elevation of living standards, and the wider distribution of managerial skills and advanced technology.

RCA has always been an innovative company. I feel that it is in an excellent position to grow and prosper in an environment increasingly dependent on new technology. As we raise our sights to embrace more of the international market, I believe that RCA can achieve a more vigorous growth rate, and a significantly higher level of sales and profit, than if we confined our attention solely to domestic activities.

Robert W. Sarnoff,
Chairman of the Board and
Chief Executive Officer,
RCA

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Our cover

...is a global array of RCA's products that sets the theme for this issue which features RCA's international activities.

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

Contents

Emphasis — International activities

Engineer and the Corporation

Profiles of International Activities

Papers on International Topics

Of general interest

Engineering and research notes

Departments

The
Engineer
and the
Corporation

RCA International — a business update

Dr. E.A. Sekulow

Since 1919, RCA has been concerned with the need for communication products and services on an international scale. The author provides an update for the reader by describing present day opportunities abroad, the commitment of a free flow of goods and capital, general international growth and the effects of nationalism in many parts of the world.

In 1968, the RCA Corporation was born and the Radio Corporation of America passed into history; there was considerably more to this change than a new name for the company. It reflected a management decision to build outward from what had been a largely domestic business base and to create a truly international enterprise.

Early interests

RCA has, of course, had interests abroad from its beginning in 1919 as an international wireless communications company. Since becoming a manufacturing enterprise at the end of the 1920s, RCA has maintained subsidiary home instrument and record companies in Europe and Latin America and a major Canadian subsidiary that provides a wide range of electronic products and services.

Dr. Eugene A. Sekulow, Vice President, RCA International, is a graduate of the Johns Hopkins University; Dr. Sekulow received his M.A. in Political Science there in 1953. He then studied and taught International Relations and Economics at the University of Oslo, Norway, and later returned to Johns Hopkins where he received his Ph.D. degree in 1960. In 1956 Dr. Sekulow was appointed an Instructor in Political Science at Johns Hopkins and continued in that capacity until he joined RCA in 1960. Prior to assuming his present duties in 1973 as Vice President, RCA International, Dr. Sekulow was RCA Director of Licensing for Europe, Middle East and Africa. He also had served the Corporation in its licensing activities at the Geneva Office since 1965.

In the post-World War II growth of electronics here and abroad, RCA established technical centers and research laboratories in Switzerland and Japan for contact with the principal foreign scientific communities and to provide technical assistance to overseas licensees.

Together, however, all of RCA's foreign manufacturing and export sales activities accounted until recently for only a small fraction of the company's business volume. In 1965, these international operations produced less than 8 per cent of its $2.3 billion revenues.

Increased sales

By contrast, RCA's foreign sales this year are expected to account for approximately 17½ per cent of a corporate business volume that should be more than double the 1965 total. Much of the higher percentage is generated by activities that were either insignificant or wholly absent from RCA's international business in 1965 — foreign ventures in the manufacture of color kinescopes, overseas production and sale of solid-state components and devices, worldwide vehicle rental operations of Hertz, and the distribution of food.

The comparison illustrates a pattern that should prevail for some time. During the next five years, for example, RCA is projecting an increase in foreign business at a rate substantially greater than that of its domestic growth. The expectation is based on past performance. For at least a decade, most other industrial nations have outstripped the United States in economic growth rates. New growth patterns are now appearing in the Middle East and portions of Africa and Latin America in the wake of the energy crisis and the sharp rise in income among the world's oil producing nations.

Opportunities abroad

While the domestic U.S. market is and will remain the world's largest in the foreseeable future, the more rapid pace of economic expansion abroad opens the prospect of major busines opportunities in countries that still lag well behind our own in absolute terms.

In most of our product and service lines, in fact, the opportunities abroad today are comparable to those that confronted RCA at home from five to ten years ago — and even longer in some cases.

In color television, Europe generally is perhaps five years behind the United States in market penetration, while Latin America is poised at the threshold. In solid state, RCA enjoys a significant technological and marketing lead, especially in power devices and integrated circuits for consumer application. Across the board, there is substantial demand abroad for the best American technology, and it is reflected particularly in these areas. We can expect further business growth in both categories as long as we continue to support our activities with a vigorous program of research, engineering development, and product innovation.

The high level of unsatisfied consumer demand generally, particularly in Europe, also has created a strong market

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potential for the non-electronic products and services into which RCA has diversified since 1966, such as frozen prepared foods and carpets.

Free flow of goods and capital needed

Beyond these visible considerations are further basic reasons for a company like RCA to develop a truly international base.

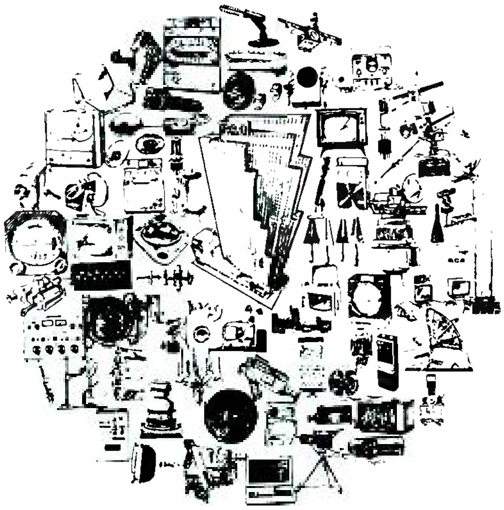
It is a logical evolution for a multi-billion-dollar industrial enterprise in an era of jet travel and global wideband communication. These developments have largely removed the barriers to effective management of a common corporate strategy for operations scattered across several continents. In the case of a company engaged in the universally applicable technologies of communications and electronics, global expansion under these conditions is perhaps inevitable.

At the same time, shifting economic and monetary patterns have increased the attractiveness of investment abroad, enhanced the price-competitiveness of American products overseas, and strengthened consumer purchasing power and demand in many countries. Furthermore, the trend toward wider economic groupings, such as the European Common Market, has created large regional markets where fragmentation and formidable trade barriers once prevailed.

Finally, RCA has always been committed to the freest possible flow of goods and capital as an essential condition for a healthy world economy. And the communications and information technology which constitutes so much of our business has a key role to play in advancing both trade and investment on a global scale.

RCA international growth

In response to these opportunities and commitments, RCA today is accelerating its international growth. Recent expansions have increased production facilities for color kinescopes at its affiliated companies in Britain and France, and a further increase is in prospect. Carpets are now rolling off the line at a new Coronet Industries plant in Belgium. This year, RCA Records has started marketing in Germany for the first time. The acquisition of Oriel Foods and Morris & David Jones in Great Britain has opened a door for RCA to a promising new market for food distribution.



A new solid state plant in Malaysia is to be in production later this year to serve growing customer demand in the Far East.

Barring the unlikely occurrence of a major worldwide economic setback or a large-scale conflict, this pattern of growth should continue in parallel with the domestic advance of RCA's business to create a well-balanced international company providing a broad range of consumer and commercial products and services in all major world markets.

Effect of nationalism

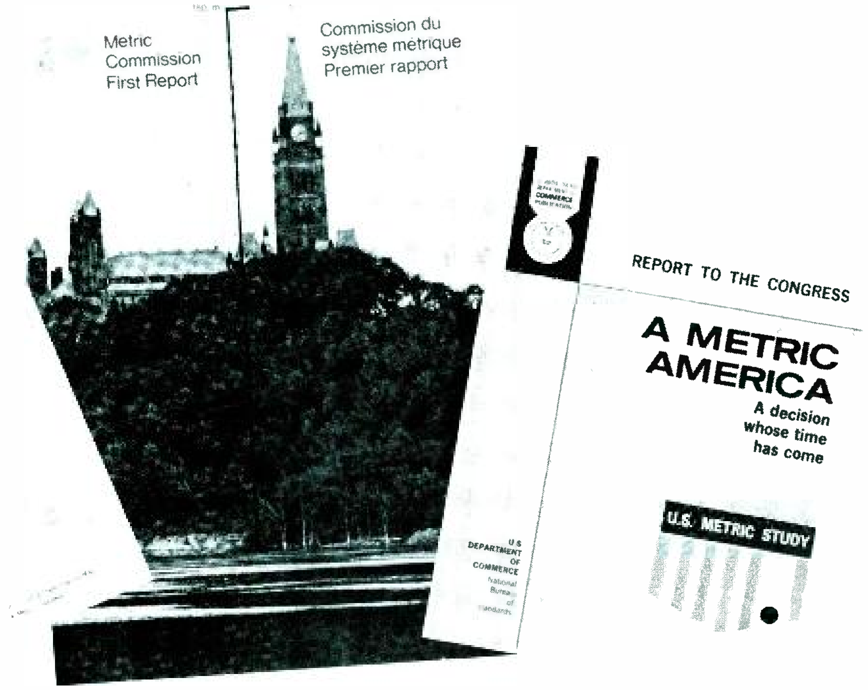
It must be recognized, of course, that activity abroad entails certain problems unlike those encountered at home. Customer expectations and tastes vary from one country or region to another. Business procedures differ widely in Europe or Latin America or the Far East. The laws and regulations governing business form a worldwide patchwork of inconsistencies. Nationalism remains a strong force everywhere, leading to or reinforcing protectionist attitudes. And, finally, there is a widespread antipathy to the operation of international companies generally and to American companies in particular in many parts of the world.

While these conditions may add to the cost and complexity of doing business abroad, they are no more insurmountable by an experienced and competent management than difficulties encountered at home. Anticipating change in customer demand is a constant challenge to any company that serves the nationwide domestic market. The participation of foreign nationals can lessen the difficulty of adhering to unfamiliar local procedures and regulations. Quite apart from the fact that it is obligatory in some countries, a company that does not rely upon local skill and talent in the management and operations of a foreign subsidiary imposes a severe handicap upon itself.

Nationalism and the distrust of foreign enterprise represent the most serious problems, because they evoke common and deep-rooted emotions in every country—including our own. The only effective answer is responsible and responsive management: the conduct of company affairs in all other countries according to the same high standards that are demanded of us and that we impose upon ourselves at home. This applies to every facet of corporate behavior, from fair labor practices to the maintenance of product quality and safety.

Conclusion

RCA is committed to good corporate citzenship abroad as well as at home. On this basis, and supported by a strong and continuing management commitment to technological and marketing excellence across its full and diversified range of operations, RCA expects to grow and prosper as a leading international enterprise in the years ahead.



Metric conversion: the beginning

Harry Kleinberg

Recently, the international system of measurement has been an intriguing subject to engineers who, as a group, would necessarily become totally involved in any metric conversion. The movement or change in American attitudes toward the metric system, earlier opposition, the effect of international trade, and a procedural recipe for metric adoptions are given in this paper.

THE UNITED STATES has taken its first, irrevocable steps toward conversion to the International System of measurement. So definite a statement may carry the ring of unrealism when read against the background of the most recent Congressional action on the subject. In May 1974, the House of Representatives resoundingly defeated a move to introduce a bill calling for an orderly national conversion. The issue is now back with the sponsors and may not resurface until after a new Congress convenes.

Movements toward change

But the statement remains true, nonetheless. The U.S. is moving irreversibly to the metric system. The vote in the House was the end of a series of complex parliamentary moves centering around the rules under which the bill would be debated. Underlying this, in turn, was the basic issue of whether Federal subsidies should be provided to individuals and small businesses to buy new tools and equipment. The result is not an indication of how the House might have voted on the issue of metrication itself.

But what Congress does and what the nation does are not always the same thing. While total national conversion cannot come about without eventual government action, the impetus for the change can nevertheless come from the private sector. And that's what is happening. The movement to start the change is coming from industry as a growing number of major corporations decide to make the change now, not later.

While this spirit of action may seem to be in keeping with the dynamic image that industry likes to project, it is, in truth, a remarkable phenomenon.

Opposition prior to 70's

Less than five years ago, many of these same companies were lined up solidly against the idea of metric conversion; for a full century, sporadic attempts to convert to that measurement system were opposed vigorously and successfully by the general body of American industry. Time after time, the industrial community argued successfully that the returns from the required investment would be, at best, zero, and probably negative.

Typical of the opposition is the following account of the debate during the 1920's taken from *A Metric America* (Published by the U.S. Dept. of Commerce, National Bureau of Standards).

> "The anti-metric forces continued to be led by Halsey and Dale and this time they had the backing of a formal organization, the American Institute of Weights and Measures.
>
> "With financial and political backing from a large portion of the nation's major manufacturers and manufacturing associations, the Institute was able to overwhelm each pro-metric proposal with organized protests and adverse publicity. In addition to publishing its own journals, bulletins, and pamphlets the Institute enjoyed the support of some leading professional and trade journals.
>
> "The main anti-metric arguments, though not radically changed, were embellished with inflammatory flourishes. One series of articles in 1920 carried such titles as 'What Real He-Men think of the Compulsory Metric System,' 'Metric Chaos in Daily Life,' and 'A Metric Nightmare.' Newspaper and magazine articles sympathetic to the metric system were methodically rebutted, and those refusing to publish the Institute's replies were often charged with suppressing the facts."

Harry Kleinberg, Mgr., Corporate Standards Engineering, Corporate Engineering, Cherry Hill, received the Bachelor of Applied Science in Engineering Physics from the University of Toronto in 1951. In 1953, Mr. Kleinberg joined RCA as an Engineer in Camden, New Jersey. He was assigned to the newly organized Commercial Computer activity which at that time was the New Business Department of Engineering Products Division. Subsequently Mr. Kleinberg was appointed Engineering Group Leader on the RCA 501, first of the transistorized computers; later he became Project Manager of the RCA 301 computers; transferring in 1962 to the Palm Beach Gardens plant as Manager, Engineering. In 1969 Mr. Kleinberg returned to Camden as Manager, Camden Engineering, Computer Systems. In 1971 he transferred to this present position in Corporate Standards Engineering.

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Changes in attitude

Why the dramatic change? This article will adress itself to that question, and to a review of how, once started, the transition is being handled.

There are two basic reasons for the switch from yesterday's opposition to today's leadership. The first of these is the growth of the multinational corporation. In this context, multinational does not mean merely that a company assembles or sells its products in many countries. It means, rather, that all the resources of a company—management, engineering, marketing—are global, and are staffed to a significant degree by nations of the resident country. Such companies can engineer a product in Belgium and build it is Iowa, or vice-versa. Designs, processes and specifications flow across boundaries, across continents and across oceans.

Clearly, such interchange requires a high degree of organized and disciplined communication. Those who have worked in a multiplant environment within RCA are aware of the problems that mere geographical separation can introduce into the communication of technical information. When the spoken language and the technical language are additional variables, the problems are compounded at what is probably an exponential rate.

The companies facing these problems can do little about the spoken languages, except, by their very existence, to hasten the adoption of English as a *de facto* standard. But industrialists have decided that they can and must do something about the technical language. Increasingly, they have found that trying to maintain effective technical communication without a common measurement system is an unnecessary burden, a troublemaker with no redeeming benefits. Many companies have tried dual-dimensioning as a remedy, but the universal result has been added cost, increased errors, more complicated drawings, and, in general, the creation of more problems than were solved. Such companies, for their own internal reasons, have decided to choose a single system of units. Once that decision is made, the choice is obvious. . .switch to the metric system.

Other reasons for the new willingness to pioneer metric conversion can be put into perspective by recognizing that the central symbol, which used to be the academic gown, is now the dollar sign. Past movements to convert generally pointed to such advantages of the metric system as its more rational origins, its decimal nature, its coherence and so on. All of these can be disputed, some of them rather successfully. The origins of a system of measurement are, after all, totally irrelevant to its practical, everyday usage. Besides, is there anything less rational in basing a system on the length of a dead king's thumb, than there is in basing it on the incorrect distance from the equator to the pole?

Nor is the decimal nature of the metric system a persuasive argument. Mistakes in moving decimal points are as common as errors in division. The prefixes are not all that easy to learn (is femto bigger than atto?). The binary fractions are far too frequent and natural to be legislated out of existence and besides, if the decimal system has so much value, why haven't the circular measurements, including time, ever been changed? None of the old arguments is totally convincing, and none of them has ever carried enough weight to convince business that it would be worthwhile to convert. As a final argument, business has always been able to point out that there is absolutely no correlation between the success, by any criterion, of a society, and the measurement system it uses.

Effect of international trade

Today, earlier established arguments have been very largely bypassed by the new realities of America's position in international trade. The debatable benefits of a more rational system have been overridden by the balance-sheet factors of growth and market potential.

Until recently, our internal market for almost all our products has far outweighed our foreign export potential. Today, with the rapidly accelerating rise in the standard of living in Europe, and in such countries as Japan, the greatest growth in markets is to be found outside the United States. Since growth is still a major factor in the plans of most companies, these markets have yearly become more important targets.

The resulting increase in international trade has led to a corresponding increase in the importance of international standards. While presently such standards are completely voluntary in nature, more and more, the countries with whom we trade are expecting that commodities be in their own system of measurement, which means metric.

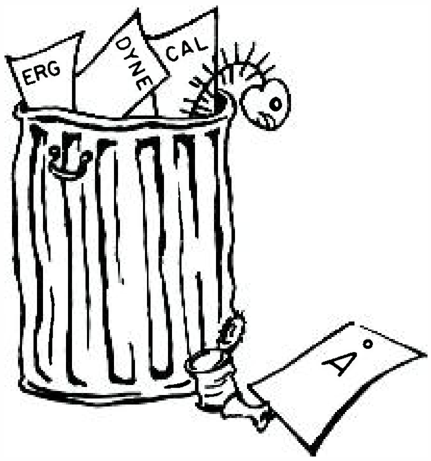
The factors of trade are not a problem of the immediate present. It is very difficult to find a specific current example of the loss of foreign business due to our national standards not being metric. But looking ahead a decade, projecting the trends of foreign competition in engineering and mass production, and recognizing the time needed for the changeover, it becomes clear that industries wishing to be competitive in foreign trade tomorrow must think about conversion today.

Procedure for conversion

Whatever the reason may be, when companies decide to convert, most of them are making the changeover in an intelligent, orderly, and relatively inexpensive manner. The general conversion procedure is as follows:

1) A schedule is set by management, usually centered around the introduction of new product lines. While the schedule is rational, and sometimes quite long, it is nevertheless definite and mandatory. Operating units within the company are not free to decide to stay with the customary system.

2) Little or no corporate funding is allocated for the change. Profit centers are expected to make the change in the normal course of their business. This is based on two reasons, the first of which is a deep concern that any conversion "kitty" might become a burial place for all sorts of unrelated problems and projects. The other factor is that, where conversion has been made, the cost has been impossible to sort out, even after the fact, which leads to the conclusion that costs are not as great as originally feared. It is found that there are often very simple solutions to many of the problems.



3) Only those things are changed which should be changed. Such items as punched cards, magnetic tape, and spark plugs, whose dimensions have become *de facto* international standards will probably never change. This reduces a considerable fraction of the conversion problem to "soft changes," which means leaving physical dimensions alone, but referring to them in the new language.

Some industries have started to take advantage of metric conversion as an opportunity to undo many of the errors of the past. For instance, the industrial fastener manufacturers (nuts and bolts) have completed the design of an entirely new series of fasteners called OMFS (optimum metric fastener system) which covers the range from the smallest diameter up to 100 mm (4 inches) with only 25 different combinations of diameter and pitch, and all of them with the same thread design. The OMFS represents a complete rethinking of the fastener problem, replacing all the old systems and their traditional mutations. Similar opportunities for simplification will be found in most industries.

4) An individual is named as the corporate coordinator for the change, assisted by a Task Force or Steering Group made up of representatives of appropriate corporate functions. The purpose of the group is primarily for interdisciplinary communications, for planning specifics of the change, and to minimize the number of ugly surprises that one part of the company presents to another. For example, one of the important functions easily overlooked is data processing, but the impact there can be significant, ranging from field sizes in large files, to the need for conversion subroutines.

5) Training programs are set up, generally with the goal of teaching only what is needed, when it is needed. Such programs and training aids are most intensive for the working engineer and technician, and are simplified to be understood by the assembly worker and higher management. Engineers are often surprised to find that the SI units, to which we are converting, are not always the metric ones they have come to know. Just as the horsepower and psi disappear, so do the calorie, dyne, gauss, Angstrom, and a number of other old, familiar metric faces. The new system is different enough that many engineers will find it difficult to unlearn the old.

It has also been found that training of secretaries and typists is important and must not be overlooked. The rules for the use of SI symbols are definite and rigorous, with carelessness a potential source of major confusion. Unfortunately, the standard symbols are a mixture of upper and lower case, so that k & K, m & M, p & P, h & H, n & N, etc. all means different things. Considerable care will have to be taken, especially by engineers, who are not noted for their meticulous attention to "clerical" matters.

In discussing the subject with people from companies involved in the change, one finds the general reaction to be quite calm. Entrepreneurs are finding it to be a less traumatic experience than some had anticipated. While there are many problems, most are solvable in a fairly straightforward way. As one manager summed it up, "Metric conversion is no worse than a bad cold."

What about RCA

What should RCA be doing? Our most sensible attitude at this time is still one of keeping in touch with national developments. Few of the factors leading other companies to start converting applies in the case of RCA. In most of our markets, international standards are generally the same as American standards because of our technical primacy, and regardless of the measurement system. Our corporate interest still lies in making sure that our customers' requirements and our materials availability remain in step.

This situation may change rapidly as metrication develops momentum within American industry. The new OMFS fasteners, for example, will start to appear in some 1975 model automobiles and will be used across the board by one major American automobile manufacturer in the 1976 models. It is not unreasonable to expect that other commodities will begin to appear commercially within about the same time frame. As these metric supplies become more common, it will become increasingly important for us to carefully plan and schedule our own conversion.

Research at Laboratories RCA Ltd. Zurich, Switzerland

Dr. W. J. Merz

Dr. Walter J. Merz, Director of Research, Laboratories RCA Ltd., Zurich, Switzerland, received the diploma in physics in 1945 and the PhD in physics in 1947 from the Swiss Federal Institute of Technology (ETH) at Zurich, Switzerland. Starting in the fall of 1948, he spent two years at MIT Cambridge, Mass., as a research assistant. After a 9-month assignment at Pennsylvania State University as a research professor, in the fall of 1951 he joined Bell Telephone Laboratories at Murray Hill, N.J., working in solid-state physics research, particularly on ferroelectricity and ferroelectric materials. In the spring of 1956, he joined RCA and after a one-year indoctrination period became manager of the research laboratory of Laboratories RCA Ltd., Zurich, Switzerland. In these years, with the exception of 1964/65 when he again spent one year at the RCA Laboratories at Princeton, he has been responsible for the research work at Zurich. Under his leadership, the staff and the program have grown considerably in size and sophistication. In 1968 he was appointed Director of research. Dr. Merz has published more than 50 technical papers and a book on ferroelectricity. He is a Fellow of the American Physical Society and the Institute of Physics of Britain, and is a member of the Swiss, German, and European Physical Society

Research in Zurich began in 1955 with the creation of a nucleus of scientists devoted to fundamental studies in solid state, mostly properties of insulators, under the direction of Dr. Albert Rose, of RCA Laboratories. Over the years the staff and its program have grown in size and scope under the leadership of Dr. Walter J. Merz, who has been managing the research activity since 1957. He was appointed Director of research in 1968. Today the research staff comprises 23 scientists and engineers, mostly Ph.D's, and some 20 technical assistants.

MANY OF OUR READERS can't remember the time when there was no RCA research activity in Switzerland! That is understandable. Next year will mark the twentieth anniversary of RCA's scientific program in that country. The story is a fascinating one.

In 1955 RCA established the Zurich, Laboratories RCA Limited, for the dual purpose of conducting fundamental and applied research within the European scientific community and of furnishing service to RCA's European licensees.

The Managing Director of the Zurich facility is C.W. Slaybaugh. The licensee activity is directed by Ron Mills; this activity works in various technical areas concerning licensing.

The research activity extends, complements, and enriches research at RCA Laboratories in Princeton, N.J., whose management is responsible for it. It is under the purview of Dr. Jan A. Rajchman, Staff Vice President, Information Sciences, who also oversees RCA Research Laboratories Inc., in Tokyo that operates in a similar manner.

A broad technical activity continues in solid-state physics and optics. On the one hand, the laboratory is engaged in materials research and the study of fundamental problems. On the other hand, it is working on device developments and applications. Since it is impossible to describe all the current activities, reports on only two topics follow.

Exemplifying the fundamental studies is a report on "Luminescence due to impurities and excitons." It will be shown how a classic topic, like luminescence, which has been of great interest to RCA for many years, has in recent years become one of the most exciting fields in solid-state physics research due to the study of excitonic effects. These findings are both of fundamental and practical interest.

An example of an applied project is given in "Color-encoded focused-image holograms for micropublishing." This reveals how fundamental studies can lead to a practical technology that opens the way to a new approach in micropublishing, a field of immense commercial interest. The problems involved in the preparation and reproduction of microfiche and in the construction of a reader are described.

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Luminescence due to impurities and excitons

Dr. W. Czaja

Typical phenomena of impurity-related and intrinsic luminescence in inorganic crystals are reviewed. The physics of donor-acceptor-pair luminescence, bound-exciton and free-exciton luminescence is explained and the relevance of these mechanisms for applications is pointed out.

IN HIS WELL-KNOWN text, *Introduction into Solid State Physics*, C. Kittel states[1]:

> "*Luminescence* denotes the absorption of energy in matter and its reemission as visible or near visible radiation. The initial excitation may be by light, particle bombardment, mechanical strain, chemical reaction or heat. If the emission occurs during excitation, or within 10^{-8} sec of excitation, the process is commonly called *flourescence*. . . . If the emission occurs after excitation has ceased, the process is called *phosphorescence* or *after glow*, · · · Crystalline luminescent solids are known as *phosphors* · · ·".

It hardly needs any further justification for RCA to be interested in this area of solid state physics.

The main emphasis in the following sections will be on photoluminescence; *i.e.* we discuss emission of light from single crystals which are excited with light of energy higher than the band gap. We furthermore will concentrate on inorganic crystals, for instance III-V-compounds, specifically on *GaP*, and similar materials. In view of the extremely wide variety of possible luminescence phenomena, it is reasonable to distinguish between impurity-related emission and intrinsic emission. In the next section, we deal with pair spectra and bound-exciton phenomena; a later section is concerned with free-exciton effects at low and at high excitation density. Before going into details, however, we will define some important concepts and will simultaneously demonstrate their relevance for practical applications.

It is well known that techniques exist to tailor-make phosphors for specific applications by adding suitable activators and coactivators. This procedure was based for a long time on more or less heuristic rules. A special class of activator-coactivator phosphors which have been studied very thoroughly and

Dr. Wolfgang Czaja, Laboratories RCA Ltd., Zurich, Switzerland received the diploma in physics in 1950. When he received the PhD in 1957 he had already worked for 3 years in the development laboratory of a small company. He then worked eight years at the Institute of Applied Physics, University of Basel, and two years at Bell Telephone Labs., Murray Hill. In 1966 he joined Laboratories RCA Ltd., Zurich. He is author and coauthor of about 20 papers and has a teaching assignment for Solid State Physics at the University of Basel. He is a member of the Swiss, European and American Physical Societies.

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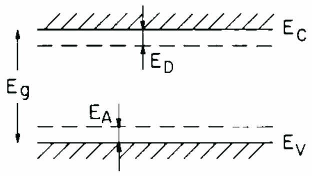

Fig. 1 — Band scheme for DAP-luminescence.

which by now are well understood even quantitatively are donor-acceptor pairs (DAP) in semiconductors.[2] These will be treated first. Furthermore, it is a good illustrative starting point to explain luminescence based on DAP-emission in semiconductors, since this process can be explained to a large extent in a weakly perturbed one-electron approximation; *i.e.*, it can be understood in terms of nearly independent electrons and holes, donors and acceptors, and is therefore easy to visualize.

Quite generally, however, one cannot always neglect the Coulomb interaction between the negatively and positively charged carriers. Because of this attraction an electron and a hole may form a bound state — similar to a hydrogen atom — just before the two carriers recombine. This entity is called an exciton. At low temperatures, excitons may move freely in a semiconductor or they can be trapped or bound to impurities. Bound excitons occur also at higher temperatures and play a dominant role in the red and green light-emitting diodes (LEDs). Bound or free exciton emission is responsible for laser action in many crystals having a direct band gap;[3] and even in the indirect band-gap material, *GaP*, stimulated emission due to bound excitons has been achieved. Although in *GaAs* and related[3] injection lasers stimulated emission is not due to an excitonic process, it appears as if the electron-hole interaction cannot be neglected at high excitation densities.

Impurity luminescence

Donor-acceptor-pair spectra

One of the earmarks of the more modern era of the physics of luminescence was the detailed analysis of DAP-spectra in semiconductors, in particular in *GaP*,[2] which was initiated more than 10 years ago.

Let us assume that a semiconductor with a band gap (E_g) doped with an equal amount of donors (ionization energy E_D) and acceptors (ionization energy E_A) is kept at low temperatures ($kT << E_D, E_A$) in complete darkness, Fig. 1. In this state, the valence band is filled with electrons, the conduction band is empty, the donors are positively charged and the acceptors are negatively charged. Therefore, donors and acceptors attract each other over a distance r due to the Coulomb force $-e^2/\epsilon r$, where ϵ is the dielectric constant describing the screening due to the crystal lattice. Eq. 1 is the energy-balance of our crystal in the quiescent state provided the zero of energy is taken at infinite separation of donor and acceptor. After excitation with light of sufficiently short wavelength λ_o ($hc/\lambda_o \geqslant E_g$) we have generated an electron-hole-pair at infinite distance (Eq. 2).

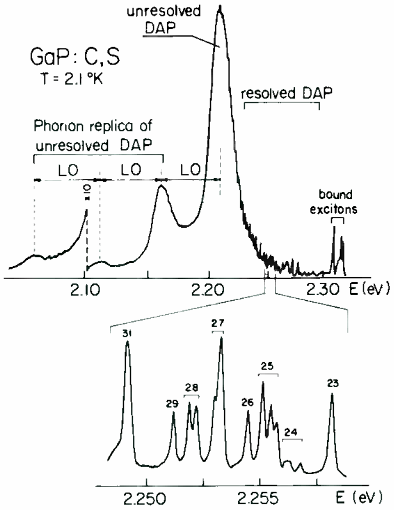

Fig. 2 — C-acceptor, S-donor pair spectrum in *GaP*, both impurities substitute for *P*. Concentration approx. 10^{18} /cm^3, approx. 70% compensation.

$$E(1) = -e^2/\epsilon r \quad (1)$$

$$E(2) = E_g - e^2/\epsilon r \quad (2)$$

$$E(2) = E_g - E_A - E_D \quad (3)$$

$$E(4) = E(1) = -e^2/\epsilon r \quad (4)$$

Electron and hole will be captured immediately by donor and acceptor respectively, leaving impurities which now are neutral (Eq. 3). State 3, however, is only short lived; we will observe radiative recombination of electron and hole and the final state 4 is then equal to the ground state 1. The energy difference between 3 and 4 corresponds to the energy of the photon emitted.

$$E(3) - E(4) = h\nu = E_g - E_D - E_A + e^2/\epsilon r \quad (5)$$

From Eq. 5, we expect to observe a line spectrum since the donor-acceptor distance, r, if both impurities are substitutional, is discontinuous and basically given by the lattice constant a_o (for donor and acceptor at P-sites)

$$r = a_o\,(m/2)^{1/2} \quad (6)$$

In Eq. 6, the "shell-number" m is a running index labelling the various pair distances as shown in Fig. 2. All DAP-line spectra are — at least in this approximation — similar except for the difference in $E_g - E_A - E_D$, as shown in Fig. 3.

Apart from the resolved DAP-spectrum there exists at larger distances r (lower energies) also an unresolved spectrum, (Fig. 2) which has very specific properties[4] and which persists to higher temperatures than the line spectrum.

Although the coarse features of our model are rather well confirmed experimentally, there are a number of fine details which we have not yet explained. However, we will only list a few of these

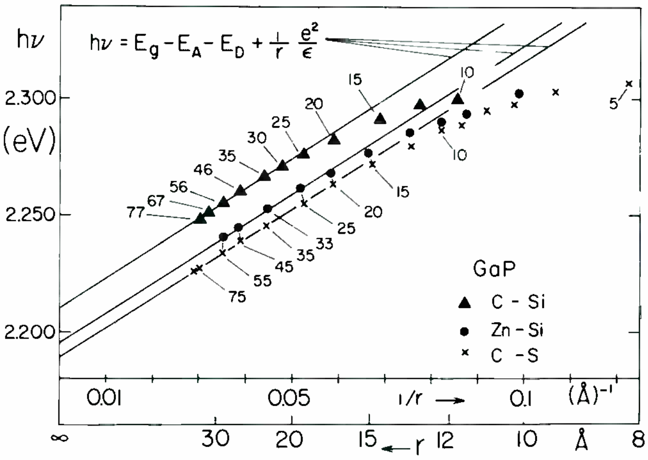

Fig. 3 — Energetic position of resolved DAP-emission lines in function of DAP-separation r. Data from P.J. Dean, C.J. Frosch, C.H. Henry, *J. Appl. Phys.* Vol. 39, (1968) p. 5631.

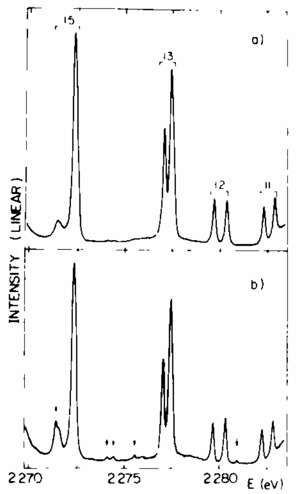

Fig. 4 — Strong, well resolved C,S-DAP-lines and weak C,Si-DAP-lines in GaP, a) Sample with no detectable Si, b) sample containing some Si, other parameters similar to Fig. 2.

higher order effects and emphasize that much can be learned about impurities and the host lattice just by studying these details.

Some of the fine structures exhibited in Fig. 2 can be explained by considering a more realistic charge distribution of donors and acceptors as compared to a point-charge model.[5] The measured deviation of the emitted photon energy from the predicted $1/r$ dependence of Eq. 5 (see Fig. 3) has been explained to a large extent using an improved model for the donor-acceptor interaction.[6] These two examples shall suffice to demonstrate that the static properties of DAP-spectra are rather well understood; dynamic properties such as the capture process of charge carriers prior to recombination and the radiative decay times of the emission have also been explained in considerable detail.

So far, we have been exclusively concerned with DAPs in *GaP*. In fact, other materials such as *BP*, *AlSb*, *SiC*, *ZnS*, and *CdS*, to name a few, also exhibit well resolved DAP-spectra, although they have not been studied as extensively. In addition, work done at our laboratory has demonstrated recently[7] that lattice point defects (Frenkel defects) within a *Bi* plane of the layer structure compound BiI_3 give rise to DAP luminescence, since interstitial and vacancy act as donor and acceptor.

Finally, in Fig. 4 part of a *GaP:S:C* DAP-spectrum is shown where weak DAP-lines due to the presence of some *Si*-donors are visible. Such small amounts of *Si* in the presence of a relatively large ($\sim 10^{16}$ cm^{-3}) *S*-donor concentration are usually difficult to detect. This example demonstrates the potential use of luminescence spectroscopy as a qualitative analytic tool, although more often than not this work may involve rather time-consuming, high-resolution, low-temperature spectroscopy. This technique is at present being used in our laboratory by Miss. L. Krausbauer in connection with a materials research program on *GaP* epitaxial layers for integrated optics.

Bound-exciton luminescence

At the high energy side of Fig. 2, some very sharp lines are observable which again are related to impurities in *GaP*. This emission is due to the radiative recombination of an exciton bound to neutral impurities. Excitons bound to neutral donors as well as excitons bound to neutral acceptors have been identified and their emission spectra have been studied in detail.[8] Emission spectra observed at liquid-*He* temperatures in magnetic fields of 30 to 60 kG very often allow a definite statement about whether the observed spectrum belongs to an exciton bound to a donor or to an acceptor. Upon rotating the magnetic field with respect to the crystalline axis, one learns whether the respective impurity is a point defect or an extended center of, for instance, two impurities in nearest neighbor positions.

Also, excitons bound to isoelectronic impurities, which act as neutral traps, have been found in a number of semiconductors.[9] An isoelectronic impurity is an atom which has the same valence-electron configuration as the lattice atom for which it substitutes. Examples are *N* and *Bi* for *P* in *GaP*, *Bi* for *P* in *InP*, *O* for *Te* in *ZnTe*, *I* for *Br* in *AgBr*. Since isoelectronic impurities do not influence the number of carriers present in a semiconductor, they open up the interesting possibility to dope a material in order to influence its luminescence-spectrum practically without affecting its electrical conduction. This principle has been successfully employed in green light-emitting *GaP* LEDs, with the isoelectronic impurity nitrogen.

As in the case of the DAP spectra, the study of the finer details of the bound-exciton spectra has turned out to be a powerful tool to understand the properties of bound excitons and of the binding impurities.

It is also clear that the identification of bound exciton spectra lends itself as a very helpful analytical tool.

Intrinsic luminescence

Clear evidence for intrinsic luminescence is very often difficult to obtain since not only material of high chemical purity is necessary but also of high crystalline perfection. The additional recombination of charge carriers at dislocations in *Si*, for instance, is so effective that this very fact has been successfully applied ten years ago to display individual dislocations in highly doped *Si*-crystals[10] (Fig. 5).

The required high crystal perfection and a line-broadening effect to be mentioned later make it difficult to observe an exciton spectrum including ground and excited states in luminescence. A rare exception[11] is Cu_2O as shown in Fig. 6. The agreement between the free-exciton line spectrum and the hydrogen-atom Balmer-series dependence on the main quantum number *n* is striking, whereby even the disagreement with the exciton ground state energy can at least be qualitatively explained.

It is tempting to visualize free excitons as a gas of particles in a semiconductor with a temperature which is about the temperature of the crystal. This implies that relative to the energetic position with respect to the band edge, excitons have a certain kinetic energy which would be distributed according to Boltzmann

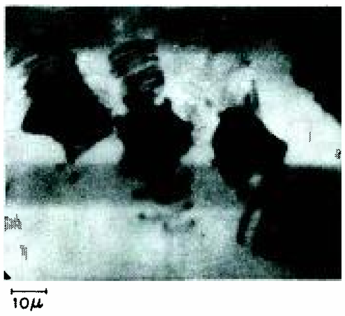

Fig. 5 — Individual dislocations which have emerged from indentations after heat treating a Si-crystal occur as dark lines.

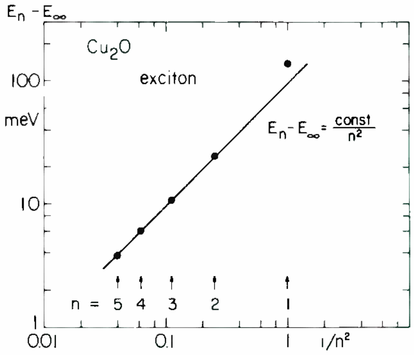

Fig. 6 — Relative positions of free exciton luminescence in *Cu_2O* (data from ref. 11) in function of quantum number n.

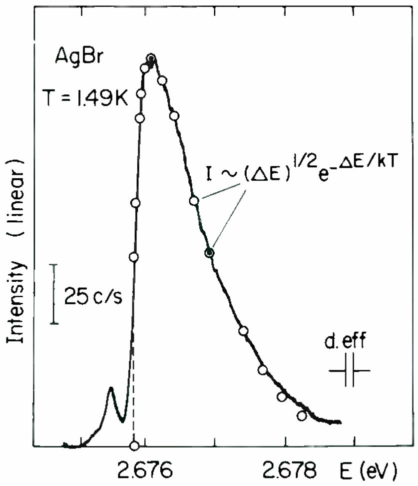

Fig. 7 — Boltzmann broadened free exciton emission in AgBr. The weak sharp line is due to high density excitation effects.

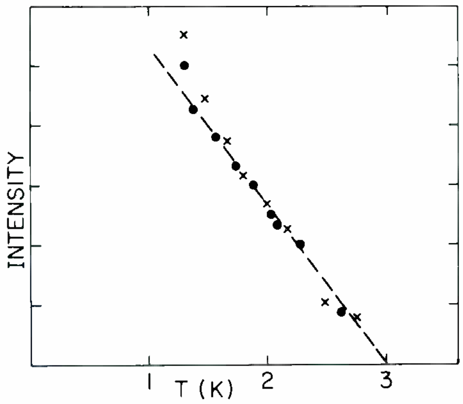

Fig. 8 — Temperature dependence of the emission due to Bose-Einstein condensed free excitons in AgBr.

statistics as in a normal gas. Radiative emission of free excitons therefore must be broadened and should display a spectral line shape which is determined by this energy distribution. This is actually observed and Fig. 7 can be taken as evidence that excitons behave to a large extent as if they were real particles.

It is exactly this property of excitons which becomes very prominent if one is concerned with effects at high excitation densities and at low temperatures. The physics of semiconductors under conditions of extremely strong excitation is a relatively new field of fast growing interest. In rough terms, one can distinguish two main kinds of behaviour.

In direct band-gap materials like *CdS*, *CdSe*, *ZnO*, the recombination probability is so large and therefore the lifetime of excitons so short that thermal equilibrium for the exciton gas will never be established. Therefore one observes new emissions due to processes which occur during equilibrization, such as inelastic exciton-exciton scattering.[12] A number of radiative transitions due to these scattering processes can be brought to lase.

On the other hand, in indirect band-gap materials (like *Ge*, *Si* and *AgBr*) the exciton lifetimes are rather long and consequently the exciton gas will be in thermal equilibrium as exemplified in Fig. 7.-Upon an increase of the exciton concentration and at sufficiently low temperatures, a condensation may become possible similar to a normal gas where a condensation into a liquid will occur. A condensation of a high density exciton gas into an electron-hole plasma state has in fact been observed for *Ge* and *Si*.[13]

Recent and still continuing work on luminescence of *AgBr* in our laboratory has produced evidence that there exists yet another type of condensation of an exciton gas.[14] Excitons are bosons, *i.e.*, they follow Bose statistics. At low temperatures and sufficiently high exciton densities they can experience a quantum effect called Bose-Einstein-condensation. The excitons behave as if by losing their kinetic energy they start piling up in one particular energy state at 3°K, producing a very narrow emission line. Upon lowering the temperature, the intensity of this line increases drastically and at 1.3°K there is no sign of a saturation, rather the intensity increases even faster than at higher temperatures, (Fig. 8). Although a related effect may have been observed in *CdSe* quite recently,[15] our observations in *AgBr* lend themselves relatively easily to a number of experiments. This is of particular interest since Bose-Einstein-condensation so far has only been a theoretical model; there are no experimental data on this effect.

All these high excitation density phenomena are related to rather complicated many-body effects which are not well understood in detail and some not even in very rough terms. At least in this field of luminescence many surprises are still hidden, demonstrating that this relatively old field is still vigorously alive.

Acknowledgment

The author is grateful for the help, support and encouragement he has received from his colleagues, in particular he is indebted to G. Harbeke and C.F. Schwerdtfeger.

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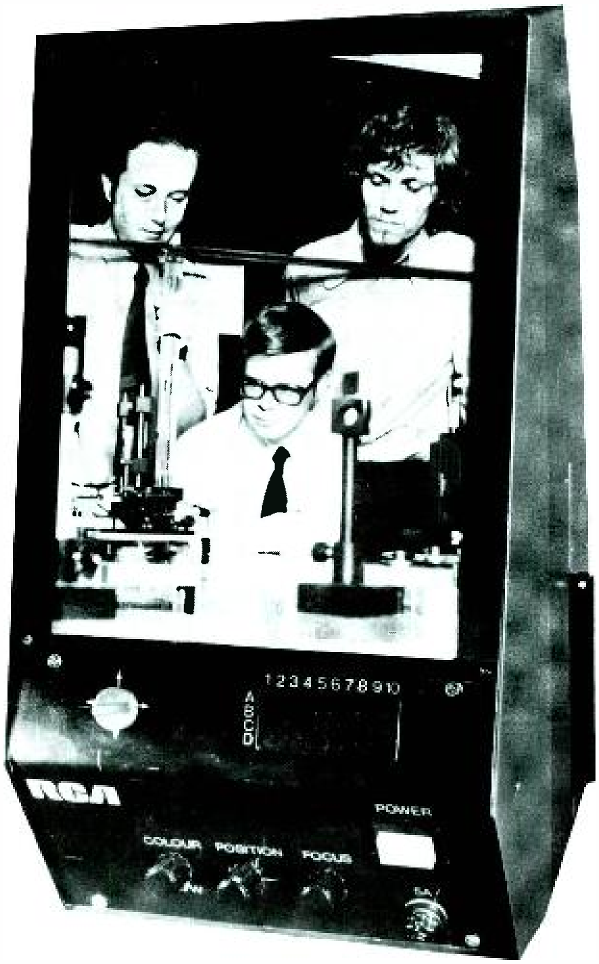
Color-encoded focused-image holograms for micropublishing

M.T. Gale | Dr. K. Knop | Dr. J.P. Russell

Color-encoded focused-image holograms have been investigated as a possible medium for micropublishing. The colorimetry and resolution is better than with conventional color film, and with high speed replication by embossing into thermoplastic materials there is a significant cost advantage over color film. To demonstrate the reality of the system we have constructed a number of microfiche readers for color-encoded focused-image holograms and have made both master and replica fiche. The readers and microfiche are available in Princeton and Zurich for demonstration.

TODAY'S "information explosion" has presented the publishing industry with one of the most tantalizing business opportunities it has ever faced. The information explosion has created the need to print, store, and distribute more material than ever before. However, printing, storage, and distribution costs are rising rapidly; annual rates of 10 to 15% are typical for conventional publishing. One of the promising alternative methods currently being investigated is



Authors Russell, Gale, and Knop (from left to right) displayed in microfiche reader for focused-image hologram.

Michael T. Gale, Laboratories RCA, Ltd., Zurich, Switzerland received the BA in Physics from Cambridge University, England in 1968 and the MSc in Optoelectronics from Essex University, England in 1969. He joined the Optics group at Laboratories RCA, Ltd., Zurich shortly afterwards, where his initial work was concerned with the identification of works of art by optical and holographic techniques. Since late 1970, he has worked on a number of holographic projects and, in particular, on the development of color-encoded focused-image holography and its application to micropublishing. He has published two papers.

Dr. Karl Knop, Laboratories RCA Ltd., Zurich, Switzerland received the Physics Diploma in 1967 and the PhD in Solid State Physics in 1972 from the Federal Institute of Technology, Zurich, Switzerland. His thesis work was concerned with the reorientation of electric dipoles in solids, at very low temperatures, down to 0.025° K. He has published several papers on this topic. In 1973, he joined Laboratories RCA Ltd., Zurich, as a member of the Optics group. Since he joined RCA he has been working on the development of color-encoded focused-image holograms, its application to micropublishing and related coherent optics problems.

Dr. John P. Russell, Laboratories RCA Ltd., Zurich, Switzerland received the BSc from Queens University, Belfast, N. Ireland in 1958 and the D Phil from Oxford University, England in 1962. From 1963 until 1967 he worked at the Royal Radar Establishment, Malvern, England on Raman and Brillouin scattering from solids. He joined Laboratories RCA, Ltd., Zurich as a member of the Optics group in 1967. Since then he has worked on holographic techniques for the storage and generation of integrated circuit masks, holographic identification systems and various applications of focused-image holography. In 1970, he spent nine months at RCA Laboratories in Princeton working on the holotape project. He received an RCA Laboratories outstanding achievement award for team performance in holography in 1969. He has published 16 technical papers and holds 5 U.S. patents.

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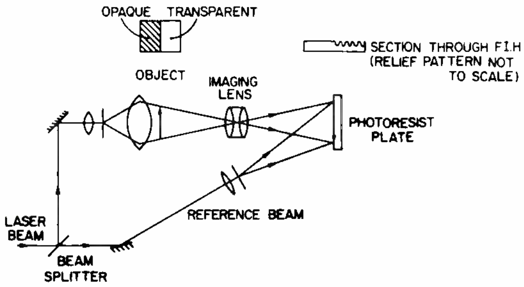

Fig. 1 — Recording of a simple focused-image hologram (FIH).

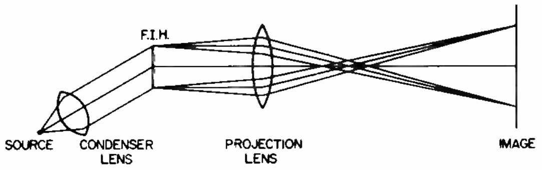

Fig. 2 — Readout of a FIH.

micropublishing, where the information is distributed in a microformat (*e.g.*, microfiche) and then displayed on an optical viewer

The micropublishing business is growing rapidly today; the value of distributed copies of micropublished material has increased from $15 million in 1966 to $55 million in 1971 and is predicted to increase to at least $400 million by 1980. This rapid growth market is based almost exclusively on black and white material due to the much higher cost of color film. However, the market would be enhanced by the ability to micropublish in color at a reasonable cost. Color-encoded focused-image holograms fit ideally into this situation. They may be replicated in a microformat very economically and used to produce full color pictures on a simple optical viewer with a quartz halogen lamp. Hence, we have orientated our R and D program on color-encoded focused-image holograms to match the requirements of micropublishing.

Simple focused-image hologram

A hologram is the record of the optical interference pattern formed between an object beam and a coherent reference beam. It has the property that if, after development, it is illuminated with the same coherent reference beam it will reconstruct both the phase and intensity of the object beam. This leads to many of the familiar properties of holograms such as the reconstruction of three-dimensional objects and immunity to dust, dirt, and scratch marks.

A focused-image hologram (FIH) is the name given to a hologram formed by recording the interference of a two-dimensional focused image with a coherent reference beam. The spatial form of the interference fringes that are recorded depends on the recording geometry. In the simple case shown in Fig. 1, the fringes are, for all practical purposes, parallel and the FIH is an amplitude-modulated diffraction grating. This is similar to a carrier-frequency photograph in which the grating is the carrier and the amplitude modulation is the picture information. Such a FIH does not possess the familiar hologram properties of reconstructing three-dimensional objects or redundancy. However, no laser is required for reconstruction (readout); instead, as shown in Fig. 2, a collimated beam of white light is sufficient. The picture is projected onto a screen using a simple achromatic lens to image the first-order diffracted light coming from the FIH. As in any picture storage and retrieval system, it is desirable to have a 1:1 relationship (unity gamma) between the input picture brightness and the final projected picture brightness. To determine the gamma for the FIH display system, we must consider the recording and reconstruction processes. The interference pattern in the recording plane is a sinusoidal intensity variation of amplitude $2a_R a_1$ where a_R is the amplitude of the reference beam and a_1 is the amplitude transmission (the square root of the intensity transmission) of the original transparency. When photoresist is used as the recording medium and developed linearly, the FIH consists of a sinusoidal relief pattern whose modulation is proportional to that of the interference pattern. For such a sinusoidal grating the intensity of light I_1 diffracted into the first order is given by:

$$I_1 = I_0 J_1^2 [2\pi a(n-1)/\lambda] \qquad (1)$$

where I_0 is the intensity of the readout beam; J_1 is the first-order Bessel function, a is the amplitude modulation of the sinusoidal grating; n is the refractive index of the medium; and λ is the wavelength of the readout light.

For gratings with efficiencies up to about 10%, the Bessel function is almost linear and Eq. 1 approximates to:

$$I_1 = I_0 [\pi a(n-1)/\lambda]$$

Since the grating amplitude a is proportional to a_I, the diffracted intensity I_1 is linearly related to the intensity transmission of the original transparency (a_I^2), *i.e.* we have a unity gamma.

Color-encoded FIH

A color-encoded FIH is a superposition of three such FIHs in registration with different carrier frequencies, corresponding to the three primary color components — red, green, blue (R, G, B)

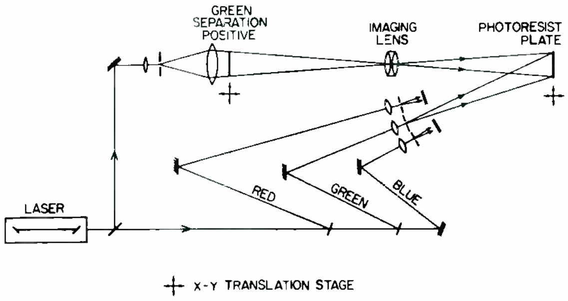

Fig. 3 — Recording of a color-encoded FIH. For the case shown, the green color separation is being recorded.

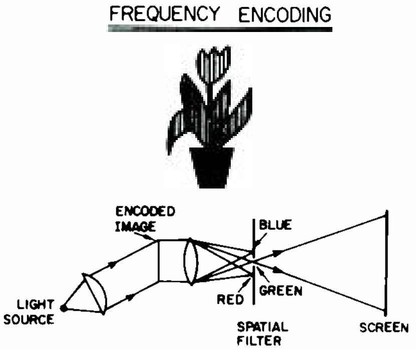

Fig. 4 — a) Color-encoded image of a red tulip with green leaves growing in a blue pot, (example given by R.W. Wood in *Nature*, 1899). b) Readout for green portion of color-encoded image. The spatial filter transmits only the green component of the first order diffracted light.

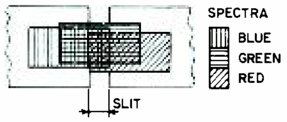

Fig. 5 — Spectra at filtering plane. For convenience the three spectra have been shown slightly displaced vertically from each other. In practice, for parallel gratings they are superimposed on top of each other, but displaced laterally as shown.

— of the original picture. Each component FIH is formed from the corresponding positive color separation; Fig. 3 shows a typical recording geometry.

Two general techniques exist for this color encoding. In the one we are using (frequency encoding), parallel gratings of different carrier frequencies are used. The alternative method is angular encoding (θ modulation) in which the three gratings have the same spatial frequency but different orientation. Biedermann[1] has given a short review of these techniques. In general, with θ modulation an on-axis point source of light such as a Xenon lamp is used to illuminate the hologram and the zero-order transmitted beam is removed with a central stop. The projection lens must have a large aperture in order to collect all the first-order diffracted beams which, after passing through the appropriate color filter, are then imaged by the projection lens to form a color picture.[2] An alternative approach has been followed by Burton and Clay[3] who use a condenser system consisting of six prefiltered beams ($2 \times R,G,B$) derived from a quartz-halogen lamp to form off-axis illumination for the hologram. The projection lens collects the first-order diffracted light which emerges perpendicular to the hologram surface to produce a color image.

We have decided to use frequency encoding, since this leads to a simple condenser system. Fig. 4 shows such a color-encoded FIH. The carrier frequencies are chosen such that for read out using a collimated off-axis beam of white light, each component hologram diffracts its color perpendicular to the hologram surface. An on-axis spatial filter (slit) in the focal plane of the projection lens transmits the appropriate portion of the color spectrum and blocks the rest (Fig. 5). The picture projected onto the screen is a superposition of the red, green and blue images and is seen as a true color picture. Since the color encoding involves parallel gratings of different spatial frequencies, the parameters which determine the colorimetry of the system (source width, collimation and spatial filter width) are constrained in one plane only. Thus we are able to use an extended source (quartz halogen lamp) and spatial filter, each of which is 1 to 2 mm wide and about 20 mm long. In this case, the focal lengths of the condenser and projection lenses are 30 and 38 mm respectively

The primary colors are determined by their mean wavelength, λ_p, and spectral width $\Delta\lambda_p$. For a line source this spectral width is given by

$$\Delta\lambda_p = \lambda_p \; W/f \sin \alpha \qquad (2)$$

where W is the spatial filter width; and f is the projection-lens focal length.

For a readout angle α of 20°, the optimum value of W/f was found to be 1/25. This gives the following primaries:

	Red	*Green*	*Blue*
λ_p (nm)	650	530	460
$\Delta\lambda_p$ (nm)	76	62	54
S(lines mm)	526	645	744

where S is the spatial frequency of the corresponding grating.

For a line source, the primaries are rectangular with the spectral widths as given above; increasing the source width changes these primaries by sloping the sides of the rectangles resulting in loss of saturation and eventually overlapping of primaries (Fig. 6). A source width of about 1 mm has been found optimum for the system described here.

In practice, for any color encoding scheme, the color quality of the picture (colorimetry) is limited by a number of factors. Any values of λ_p may be chosen, as these correspond to the spatial frequencies of the carriers which are selected when the FIH is recorded. However, the other factors — source width, slit width, and the focal lengths of the condenser and projection lenses — are compromises between picture brightness and colorimetry. The effect of this compromise is shown in the chromaticity chart (C.I.E. diagram) in Fig. 7. The theoretical limits (for very small source and slit widths) to the colors which we can obtain are set by the triangle joining the λ_p points. However, the actual range of colors which is obtained with our parameters lies inside the triangle shown on the chart. It is important to note that our color quality is permanent, unlike color photography where slow bleaching of the dyes on exposure to light desaturates the primary colors and degrades the color quality.

The optical efficiency of these color-encoded FIHs must be considered in terms of a "white" area. In this area, all three gratings are present with similar modulation. In the absence of interaction between gratings, each grating has ⅓ of the incident light available to it and could diffract at best 34% of this light into the first order (theoretical maximum diffraction efficiency for a sinusoidal phase grating) giving an efficiency of about 11%. In fact, as we are using overlapping gratings, there are interaction terms which reduce the efficiency to about 7% for collection of a single first order. The use of a condenser system which illuminates the hologram symmetrically with two off-axis beams doubles the overall system efficiency since we collect the +1 order for one beam and the −1 order for the other.

The photosensitive medium which is used for recording the color-encoded FIH is positive working photoresist, Shipley AZ 1350. Exposure to light increases the solubility of the photoresist on development. Thus, the color-encoded FIH is recorded as a surface relief pattern. Replication techniques for such surface relief holograms have been developed in Princeton as part of the holotape program.[4] First, a metal master is made using suitable plating techniques. With this master, copies may be made by embossing into a thermoplastic, *e.g.* polyvinyl chloride, cellulose acetate, polyvinyl chloride-acetate or polycarbonate, using a roller press with heated rollers. The economies of the color-encoded FIH in the micropublishing business really depend on this replication process. When high speed replication techniques are used, *e.g.* 50 in./s, there is a large cost advantage compared with conventional micropublishing. This is particularly obvious in the case of color where the asymptotic cost of conventional color microfiche is 50 cents each in quantities of 1000 or more. Color encoded FIH microfiche would cost a few cents each to produce in similar quantities.

Reader

A number of compact, desk-top readers have been built to display color-encoded FIH microfiche. These readers demonstrate the quality and potential of color-encoded FIH microfiche and are not intended to be production prototypes. They are not compatible with conventional microfiche, but this feature could be incorporated with a minor alteration to the condenser optics. Two of these readers are located in Princeton under the charge of R.D. Lohman who should be contacted to arrange demonstrations.

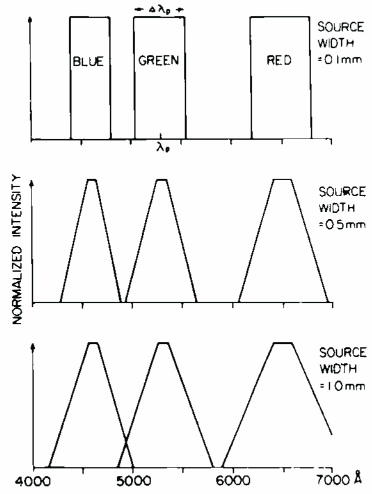

Fig. 6 — Spectral shapes of transmitted primaries for different source widths.

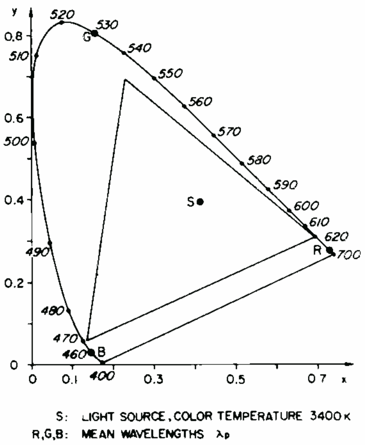

Fig. 7 — C.I.E. diagram for the present system.

The readers have a 15 × magnification to produce a 150 × 210 mm color picture on the screen from a 10 × 14-mm hologram. This low magnification ratio was chosen to enable us to use an inexpensive projector lens and to relax the mechanical tolerances in the construction of the readers; this will ultimately make the readers much less expensive to produce. The reader is shown schematically in Fig. 8. The lens housing and the slit are constructed as a single unit. Controls on the front panel allow adjustment of the picture focus and slit width. The minimum slit width is set at 1.5 mm. Increasing the slit width reduces the saturation. When the slit is fully open, the picture is presented in black and white with a threefold increase in brightness. The optical path is folded by means of four mirrors. The first two mirrors are mounted on a common adjustable block to give a fine adjustment for the picture on the screen. The condenser optic shown in Fig. 9 is unconventional. It consists of two prisms and two cylindrical lenses designed to form (in the horizontal plane) two collimated beams which illuminate the color encoded FIH symmetrically at ±20°. The microfiche replicas contain 40 pictures arranged in a 10 × 4 array; the replica is placed in a cassette before insertion in the reader. The position of the cassette is controlled automatically by a motorized X-Y stepping movement. This movement is performed by two motors operated from a four-function toggle switch mounted on the front panel. The position of the fiche is sensed by a sliding contact arrangement on the movement and shown on an LED display on the front panel.

Future work

Our work has shown that color-encoded FIHs have a large potential application in micropublishing. A critical analysis of the system as it exists today reveals several areas in which improvements are desirable.

In particular, the criticality of aligning the lamp with respect to the condenser optic, the desirability of producing brighter pictures and improving the colorimetry. An R and D program is in progress to improve the system in these areas.

Acknowledgments

The authors are indepted to D. Meyerhofer and R.J. Ryan for replication studies performed in Princeton and the A.H. Firester for many valuable discussions and for calculation of the superimposed grating efficiencies.

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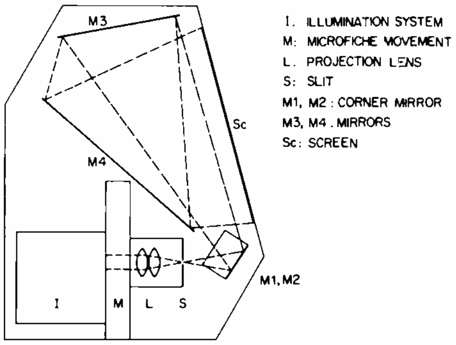


Fig. 8 — Microfiche reader for color encoded FIH.

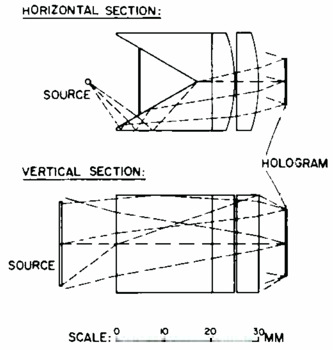
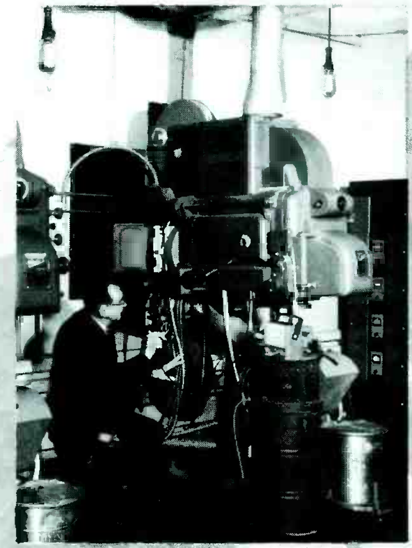


Fig. 9 — Condenser system.



Servicing theatre film projector.

RCA Service Company Training Center.

RCA Service Company tv branch.

Servicing shipboard electronic equipment.

BMEWS radome, Thule, Greenland.

RCA Service Company: worldwide services

R. W. Alnutt

The international operations of the RCA Service Company are broad-ranging and many-faceted and, like the domestic operations, encompass consumer, commercial, industrial, and government customers. From its home offices in Cherry Hill, New Jersey, the Service Company extends the service arm of the corporation around the world. At the end of that arm may be one man in Israel, helping bring television to Tel Aviv, or hundreds in Greenland maintaining 24-hour-a-day operations at a Ballistic Missile Early Warning System site for the U.S. Air Force.

Dowrange electronic shop in the Bahamas refurbishes equipment for later tests on AUTEC ranges.

RCA Service Company AUTEC recovery team retrieving experimental torpedo after test run.

Kwajalein TRADEX-PRESS radar installation

Mobile van with repair and measuring equipment.

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Final manuscript received August 28, 1974.

The Service Company's "man in Israel" illustrates, on a small scale, the blending and meshing of inter- and intra-divisional efforts to achieve customer goals. In 1973, the Israel Motion Picture Studio, which provides television broadcasting to the Israeli nation, purchased its first RCA color mobile unit from RCA's Government and Commercial Systems. No off-the-shelf assemblage, this outside broadcast van was custom designed and fabricated specifically for the customer. RCA Service Company's Technical Services contributed the facilities of its Custom Repair and Engineering Shop to help the Commercial Communications Systems Division prepare the van for shipment. The Service Company's Government Services headed up the installation and checkout effort and sent a system service technician to train Israeli studio personnel in the operation and maintenance of the van's broadcast equipment. This technician also served as technical advisor during the mobile unit's first and extremely important assignment: coverage of the 25th Independence Anniversary parade in Jerusalem.

This episode is repeated, with variations, many times each year and is representative of the teamwork that provides RCA's foreign and overseas customers with services similar to those offered domestically. In the instance cited, Service Company functioned in its traditional role as service arm to the corporation, providing installation, maintenance, and operational and training services in connection with RCA products. Over the years, however, Service Company has widely expanded from that traditional base and now provides similar services for other manufacturers and large-scale users of electronic equipment, both domestically and on the international market.

The operating elements of RCA Service Company that carry out these services include three domestic operations — plus the Service Divisions of two foreign subsidiaries, RCA Limited (Canada) and RCA Limited (United Kingdom) as shown in the Organization Chart.

Of these five activities, Government Services has the broadest franchise to conduct operations worldwide. A primary reason for this is that government agencies, both American and foreign, are among the largest customers for exported American technical knowhow.

While Consumer Services and Technical Services concentrate their direct operations in the domestic market, they are responsible for furnishing business guidance to their RCA Limited counterparts in Canada and Great Britain, thus maintaining a meaningful role in the international marketplace.

Consumer Services

The product lines from these domestic divisions are quite varied. Consumer Services, of course, is best known for installing and maintaining RCA home entertainment equipment through its nationwide chain of service branches. Over half the branches also service a wide range of Whirlpool Corporation appliances.

Approximately 3,000 specially trained technicians are employed in the 180 service branches, performing four million service calls a year. Over one million service contracts are currently in force. In addition to the hundreds of tubes and parts inventoried in each service truck, many thousands of parts are stocked in each branch, creating a parts investment of over three million dollars. Each of the 2,700 service trucks covers approximately 12,000 road miles a year.

To maintain the skill levels of the tv service technicians and appliance servicemen, Consumer Services has five training centers located in key areas of the United States. These centers offer a variety of continuing and specialized courses designed to upgrade skills as new and more sophisticated products come into service. The centers, in operation since 1967, are each comprised of 7,200 square feet and have large lab areas for "hands-on" training.

A second and still growing facet of Consumer Services is Commercial Product Sales, which started in 1958. This activity sells and leases television receivers, electronic systems, telephone systems, and a variety of support equipment to hotels, motels, schools, hospitals, and nursing homes. It integrates product, system design, installation, and service into a single source package — either lease or direct sale — for the demanding institutional market. Service Company is the largest supplier of tv sets and systems to the hotel/motel market. Accessory items include sound systems, message at desk, background music, wake-up alarms, room status, maid call systems, remote control hand units, nurse-call, and related communications features.

The newest activity within Consumer Services is RCA Telephone Systems, which involves the leasing, installation, and servicing of complete internal telephone systems. It is a natural addition to the Commercial Products line, particularly in the hotel/motel market, where Service Company salesmen have established day-to-day contacts. This burgeoning market — created as a result of a 1968 court decision permitting non-telephone company equipment to interface with telephone company trunk lines — has been bolstered by the evolution of RCA's Model 600 EPABX. This innovative switching unit, produced by the RCA Government Communications and Automated Systems Division, offers new standards in economy, reliability and efficiency for business communications.

Technical Services

RCA Service Company's Technical Services has expanded in recent years into a broad-based commercial and industrial service business. Initially this activity concentrated on installation and maintenance of a variety of RCA-manufactured equipment. As a result of aggressive new marketing efforts begun in the 60's, however, the bulk of its business today involves equipment manufactured by other firms.

Six service lines comprise Technical Services — Broadcast, Theatre and Industrial, Mobile/Microwave, Marine, Data Systems, and Data Communications. The first four are the traditional businesses. The latter two have taken shape over the past few years, and their growth pattern demonstrates continuing enormous potential.

Broadcast Service concentrates on installation and maintenance in such areas as television and radio broadcast transmitters and studio equipment. Each technician is a specialist in his field — thoroughly schooled in the equipment he services, as well as in all FCC rules and regulations. It also provides interdivisional shop support for custom fabrication, such as the Israeli broadcast van cited earlier.

Theatre and Industrial Service supports theatre sound systems and industrial electronics.

Mobile/Microwave Service provides complete installation and service facilities to users of RCA and other makes of vehicle fleet and microwave communications equipment.

Marine Service furnishes the services of FCC-licensed technicians to maritime users of communications and navigation equipment. It also supplies parts to customers in foreign ports where no RCA facilities are available.

Data Systems Service, among the newer of Technical Services' lines, maintains computerized airline reservation systems. As a subcontractor to RCA Limited (United Kingdom), this activity supports the American facilities of the British Airways communications network.

Data Communications Service, Technical Services' leading growth activity, leases, installs, and services teleprinters and associated peripheral equipment to commercial users of common-carrier and private-wire business communications networks.

RCA Limited (Canada)

RCA Limited in Canada (highlighted in the April/May *RCA Engineer*), is the most important RCA operation outside the United States. Consistent with that position, its 400-man Service Division generally provides the same broad services to consumers and commercial and industrial customers as its Service Company counterpart in the United States. Its fifteen consumer service branches provide installation and maintenance support to RCA television and stereo equipment — equipment, incidentally, that is designed and manufactured in Canada by RCA Limited. They also service a full line of household appliances that are marketed in Canada under the RCA name.

In the commercial sector, the Service Division in Canada supplies, installs, and maintains a variety of information, distribution, and control systems. These include data communications systems, whose use is expanding rapidly in Canada; CATV studio equipment and hotel room-status systems; closed-circuit television, which is being used in traffic control, industrial security, and a variety of hospital and other institutional applications; and sound systems. Sound systems installed and maintained by RCA Limited include sophisticated installations in cultural centers, such as Ottawa's National Arts Center, Montreal's *Place des Arts*, and the Centennial Concerts Halls in Winnipeg and Regina.

RCA Limited (United Kingdom)

Until 1960, and the start of work on the Ballistic Missile Early Warning System project, RCA services in Great Britain were confined primarily to theatre sound and projection system servicing. With the advent of BMEWS and the establishment of BMEWS Site III at Fylingdales, Yorkshire, RCA's service activities began to expand. A strong technical organization was developed in the process of supporting that complex defense installation, and this has provided the base for today's diversified service operations.

Services to commercial and industrial customers include data processing, utilizing the computer at RCA's Sunbury-on-Thames facility, and hotel/motel system servicing, principally of RCA's room status and message panel units.

Services to the broadcast industry have expanded steadily in recent years. Besides supporting broadcasters in Great Britain, RCA Limited has also participated in the establishment of television, radio, and other communications facilities in such places as Austria, Saudi Arabia, Iraq, and Nigeria. The Service Division also has been highly successful in the data munications field, with a major contract for servicing the computerized reservation system for British Airways.

RCA Limited receives subcontract support for this international effort from four other divisions including, as cited earlier, RCA Service Company's Technical Services activity in the United States.

The theatre service activity continues to be a steady source of business, as does BMEWS. RCA Limited has been the sole contractor for the operation and maintenance of BMEWS Site III since it became operational in 1963.

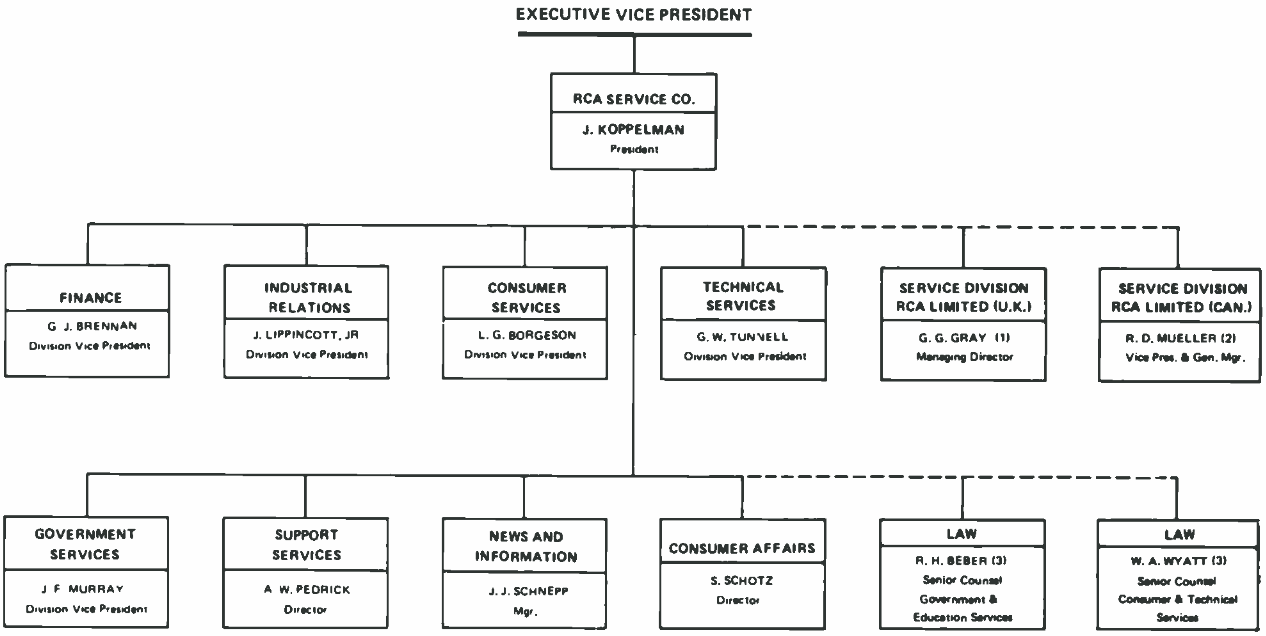
Government Services

BMEWS services have long been associated with the Government Services operation of RCA Service Company. This organization assisted with the development of the BMEWS Site III capability in Great Britain as part of its broader responsibility for system installation and integration in support of the Missile and Surface Radar Division, which was prime weapon systems contractor to the U.S. Air Force. And Government Services has operated and maintained the North American installations of BMEWS for all but three of the 14 years the system has been operational.

BMEWS is but one example of Government Services' international operations – neither the largest nor the oldest. This activity places no geographic limitations on its services.

From the Arctic reaches of North America to the Union of South Africa, from Spain to the Middle East to far Japan, it sends its technicians and

Richard W. Alnutt, Government Services Marketing, RCA Service Company, graduated from Auburn University in 1956 with a BA in English. As a writer and editor of Government Services technical publications from 1956 to 1965, he edited systems manuals and handbooks for RCA and contract customers in such fields as infrared technology, radiobiology, and closed-circuit television. He coauthored two volumes of the Air Force handbook, *Techniques of Physiological Monitoring*, and for two years he supervised a team of report writers documenting propellant-actuated device development. Other assignments included DEP Marketing Services, RCA Laboratories, and the Astro-Electronics Division, where he edited reports and wrote film scripts for the Ranger spacecraft program. Since 1965 he has been with Government Services Marketing, where as writer and editor he contributes to the preparation and enhancement of competitive proposals, news releases, brochures, and other marketing documentation.



(1) REPORTS ADMINISTRATIVELY TO THE BOARD OF DIRECTORS, RCA LIMITED (U.K.) AND FUNCTIONALLY TO THE PRESIDENT, RCA SERVICE CO. FOR BUSINESS GUIDANCE.

(2) REPORTS ADMINISTRATIVELY TO THE PRESIDENT, RCA LIMITED (CANADA) AND FUNCTIONALLY TO THE PRESIDENT, RCA SERVICE CO. FOR BUSINESS GUIDANCE.

(3) REPORTS TO THE STAFF VICE PRESIDENT AND GENERAL ATTORNEY, CONSUMER PRODUCTS, COMPONENTS AND SERVICES

RCA Service Company organization chart.

engineers — one at a time or by the hundreds — to furnish quick-reaction services or broad-ranging system support in a large variety of technical fields.

Since 1972, RCA has also operated and maintained the Distant Early Warning System. Over 700 specialists are employed outside the United States in manning the radar and communications stations of the DEW Line, which stretches from Alaska across Canada to Greenland, on a line paralleling and only slightly south of the Arctic Circle. Predating the missile-era BMEWS by several years, the DEW Line monitors aircraft movement across the northern edge of North America and, through outstations in Iceland and Great Britain, ties in to the defense communications network of NATO.

BMEWS Site I, in Thule, Greenland, was the first BMEWS radar station to go operational in 1960. RCA Government Services presently has over 300 personnel located there. Besides operating and maintaining the radar and data systems for the U.S. Air Force, RCA crews provide the base support and housekeeping services that make living as well as technical operations possible in that remote, near-Arctic environment. RCA also furnishes complete logistical support to the host U.S. Air Force activity at Thule Air Base. Similar services are also provided to BMEWS Site II, located in the northernmost section of the United States at Clear, Alaska.

With over 20 years of continuous service, RCA's Missile Test Project is the oldest of Government Services' ongoing projects and the largest, with 1,000 assigned personnel. Headquartered at Patrick Air Force Base in Florida, this project has been instrumental in the successful function of the U.S. Air Force Eastern Test Range, which has supported America's missile development program and has furnished the launch and tracking capability required for both our manned and unmanned space programs.

Some 300 RCA personnel operate and maintain the downrange tracking stations of the Eastern Test Range, which extend from Bahamian cays to the British West Indies to Ascension Island in the South Atlantic. A major radar station is also located near Pretoria in the Union of South Africa and a major range communication center is located on the Seychelles Island of Mahe in the Indian Ocean.

Government Services project teams also furnish a variety of contract services to the U.S. Navy in the Atlantic area. Over 500 are assigned to the Atlantic Undersea Test and Evaluation Center on Andros Island in the Bahamas, providing instrumentation, communications, and data processing support for the testing of developmental Fleet weapon systems. Another 200 operate and maintain facilities associated with the Roosevelt Roads Naval Station in Puerto Rico. These include the Atlantic Fleet Weapons Range, where Government Services provides instrumentation and communications services and operates and maintains a fleet of drone (target) aircraft used on the range; the Navy's FORACS II facility at Roosevelt Roads, which is used to calibrate ship's instrumentation and navigation aids; and a major Naval communications center at Isabela.

In support of the Missile and Surface Radar Division, Government Services also provides depot-level support of the NASA radar system on Bermuda.

Government Services currently has about 50 personnel on assignments in Europe and the Near East. Primarily under U.S. Air Force contract, these men serve variously as service representatives to allied military units in Spain and Greece, operate a calibration facility for the Iranian Air Force, and support data collection operations for the U.S. Air Force in West Germany.

Another Government Services team in Spain, working under direct contract with *Servicios Tecnicos de Electronica*, S.A., a major Spanish electronics firm, supports the maintenance and operation of Spanish Air Force microwave and radar facilities.

Government Services also provides depot-level maintenance to RCA radar systems at Aberporth, Wales, under subcontract to RCA's Missile and Surface Radar Division.

In earlier years, Government Services provided extensive support to the communications requirements of NATO. Installation teams helped install RCA microwave systems for the Spanish Air Force and the Allied Air Force in Western Europe. For the U.S. Air Force, Government Services also installed and supported the 412L Air Weapons Control System and the RCA-produced elements of the 486L VOCOM system. Additionally, it operated large-scale test equipment calibration depots — initially in France and later in Spain — that served all U.S. Forces in Europe.

The largest ongoing Government Services effort in the Pacific area is the intracorporate support of the TRADEX installation on Kwajalein Atoll, where some 85 RCA Service Company personnel support the radar and data processing effort under the prime contract held by the Missile and Surface Radar Division. RCA Service Company assisted in the initial installation of this sophisticated missile signature radar installation in 1959 and has furnished maintenance and operational support since that time.

Other Service Company efforts in this area have extended from maintenance of Naval communications facilities in Japan to testing of U.S. Army microwave systems in South Vietnam and Thailand ... from Air Force communications engineering in Hawaii to installation of NASA ground station equipment in Australia. Radar personnel provide depot support to the Missile and Surface Radar Division for RCA systems at Kwajalein and on Canton Island, and naval systems personnel from Government Services' Springfield, Virginia, engineering office support the installation of U.S. Navy shipboard weapons systems into units of the Japanese Maritime Self-Defense Force.

During the height of the American military presence in South Vietnam, from 1966 to 1970, RCA played a central role in the establishment of television broadcasting in that nation under a program instituted by the Joint U.S. Public Affairs Office.

Under U.S. Army contract, Service Company's Government Services furnished network engineering support for the establishment of the broadcasting facilities, which were to be operated in part by the Armed Forces Vietnam Network and in part by the Republic of Vietnam. Government Services also provided installation assistance to NBC International at the Saigon National Television Center, which NBC had contracted to operate and maintain for the RVN.

While these facilities were being constructed, broadcasting was implemented from airborne television stations under the U.S. Navy's Project Jenny. Navy Super Constellations were equipped with RCA-manufactured studio and transmitting equipment that had been extensively modified by RCA's Commercial and Communications Systems Division to operate in the demanding flight environment. Government Services personnel supervised installation and operated and maintained the equipment. During nearly 5 years of flight broadcasting, they logged a total of 11,000 hours of news, information, and entertainment — up to 15 hours a day at the peak of activity.

Currently some 2,000 of Government Services' 5,300 people are employed outside the United States under a variety of contracts.

In recent years Government Services has also taken a leading role in providing educational programs for society's disadvantaged under federal, state and local government contracts. The education and training services performed range from the custom-designing of curricula and training materials to complete management and operation of large-scale residential centers providing prevocational, vocational, academic and social education.

One of Government Services' major educational projects is the Keystone Job Corps Center near Hazleton, Pennsylvania, with a resident population of 500 young women. Service Company has operated the Keystone center since its inception in early 1967, under contract with the Department of Labor.

Service Company also supports the Manpower and Career Development Agency in New York City, one of the nation's largest manpower training projects. The MCDA Program provides year-round training to an ongoing student body of 1,800 trainees. The program, under contract to New York City's Human Resources Administration, provides training and employment services for socially and economically deprived men and women selected from the city's five boroughs. Since its inception the program has served more than 17,000 persons.

Conclusions

In one form or another the RCA Service Company has been providing service since the formation of RCA in 1919. Today it is one of the world's largest service organizations. In recent years, as service has dislodged manufacturing as the most vital force in the economy, the Service Company has taken an increasingly important role among the major RCA divisions. As new servicing requirements have developed in line with the swift changes of modern technology, the Service Company has been quick to react, eliminating or decreasing emphasis on activities on the decline and developing the needed skills and personnel to meet the new opportunities as they arose.

Just ten years ago the Service Company's traditional businesses accounted for all but 2% of the sales. Today the traditional represents less than half the company's sales. The trend is expected to continue. With the increasing need for service adaptability and with every indication that service will continue to widen the gap over manufacturing, the RCA Service Company looks forward to a steady expansion throughout the forseeable future.

Designing integrated circuits in Europe

M. Riley| L. Avery| R.T. Griffin

The continuing rapid growth of the European electronics industry, together with requirements to produce both custom and standard IC's for this market, has provided RCA with considerable incentive to design the required IC's for both COS/MOS and linear product lines in Europe. Over the past year, design groups have been established at the RCA facility at Sunbury-on-Thames, the same facility that houses existing marketing, sales and applications groups serving the IC product lines in Europe.

EARLY IN 1973, the COS/MOS design group at Sunbury consisted of two engineers. The great emphasis placed on major growth of the European COS/MOS market has increased the size of this group dramatically. Similarly, the linear group, which consisted initially of one engineer, has grown rapidly to the point at which it can now support the design programs of a number of major consumer-product manufacturers.

COS/MOS design

The COS/MOS design group began by designing two custom circuits for European customers: a circuit for an electronic automobile clock and a watch circuit. However, the rapidly growing market in standard (CD4000A-series) parts, and the necessity to expand the product range in the face of increasing competition from other sources, has resulted in an increasing group commitment to the design of circuits for inclusion in the standard-parts family. To date, the COS/MOS group has produced many standard circuits (Table I) and additional standard parts are currently in the design and layout phase.

The COS/MOS design group is responsible for a proposed circuit from its inception and through the stages of detailed logic and circuit design to layout at a scale of 500X. In the case of a custom circuit, the design is established by engineering discussions and breadboarding carried out by the customer aided by RCA sales and applications engineering teams. The feasibility of a new standard part design is established by marketing and applications-engineering personnel in response to an identifiable need. Maximum use is made of C-MOX, the RCA standard-cell library which consists of a set of digital "building blocks" stored on magnetic tape. Digitizing is then carried out, the end result being a magnetic-tape containing the complete circuit layout in coded form. A test specification is also written during this phase of development.

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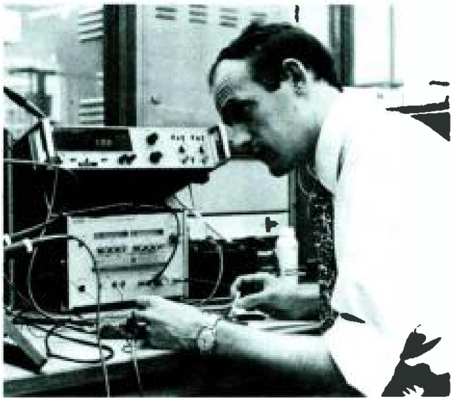
COS/MOS — circuit layout — Sunbury.



Linear ICs — i.f. testing — Sunbury.

COS/MOS — digitizer plotter system — Sunbury.

Tapes are processed through the CRITIC design-rule checking program developed by the Design-Automation Group at the RCA Laboratories, Solid-State Technology Center. The results, in the form of a printout and error plot showing faulty data, provide the material from which a final, corrected version of the tape can be prepared. Integrated-circuit masks are then prepared from this corrected tape, and samples are produced in the model shop. The samples are evaluated and tested and, provided the performance meets the original specification, the circuit is released for production.

Currently the time needed to process tapes and error plots causes a delay in the total production time of each circuit. A program is now underway to eliminate these delays by making use of a data link with the IBM 370/158 computer available to the design center. The link will be used to transmit circuit files, and will also give the design group direct access to CRITIC and RCA's circuit analysis program, R-CAP.

Table I — Some COS/MOS circuits designed at Sunbury

CD type	*Description*	*Package*
CD4069A	Hex inverter	14 lead
*	32 bit R/L shift register	16 lead
CD4067A	16:1 multiplexer	24 lead
CD 4097A	Dual 8:1 multiplexer	24 lead
CD4011A	Quad 2 input NAND	14 lead
*	Parity generator	14 lead
*	Dual 2. I/P NAND buffer	14 (8) lead

*Commercial number not yet assigned.

Linear IC design

The special requirements of the European consumer market and the necessity of working very closely with the electronics manufacturers (OEM) during all phases of design were the prime reasons for establishing a European LIC design facility. Initiated in mid 1973, the group has already designed circuits, and several more are planned for 1975.

Requests from electronics manufacturers for a specific LIC function or system are transmitted to Marketing by a salesman. These requests are then examined for business opportunity by Marketing. At the same time, technical feasibility and rough cost estimates are prepared by Engineering. If the proposal presents a good business opportunity, further discussions are held with the customer to establish a firm specification and approximate timescale for various developmental phases.

When a project is approved, a breadboard of the system is constructed and evaluated against the specification Close cooperation between the design team and the customer is maintained during this phase of the development so that any problem areas may be quickly resolved.

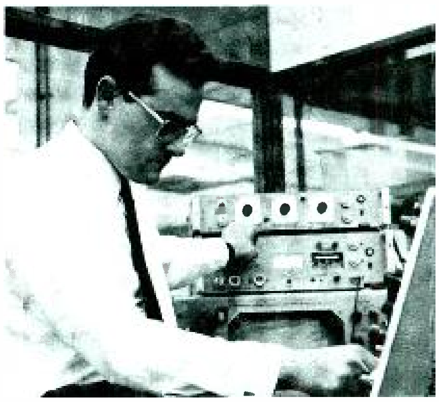
When the capability of the breadboard to meet the specification has been proved, layout of the IC chip is started. Unlike COS/MOS layouts, the LIC team does not use computer-aided design methods; there are basically two reasons for this:

1) Few standard "cells" are employed in LIC design other than the basic transistors, and even the layout of these is kept flexible to ease placement of connections, metal runs, *etc*.
2) More effective use of the silicon area is possible using the flexibility of the human brain.

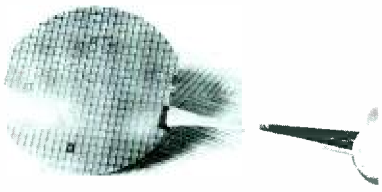
When the layout is completed, detailed drawings are prepared and sent for checking and mask making. Samples are produced from these masks in the model shop. The samples are then returned to the IC designer and customer for testing and evaluation. Any problem areas are resolved and a final layout initiated using the procedure described above. When devices meeting the full performance criteria are obtained, test limites are agreed on and a production schedule established.

L. Avery, Engineering Manager, Linear IC's, Sunbury, England has been with RCA for five years. He has previous experience in the medical-electronics field in the design of an advanced-concept EEG machine with a direct link to a computer to permit instantaneous analysis. Mr. Avery holds two British patents and has two others pending. In addition to his responsibilities with RCA, he is also a part-time college lecturer in tv systems.

R. T. Griffin, Engineering Leader, COS/MOS Design Group, Sunbury, England, has been with RCA Solid State for four years. Previously, he was a senior engineer at Transitron where his major responsibility was in TTL design. Before that Mr. Griffin was involved in the development of semiconductor memories at Ferranti. He holds a BSc in Special Physics and an MSc in Solid State Electronics.



Linear ICs — author L. Avery testing a stereo decoder — Sunbury.



COS/MOS — custom watch circuit wafer designed in Sunbury for Portescap.

COS/MOS — author R. Griffin testing an engineering sample.

RCA Research Laboratories, Inc.

(Tokyo)

Dr. B. Hershenov

Over the years, the RCA Research Laboratories, Inc. has established an excellent reputation in the Japanese scientific community for high caliber scientific work in solid-state plasmas and magnetic semiconductors. More recently work has been extended to the areas of microsonics, electrochemistry studies for displays, phosphors, and solar cells.

Fig. 1 — "Welcome to RCA" — main entrance.

Fig. 2 — Dr. Yasuo Wada at polarizing microscope used for magnetic bubble studies.

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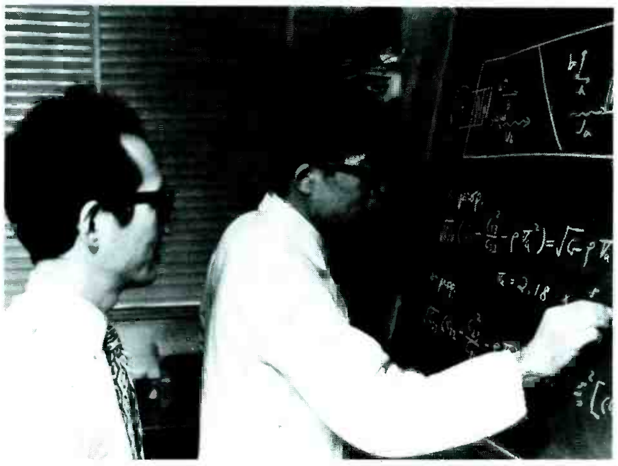

Fig. 3 — Dr. Minoru Toda (left) and Dr. Soitiro Tosima analyze acoustic material for electronic phase tuning.

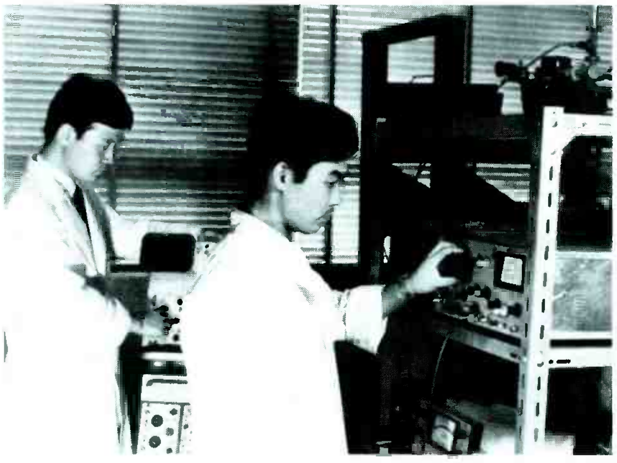

Fig. 4 — Microwave magnetic resonance studies of bubble materials (Kenichi Minimatsu in the foreground).

THE RCA Research Laboratories, Inc. was established in Tokyo in 1960 to conduct fundamental and applied research in electronics and to provide a link between American and Japanese scientific communities. Although it is a separate research organization, RCA Laboratories, Inc. is managed by the RCA Laboratories in Princeton, N.J. At first, it shared space facilities in Tokyo with RCA Engineering Laboratories, Inc. At that time a single administration group served both the Engineering and Research Laboratories.

As the Laboratories grew and the scope of work increased, new facilities — properly equipped for both chemical and electronic research — were necessary. In 1967, the research group moved to its own building in Machida, a suburb of Tokyo. In 1970, an extension to the building increased the floor space, while additional land purchases provided the facility with beautiful surrounding grounds. At the present time, the building has floor space of about 16,000 ft^2 with surrounding property of about 240,000 ft^2. The site includes heavily wooded areas as well as beautifully landscaped grounds with shrubs, flowering trees and

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Fig. 5 — View toward front entrance of RCA Research Labs, Tokyo. Former rice paddies and bamboo trees in foreground.

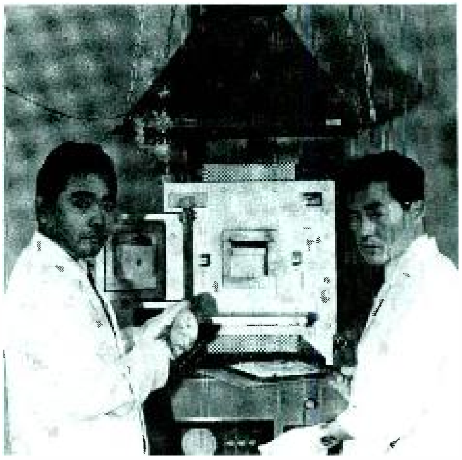

Fig. 6 — Furnace for flux growth of crystals.

bushes, bamboo trees, and a small 4-hole golf course constructed by the employees on recently acquired rice paddy fields. (By various permutations of the four holes, the course has been used as a 9-hole course by employees of the Laboratories and other Tokyo RCA operations).

The building is equipped with the facilities necessary to conduct its own programs, and includes low-frequency through GHz-frequency instrumentation, magnets, vibrating magnetometer, absorption spectrophotometer, x-ray and optical spectrometric equipment, photolithographic facilities, machine shop, and library as well as equipment for synthesizing, growing, alloying, chemically treating, cutting, and grinding crystalline solids. Fig. 1 to 13 show portions of the laboratory facilities and some members of the staff.

The members of the professional staff are scientists with backgrounds in physics, physical chemistry, and electrical engineering; all are Japanese with the exception of the Research Director.

Organization

The Laboratory is divided into the following four groups:

Administration	Mr. A. Ikeda, Mgr
Applied Physics	Dr. S. Tosima, Mgr
Materials	Dr. F. Okamoto, Mgr
*General Research	Dr. R. Hirota, Mgr

Each group manager reports directly to the Research Director, who in turn, reports to Dr. Jan Rajchman, Staff Vice President at RCA Laboratories in Princeton, N.J.

The Administration group is responsible

Fig. 7 — Kohei Ametani at atomic absorption spectrophotometer for quantitative analysis of materials.

Fig. 8 — Technical Staff Member, Kimio Suzuki (standing), observes optical probe system for measuring acoustic surface-wave velocities.

Dr. Bernard Hershenov, Director of Research RCA Research Laboratories, Inc., Tokyo, received the BS in Physics in 1950, the MS in Mathematics in 1952, and the PhD in Electrical Engineering in 1959, all from the University of Michigan. While attending graduate school, he performed research in the University's Dental Materials Laboratory and in its Engineering Research Institute. He joined the Microwave Research Laboratory of RCA Laboratories in 1960, and in 1968 was named Head of the Microwave Integrated Circuits Group, the position he held prior to his present appointment in 1972. At RCA Laboratories he has done research on space-charge waves in electron beams, crossed field amplifiers, ferrite devices, magnetic semiconductors, and microwave integrated circuits. Dr. Hershenov was awarded RCA Laboratories Achievement Awards for his outstanding research on a crossed field amplifier and on ferrimagnetic devices in 1963 and 1966, respectively. He has been active in both the Professional Society on Magnetics, in which he is the incumbent Secretary-Treasurer, and the Professional Group on Microwave Theory and Techniques of the IEEE. From 1964 to 1966 he was coadjutant in the Mathematics Department of Rutgers University. Dr. Hershenov is a Fellow of the IEEE, a member of Phi Kappa Phi, the American Physical Society, Sigma Xi, and he is listed in "American Men of Science."

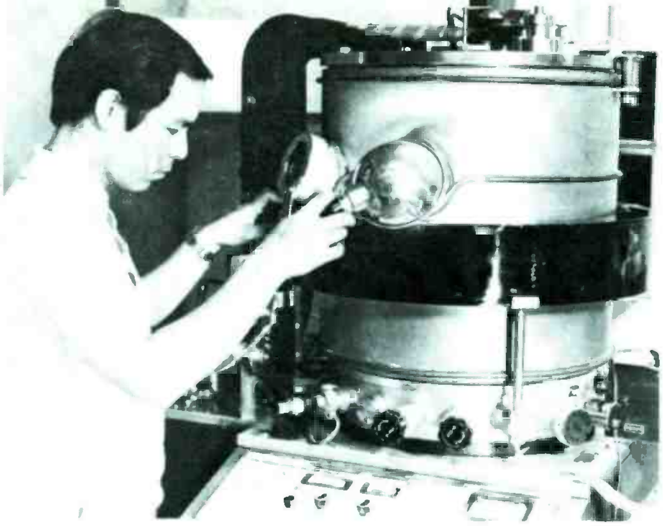

Fig. 9 — RF sputtering equipment.

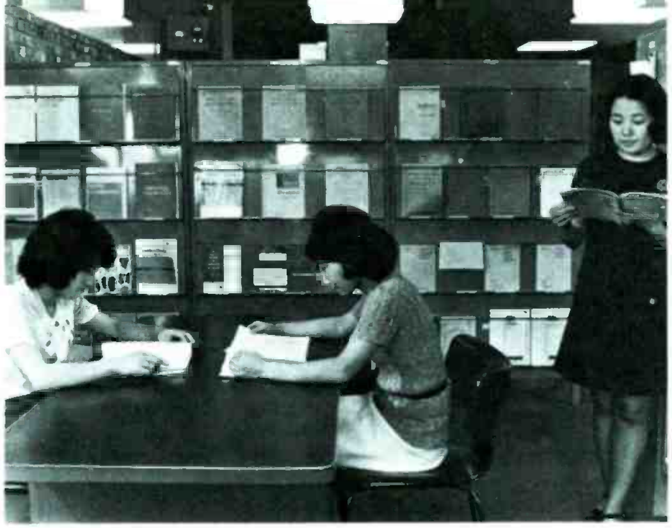

Fig. 10 — Periodical room in library: Librarian, Mr. Yong Won Kim is standing at right.

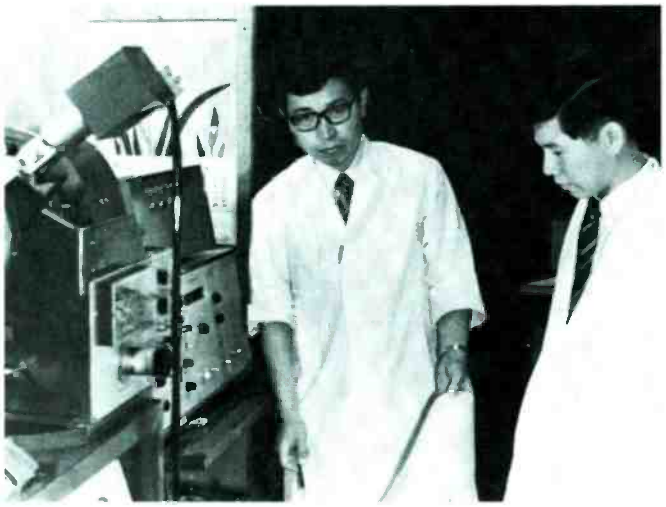

Fig. 11 — X-Ray diffractometer for crystal-structure analysis.

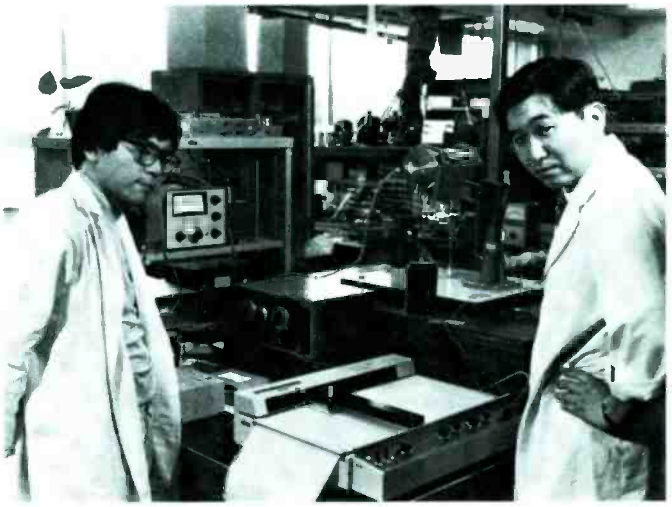

Fig. 12 — Cahn magnetic balance measurement system (Dr. Tatsuo Takahashi, right).

Fig. 13 — Czochralski growth of single crystals (Katsuhiro Kato).

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for indoor and outdoor plant facilities, library, personnel, accounting, office operations, and in general the usual administrative functions associated with any business.

The research groups keep abreast of the scientific and technological developments in Japan as well as the current programs at the Princeton Laboratories and the rest of the company. The present activities of the three research groups, in terms of recent and current programs, can be loosely defined as follows:

Applied Physics — This group is investigating the physical properties of acoustic and magnetic materials with emphasis on potential applications. More recently, studies of aqueous deposition of *CdS* for inexpensive large-area solar cells for terrestrial applications were initiated.

Materials Research Group — Both independent and cooperative research programs in the areas of new materials and new technology for current programs are carried out. Acoustic and magnetic materials are prepared and two new programs in the areas of cathodoluminescence and electroluminescence, as well as an exploratory investigation of aqueous-solution pH variation for displays, were begun. It is worth noting that a well-facilitated chemical analysis area to determine the composition of prepared materials and to develop new analytical procedures does exist.

General Physics - This group carries out basic theoretical and experimental work, generates ideas for new areas, and provides assistance to the other groups with their programs. Currently, basic work in the magnetic, acoustical and optical areas are under investigation along with a new program in the liquid-display area.

An outline as given above falls far short of providing the reader with anything more than a flavor or insight to the Laboratory's current activities. It is impossible in a survey paper of this type to cover in detail all the work in progress. As a compromise solution, a few details of some of the existing and recently initiated programs along with a brief sketch of other technical work are presented. The newly initiated programs represent a shift to programs more closely allied to work and areas of interest to both RCA and the Japanese electronic industry.

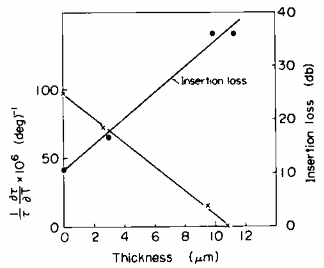

Fig. 14 — Delay-time-temperature dependence and insertion loss *vs*. silicon dioxide film thickness.

Acoustics

This area of activity was established to provide support for the signal-processing work at the Advanced Technology Laboratory in Van Nuys and, to a lesser extent, the tv i.f. filter work in Princeton. At the present time, this activity is the oldest of all current programs.

Microwave acoustic delay lines, by virtue of their low velocities and short wavelengths, have opened up a variety of new applications in communications and radar. These compact low-loss delay-line devices, which are compatible with microelectronic circuit technology, store wideband signals and complex coded waveforms and can compress, expand, and decode these waveforms when required. Acoustic surface-wave devices permit access to the signal at any point between input and output, thereby leading the way to tapped delay lines, analog matched filters, and the entire area of signal processing. Nonlinear processes may obviate the need for specially designed coded transducers. Acoustic filters can replace lumped-element television i.f. filters and eliminate the expensive individual tuning required heretofore. Furthermore, the long delays suggest data-storage and rf-memory applications. Delay and recirculation of a video signal with suitable amplification would permit a video display of several minutes (newspaper, text, *etc.*) without continual transmission and associated tie-up of a channel. Surface-wave acoustic devices convert electrical energy to acoustical energy (and *vice versa*). The transducer, a pattern of metallic electrodes desposited on a substrate surface, converts an electromagnetic signal to a time-dependent spatially varying electric field pattern. The field pattern generates an acoustic wave on the substrate by the piezoelectric effect of the substrate. The substrate provides the acoustic delay path and conversion of electrical-to-acoustical energy.

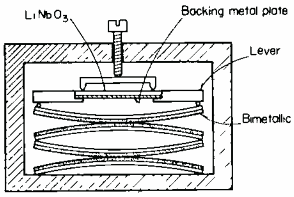

Fig. 15 — Schematic of stacked thick bimetallic-plate structure.

Cancellation of Delay-time-temperature dependence

Multiple-tapped matched-filter delay lines provide both signal-to-noise ratio improvement and decoding functions. However, they are extremely temperature sensitive because of the temperature-dependent-delay-time and resonance-frequency change. As the frequency of correlation changes, the peak amplitude decreases and a 3-dB loss in peak amplitude for a 15°C temperature change is not unreasonable.

Two different techniques were investigated to cancel the temperature effect. The first method used a SiO_2 film on $LiNbO_3$. The elastic-constant-temperature dependence of SiO_2 is opposite to that of $LiNbO_3$, and a total cancellation of temperature coefficient was measured for a film thickness of about 10μm (see Fig. 14). The method, though technically successful, proved to be impractical because the cancellation was accompanied by a large insertion loss.

The second tecnnique utilized a structure consisting of bimetallic strips to which the $LiNbO_3$ delay device was attached. This structure has a temperature-dependent mechanical strain that changes the acoustic-wave path length so that both delay-time and transducer-resonance-frequency changes are completely cancelled. A complete design procedure was formulated, and several different structure configurations were fabricated and successfully tested.[1] One structure, using a stacked array of thick bimetallic strips is shown in Fig. 15. The delay-time-temperature coefficient of $LiNbO_3$ itself (94ppm °C), was completely cancelled over a 30°C temperature range with the insertion loss unchanged. The complete device package for a $LiNbO_3$ sample 12.5mm long, 2.9mm wide, and 0.6mm thick was 16×24×37mm³, excluding cable connectors (see Fig. 16). This package is rugged, compact, and does not require a small oven-temperature control or electronic control circuits. This same technique can also be applied to the tv filter, although temperature sensitivity is not as critical as for a tapped delay-line signal processor.

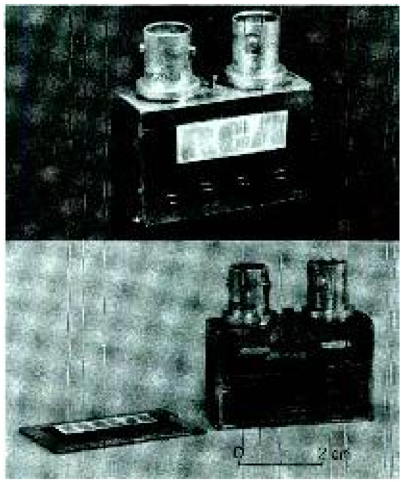

Fig. 16 — Top, packaged bimetallic-plate structure with sample. Bottom, view of stacked bimetallic plates.

Electronically variable delay line

An electronically variable delay line, using either bulk or surface acoustic waves was demonstrated with $Gd_2(MoO_4)_3$, a ferroelastic and ferroelectric material.[2] Fig. 17 schematically portrays two ferroelectric domains separated by a single domain wall. The electric polarization is indicated by arrows collinear with the *c*-axis. If the sample were a single domain, a compressional stress applied along the *b*-axis of the crystal would produce a deformation linear with stress until a critical value (coercive stress point) was reached. At this value, the *b*-axis is suddenly compressed into the *a*-axis and the *a*-axis is elongated and becomes the *b*-axis. When the stress is removed, the deformation remains and the *a* and *b*-axes remain interchanged. A tensile stress greater than the coercive stress along the new *a*-axis will produce the original crystal state. Hence, the stress-strain curve shows a hysteresis analogous to ferroelectric and

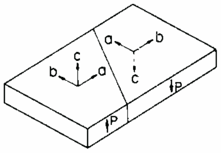

Fig. 17 — Two oppositely polarized ferroelectric domains.

ferromagnetic materials, and is called ferroelasticity. The material is also ferroelectric with electric polarization collinear with the c-axis. Reversal of the polarization by an applied electric field above the coercive-field value interchanges the a-and b-axes and produces the polarization-electric field hysteresis. The ferroelasticity is strongly coupled with the ferroelectricity, and the change of crystal state by either an applied mechanical stress or electric field is accomplished by the appearance of a domain wall at the corner of the crystal and a shift of the wall across the crystal. The acoustic velocity along the b-axis is different than along the a-axis. Hence, reversal of the polarization (see Fig. 17) with the application of an electric field will shift the domain wall in the sample and vary the delay time in the crystal. An applied electric field can be used to switch the polarization of all or part of a domain, and the portion switched determines the velocity and, hence, delay change. A maximum velocity change of 3% was obtained for surface acoustic waves and 12% for bulk waves.

High-frequency acoustic-wave generation

Conventional photomask techniques limit transducers for frequencies approaching 1 GHz. This upper frequency limit can be significantly increased by poling piezoelectric materials with a dc voltage applied to the interdigital transducer. This produces a periodic reversal of polarization below each finger (see Fig. 18) and leads to the generation of second and higher-order even harmonics of the transducer synchronous frequency (there is no resonance at the fundamental frequency) as was experimentally demonstrated on PZT.[3] The conversion efficiency under strong poling conditions for second harmonic generation was −8.5 dB, or only 1 dB worse than the fundamental frequency result with uniform poling. Unfortunately, PZT is a lossy material, and attempts to extend this technique to low-loss $LiNbO_3$ were unsuccessful because the required high poling temperature destroyed the metal transducer.

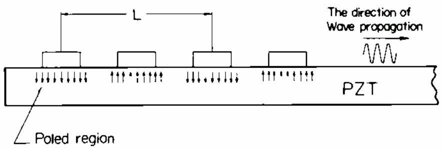

Fig. 18 — Periodic polarization in acoustic material poled by application of dc voltage to IDT.

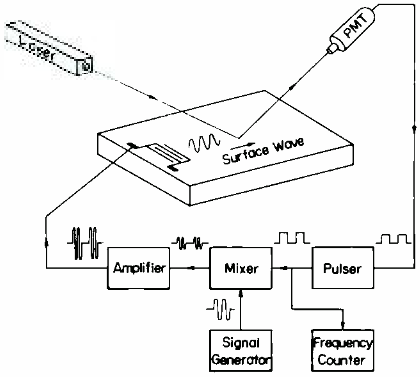

Fig. 19 — Experimental setup of optical-probe surface-wave-velocity-measurement system.

An alternative approach, which utilizes the interference pattern of two laser beams to evaporate the deposited metal film from the $LiNbO_3$ sample and to provide a periodic submicron line, has shown promise. Preliminary tests on Bi, Cr-Au, W, and Cr were carried out and the desired pattern obtained. Attention is now directed toward obtaining a uniform intensity over the desired area of the sample with the beam in single-mode operation.

Nonlinear surface-acoustic-wave propagation

An acoustic material's nonlinearity can provide signal correlation (convolver), thereby eliminating the need for metal-electrode coded-transducer patterns and associated control circuitry. Furthermore, nonlinear effects can be used to fabricate acoustical parametric amplifiers for long delay systems. With these possibilities in mind, studies of $Gd_2(MoO_4)_3$ were launched. The frequencies and amplitudes of the fundamental and higher harmonics are determined by using an optical probe to measure the intensity and diffraction angle of the surface-wave diffracted laser beam. This same system can be adapted to provide very accurate surface-wave velocity measurements[4] of both piezoelectric and nonpiezoelectric materials, as illustrated in Fig. 19. The diffracted light pulse serves as the trigger pulse of the pulse generator and the surface acoustic wave, excited by a pulse-modulated rf signal fed into the transducer, diffracts the laser beam. The photopultiplier-detected signal of the diffracted beam has the same pulse shape as that used initially to modulate the rf signal of the mixer. The detected signal is used to trigger the pulse generator and the process is repeated, resulting in a sequence of these pulses. The repetition time of the sequence is determined by both the delay time, t_e, of the experimental-apparatus electrical circuitry and the surface-wave transit time from the transducer to the point of laser-beam incidence on the sample surface. The delay, t_e, is eliminated by making measurements for two different transducer-to-laser-beam incidence positions.

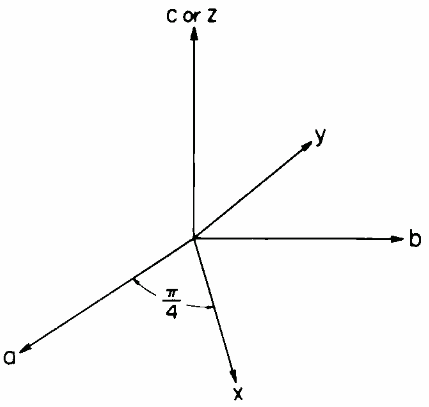

Fig. 20 — Coordinate system defining crystal axes.

In $Gd_2(MoO_4)_3$, a shear vertical strain component of the Rayleigh wave propagating perpendicular to the c-axis is ferroelastic and a strong nonlinearity is expected in the surface-wave propagation, but the mode is purely elastic (nonpiezolectric). Consequently, a ZnO thin film must be sputtered on the $Gd_2(MoO_4)_3$ to cover the transducer and excite the acoustic wave. In the coordinate system of Fig. 20, the strain, S_6 $(=S_{xy})$, vs. stress, T_6 $(=T_{xy})$, curve of $Gd_2(MoO_4)_3$ shows the ferroelastic hysteresis with a coercive stress of 15 N/cm^2. Approximating the Rayleigh wave propagating along a x (or y) - direction on a y (or x)-surface by a shear wave propagating in a plate of 30-μm (one-wavelength) thickness, with transducer width of 5mm, and power of 150mW, T_6 is estimated to be about 300N/cm^2 — much larger than the coercive force.

In addition to this shear vertical mode, the longitudinal component of the

Rayleigh mode propagating along the *a*- (or *b*-) axis on the *c*-surface will be investigated. This mode is also ferroelastic, and not only is an appreciable nonlinearity expected, but the mode is also piezoelectric—thereby simplifying the excitation problem.

Materials

In the preceding work, as with all research work, a variety of technological problems were encountered. In addition to the synthesis of new materials, the Materials Group has provided support in the investigation of techniques and new methods to eliminate such problems. For example, $Gd_2(MoO_4)_3$ and other oxide acoustic materials, such as $Bi_{12}GeO_{20}$ and $Pb_5Ge_3O_{12}$, are not resistant to strong acids and alkalis. Therefore, when difficulty was encountered in fabricating metal interdigital transducers on these materials with conventional photoresist techniques, a suitable etching solution was developed for the fabrication of silver transducers on such oxides.[5]

Recently, a new material, $4Bi_2O_3 \cdot V_2O_5$ was successfully synthesized and is currently under study as a potentially new acoustic and/or optical material. Complete crystal structure and physical property measurements are necessary before a reasonable evaluation can be made. However, preliminary measurements indicate that the crystal is ferroelectric with a maximum dielectric constant at about 700°C.

Fig. 21 illustrates some of the crystals grown and studied at the Tokyo Laboratories. In addition to the crystal synthesis, crystal properties, and composition analysis, physical parameters such as the electromechanical coupling constant, surface-wave velocity, dielectric constant, *etc.*, are determined for crystals of specific interest.

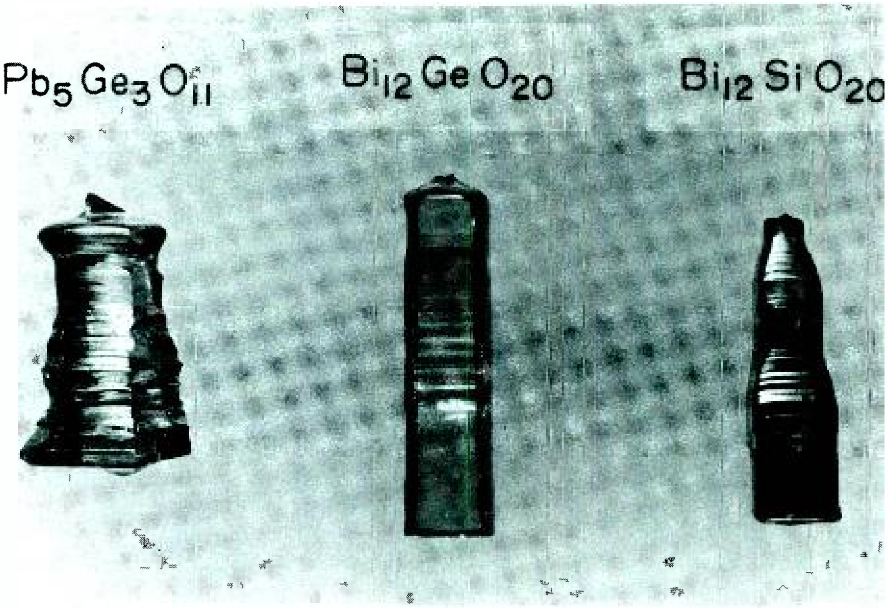

Fig. 21 — Examples of single crystals grown in the Tokyo Laboratory.

Aqueous solution deposition of II-VI compounds

The general area of aqueous solution deposition of II-VI compounds includes a number of recently initiated programs at the Laboratories that are in the very early stages of development. A simple chemical process shows promise as a technique to prepare uniformly coated penetration phosphors for vidicons, thin-film low-voltage electroluminescent displays, and inexpensive large-area terrestrial solar cells. Two strong features of this process are 1) the film area is limited only by the size of the reaction flask (no vacuum processing is required) and 2) thin films are deposited at low (85°C) or room temperature, thereby offering possibilities of high crystalline perfection.

Initially CdS films were deposited at 85°C from an aqueous solution containing cadmium acetate and thiourea with the pH adjusted by the addition of aqueous ammonia and ammonium acetate. The reaction time is 30 minutes, but the film thickness is increased by repeating the process in a fresh solution. The thin films adhere well to glass, fused quartz, $LiNbO_3$, and InO_3, SnO_2, Au, and In films. Recently, films have been prepared at room temperature using thioacetamide instead of thiourea as the sulfur agent, because it hydrolizes more readily at room temperature, even in strongly acidic solution.

Penetration phosphors for cathodoluminescence

The aqueous deposition technique can be used to uniformly coat a blue phosphor core ($ZnS:Ag$, approximately 20 μm diameter) with green and red phosphors, provided that $(Zn, Cd)S:Ag$ phosphor layers of prescribed proportions and thickness can be deposited. Heretofore, penetration phosphors have relied on a nonuniform gluing and baking of particles onto the blue phosphor core. Even at this early stage in the work, the preliminary results appear to be extremely encouraging. Phosphors were prepared by homogeneous precipitation at 80°C from a solution containing zinc sulfate (or zinc chloride), cadmium chloride, silver nitrate and thioacetamide in proper proportions at pH 5. The precipitated powers, $ZnS:Ag$ (0.01), $Zn_{0.7}CdS_{0.3}:Ag$ (0.01), and $Zn_{0.3}Cd_{0.7}S:Ag(0.01)$, luminesced blue, yellowish green, and red, respectively, under UV-light after baking at 940°C for 15 minutes in a ZnS atmosphere.

A coating of $Zn_{0.7}Cd_{0.3}S:Ag(0.01)$ layer on a blue $ZnS:Ag(0.01)$ core was also prepared and the coated powder luminesced yellowish green under UV-light after baking at 700°C in a ZnS atmosphere. The coating thickness is estimated to be of the order of 0.1 μm, far too thin for use as a penetration phosphor, but these preliminary results do support feasibility. The process is simple and the activator (and possibly coactivator as well) is included in the process. Efforts are now proceeding to further optimize the chemical constituents and deposit films of the order of 1 to 2 μm thickness.

Electroluminescence

The extension of the aqueous solution technique to ZnS immediately suggests the possibility of low-voltage thin-film

ZnS electroluminescent displays. The requirements for electroluminescence are more stringent than for cathodoluminescence because very uniform nonporous films are necessary and the processing technology is more demanding. However, the ability to deposit thin films reduces the voltage requirements and may even eliminate the need for the presence of copper. In the past, copper has been suspect as the major contributor to the short life and unreliability of ZnS electroluminescent films. It has been used to reduce the voltage required for the thick films obtained from vacuum deposition (good thin films, vacuum deposited, have not been obtained).

We have prepared $ZnS{:}Mn$ films (activator included in the deposition process) from an aqueous solution of zinc acetate, thiourea, and manganese chloride at 80°C. These films did not luminesce under UV-light until the samples were baked at an elevated temperature. The emission color at room temperature shifted toward longer wavelengths, from yellow to orange to red, as the baking temperature increased 150°C to 300°C. At baking temperatures above 350°C, no visible luminescence was detected. Voltage has been applied to extremely thin films (~1000 Å), and a faint electroluminescence was observed. At present, thicker films (~ 1 μm) are being prepared for testing.

CdS solar cells

The interest in CdS solar cells for terrestrial applications stems not only from the obvious world-wide energy problem, but from economic factors as well. Silicon solar cells are superior to CdS both in reliability and efficiency, but their cost per kilowatt is extremely high. The aqueous-solution deposition technique is an inexpensive, large-area, nonvacuum process that could make CdS a reasonable alternative. There is a big "if" associated with this, because of the life and reliability problems associated with CdS solar cells. Some of the problems, such as photochemical effects and oxide formation, can be solved. However, in the past, copper (copper sulfide is the p-type material of the solar cell) has been a major cause of the short life and degraded performance of these cells. A second look at the copper problem is warranted because of the economic advantages of the aqueous deposition process. At the same time, the properties of the deposited material will be carefully evaluated. Crystal structure and film orientation along with measurements of Hall effect and photoconductivity as a function of wavelength from visible to infrared (0.3 to 1 μm) are planned. Some recently conducted preliminary studies included fabrication of CdS-$CdTe$ heterojunctions using CdS deposited from an aqueous solution. $CdTe$ itself is unsuitable for our solar-cell fabrication because it is evaporated, and the low-cost large-area advantages of the aqueous-solution technique are lost. However, for a preliminary evaluation of the solar cell, $CdTe$ proved quite useful. The cell exhibited good rectification properties in the dark, with a reverse saturation current of less than 10^{-8} A and a breakdown voltage of 15 V. The open-circuit voltage and short-circuit current were 0.38 V and 70 mA/cm^2, respectively, when the junction was illuminated by a focused 300-W halogen tungsten lamp (200,000 lux). These preliminary results, while far from optimum, have encouraged us to examine more closely the CdS solar cell, at least insofar as the aqueous-solution technique and copper-induced failure are concerned.

Displays

Monodispersed latexes

The monodispersed latex program represents a program at the Laboratories in its earliest stages. The nature of the latex is such as to excite all sorts of ideas, although until further work is done a final assessment is impossible. At present, color display seems to be one of the more promising possibilities.

Monodispersed latexes are uniform spheres of polystyrene (or styrene-butadiene) suspended in water. The available sizes range from 0.1 μm to 100 μm. In the past their major use has been for the calibration of instruments, manufacture of latex fixation tests, and research. These suspensions have the following distinctive characteristics:

1) Particle size is comparable to the wavelength of visible light and, hence, visible light is well scattered.
2) The particles, when suspended in water, move under the influence of an external electric field.
3) The particles make an ordered structure under the proper conditions of particle density and electrolyte concentration. The ordered structure shows bright iridescense, indicating that light modulation using Bragg reflection is possible.

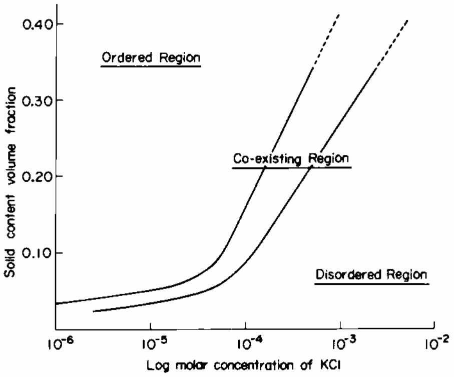

Fig. 22 — Phase diagram of polystyrene Latex with particle diameter 1700 Angstroms and containing KCL (Taken from Hachisu, Kobayashi, and Kose, "J. Colloid and Interface Science," *42* (1973) 342.)

He-Ne laser light is used for diffraction studies of latexes just as x-rays are used for the diffraction analysis of crystals. The reflected "Bragg-diffraction patterns" indicate that the ordered latexes have a close-packed hexagonal structure with the [0001] axis normal to the surface. A Debeye-Scherrer "Pattern" results when the latexes are not in the ordered state. Some points of the phase diagram have been measured, and two different phases of the ordered latex have been found. One is a high-particle high-electrolyte concentration while the other is a low-particle low-electrolyte concentrate. We believe that these states correspond to two metastable states, A and B, respectively, of the solid-gas isotherm of a finite system of hard spheres (Figs. 22 and 23). Phases A and B are characterized by long-range ordering without short-range ordering and short-range ordering without long-range ordering, respectively.

A small sample of latex material was sandwiched between two glass plates coated with transparent electrodes. With the sample illuminated and a voltage applied to the electrodes (3 to 9V), the reflected light from the latex material in state A, viewed at a fixed angle, changed from red to yellow to blue with increasing voltage. The voltage changed the particle

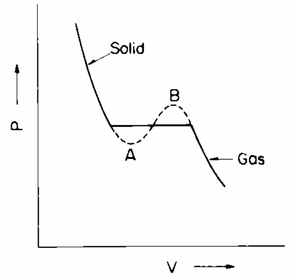

Fig. 23 — P-V plot qualitatively describing Tokyo Laboratory model of A and B phases and order-disorder states.

density and, hence, the Bragg diffraction condition. The power required is about the same as for liquid crystals (up to 0.1 mW/cm^2). At present, measurements are under way to measure the time constant, power, contrast, temperature range, color, *etc.*, and to compare the results with liquid crystals and electrophoretic-image-display materials.

Aqueous-solution pH variation for image recording or display

A number of substances change color in an aqueous solution due to a change in pH or concentration of specific metal ions. They are ordinarily utilized as indicators for analytical titration. However, if the local variation of protons or metal ions is controlled by external forces such as osmosis, electrolysis, photolysis, *etc.*, such indicator systems could be used for image recording or display. We recently initiated an exploratory program with this goal in mind. A survey to ascertain the practicality of using the coloration arising from an aqueous-solution pH variation for display or image recording revealed that almost no attempts have been made to utilize these to demonstrate the feasibility of such an approach. Phenolphthalein and thymolphthalein, with a proper buffer solution, were used as typical common indicators. The former changes from colorless to pink at a pH of about 8 while the latter changes from colorless to blue at a pH of about 9. The indicator solution is either mixed with a gelatin or soaked directly into filter paper or a thin sponge pad in contact with a platinum sheet electrode. A thin platinum wire (0.05 to 0.1-mm diameter) is used as a cathode and writing probe. When current passes between the two electrodes after the cathode wire contacts the gelatin film or filter paper, an immediate coloration is observed in the area of the probe contact. This occurs because of the local increase in the OH^- ion concentration arising from the loss of H^+ ions as H_2 gas is evolved at the cathode. The current density and voltage required for this process are of the order of 10 to 50 mA/cm^2 and 4 to 5V, respectively. The writing time is of the order of 10 ms. Decoloration (erasing) is caused by reversing polarity but generally takes more time than writing. There are, of course, many problems to overcome to make this idea practical, but the obvious advantages are the availability of relatively inexpensive materials and the low power requirements.

Additional technical activities

We have discussed acoustics, the oldest active program in the Laboratories, as well as some of the recently introduced programs. As I indicated earlier, it is impossible to cover all the Laboratory work in any detail. However, it would be an error to assume that what has been discussed represents the extent of the Tokyo Laboratory work. In an attempt to provide some balance, and to also give credit to the activities of other scientists working in equally important areas, some of the remaining work at the Tokyo Laboratories is briefly described below.

Magnetic "bubbles"

This program was recently terminated, both in Princeton and Tokyo because of changes in the RCA business plan. However, it is worth citing because it represented not only a joint effort with Princeton and Tokyo but also an activity in Tokyo which overlapped all the technical groups.

Magnetic "bubbles" are small cylindrical magnetic domains in an epitaxial magnetic film which can be used for the storage and manipulation of information. Tokyo was responsible for the following: flux growth of garnet crystals for characterization and mobility studies; investigation of liquid-phase epitaxial growth of garnet films leading to an understanding of the factors important to successful film growth; and a fundamental investigation of the material properties controlling mobility in garnet materials.

Tokyo was active in relating the crystal composition and growth conditions to the measured physical material parameters such as magnetization coercivity, collapse field, *etc.*, and in conducting measurements of magnetostriction and anisotropy in order to correlate material parameters with bubble mobility.

Solitons

A soliton is a solitary wave propagating in a nonlinear dispersive media and behaves like a particle; it preserves its shape and velocity upon collision with another soliton. Solitons correlate a number of otherwise uncorrelated fields in applied science with each other. A number of differential equations that describe a variety of physical phenomena, such as the Korteweg-de Vries, Sine-Gordon, nonlinear Schrodinger, Boussinesq, and nonlinear lumped-element network equations, exhibit soliton wave solutions. A unified method to obtain exact N-soliton solutions which can be applied to these equations was developed at the Tokyo Labs. Experiments using a nonlinear low-pass filter were carried out and the soliton properties experimentally observed.

Two invited papers (Refs. 6 and 7) one of which is authored by Tokyo Lab scientists, provide excellent coverage of this field for the interested reader.

Metal-semiconductor transition in FeS

Several transition metal oxides and sulfides exhibit sharp changes in both electrical and magnetic properties as a function of temperature or stress. FeS, in particular, was studied at the Tokyo Laboratories and was shown to be very sensitive to stoichiometry.[8] Ordered stoichiometric FeS transforms into a high-temperature-disorder form at $T_\alpha \sim$ 150°C (α-transformation). At the metal-semiconductor transition, T_α, the electrical conductivity, lattice parameter, and magnetic susceptibility change abruptly. Of special interest has been the measurement of an anomalous-voltage generated by T_α, which to the best of our knowledge, has never been reported in the literature. The magnitude of the generated voltage increases approximately exponentially with interface velocity. Values as large as 460 μV at interface velocities of 3×10^{-2} cms have been measured with no evidence of saturation. This voltage is independent of specimen size and is also generated in polycrystalline speciments when a heat source is located at one end of the sample, but to date, the voltage generation mechanism remains unexplained. The spin-flop transition occurs at a much higher temperature, $T_s \sim$ 190°C, than the crystallographic transition, T_α.

Optical properties of materials

Both experimental and theoretical studies have been carried out utilizing optical techniques to investigate the fundamental properties of materials.

A theoretical study of Raman scattering[10] and far-infrared absorption due to magnetic excitation of spinels with magnetic impurities provided quantitative information about the excitation modes of spin-waves associated with an impurity, as a function of a few observable parameters. The optical absorption of a Frenkel exciton due to spin-forbidden magnetic dipole transition of Cr^{3+} in ferromagnetic spinels indicated that the absorption line has a shoulder or sideband due to scattering of magnons, and the intensity increases with temperature at the expense of the central line.

Optical reflectivity measurements are a powerful tool for materials studies and the Tokyo Laboratories has applied this technique.[11,12] Recently, we have extended our work to include $LiNbO_3$, in support of Princeton's work on this material for optical storage applications. A high-precision reflectometer was constructed[11] so that even a slight change in the reflectivity spectrum can be detected. The optical portion of the reflectometer is shown schematically in Fig. 24 and includes a rotating disc with two mirrors. The two mirrors, which rotate with the disc, chop the light beam so that the detector can pick up the incident (Fig. 24a) and reflected beams (Fig. 24b), one after the other. A dual boxcar circuit selectively integrates the signal pulses, and a dividing circuit provides the ratio of the reflected-to-incident signal.

Chemical analysis

The major role of this facility is the determination of the composition of materials prepared and used in the Laboratory. This requires the development of new analytical procedures[14] along with well-established procedures. The facilities include gravimetric and volumetric analyses, potentiometric and photometric titrations, colorimetry and spectrophotometry, and atomic absorption spectrophotometry.

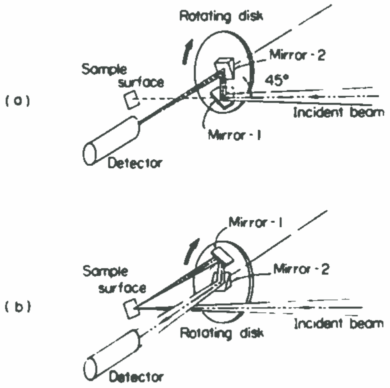

Fig. 24 — Optical portion of reflectometer: a) incident beam measurement, b) reflected beam measurement.

Summary

We have presented a survey of the Tokyo Research Laboratories' organization, facilities, and technical work. The broad scope of research has not only contributed to specific technical activities within RCA itself, but has also provided the basis for an exchange of information between the scientific community of the Far East and RCA; both items represent the major goals of the Laboratory.

Acknowledgments

I would be sadly remiss if I failed to acknowledge the contributions and assistance of the entire staff in the preparation of this paper. Every person contributed in some way to the final product.

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Communications satellites — Around the world in 800 milliseconds

D. R. Ellis

Several generations of satellites capable of providing communications to all parts of the world have been launched in the past nine years. A global commercial satellite system has been developed by the International Telecommunications Satellite Organization (Intelsat), a multi-nation organization which owns and operates satellites circling the earth in geostationary orbit above the Atlantic, Pacific, and Indian Oceans. Intelsat satellites are launched by NASA from Cape Canaveral and are monitored and controlled at tracking stations around the world. Earth stations in every major country provide the link between the satellites and the communications network on the ground. RCA Global Communications, Inc. is an international communications common carrier which operates almost 300 satellite voice and television circuits for the provision of its global services. Technological advances in the satellite communications field have made possible greatly increased capability, speed, and efficiency in communicating around the world by satellite.

TELECOMMUNICATIONS satellites and associated technology developed over the past decade have made possible an efficient high-speed global commercial network linking almost any part of the world with any other within fractions of a second. Communications carriers like RCA Global Communications, Inc. (Globcom) use these communications satellites, positioned in geostationary orbit 22,300 miles above the Atlantic, Pacific, and Indian Oceans, to carry many different forms of communications, including telephone, telegraph and telex messages, data, facsimile, photographs, and television programs. The latest generation of satellites, launched between 1971 and 1973, is capable of carrying as many as 5,000 simultaneous telephone calls or 12 television channels, or various combinations of these. More advanced satellites, expected to be launched in 1975, will have greater capability — as many as 7,500 simultaneous telephone calls or 20 television broadcasts.

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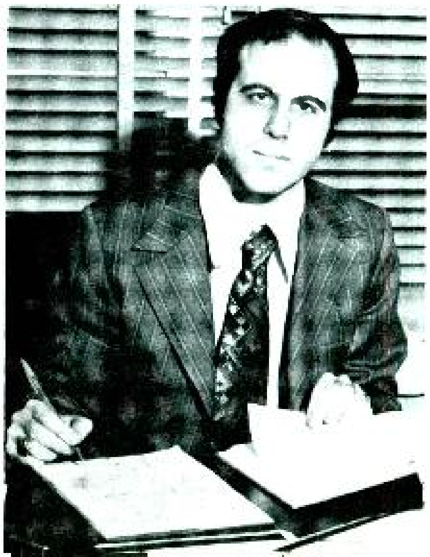

Communication satellite operations

Telecommunications satellites operate as combination receiver-transmitters of radio signals sent and received by ground stations on the earth's surface. Each of the Intelsat satellites is positioned in geostationary orbit so that it revolves around the earth at exactly the correct speed to enable it to remain directly over a fixed point on the earth's surface at the equator and a specified longitude, chosen to give optimum lines of sight to existing earth stations. Communications signals are transmitted from earth station to satellite at microwave frequencies in the 6-GHz range and transmitted back from satellite to earth station in the 4-GHz range.[1] Each of the Intelsat satellites presently in operation contains twelve transponders which function as radio relays — receiving, amplifying, and retransmitting the signals sent them by the earth stations. Each earth station in the Intelsat system has a large antenna structure capable of being rotated and elevated so that it is focused directly on a given satellite in orbit. The earth stations are interconnected through a vast network of terrestrial facilities which relay the communications — long distance telephone calls, telegrams, or international television programs — to the consumer.

Intelsat organization

The satellites in the global commercial system are owned and operated by the International Telecommunications Satellite Organization (Intelsat) an international joint venture of telecommunications entities consisting of 85 member nations representing approximately 95% of the telecommunications traffic of the world. Intelsat came into formal existence on February 12, 1973, succeeding the Interim Telecommunications Satellite Consortium (ICSC), which had been established in August 1964 with only fourteen nations as members.

The United States representative in Intelsat is the Communications Satellite Corporation (Comsat), which is the major investor in Intelsat with about 40% of Intelsat's leased circuits. (Each member of Intelsat has an investment share approximately equivalent to its use of the system.[2]) Comsat is a privately owned U.S. corporation incorporated in early 1963 under the provisions of the Communications Satellite Act of 1962, which directed that a commercial communications satellite system be established as quickly and expeditiously as practicable, in conjunction and cooperation with other countries of the world.

Intelsat satellites

The world's first commercial telecommunication satellite was launched for the Intelsat organization on April 6, 1965 and

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placed in operation over the Atlantic Ocean on June 28, 1965. INTELSAT I, or Early Bird as it was more popularly known, had a capacity equivalent to 240 telephone circuits or one television channel, and made possible for the first time the broadcasting of live commercial television programs across the ocean. Although Early Bird had an 18-month design life, it remained in satisfactory operation for about four years.

Since Early Bird, three successive generations of Intelsat satellites have been launched and placed in commercial operation, culminating in the five INTELSAT IV satellites presently in operation over three of the world's oceans. (See Table I.) These INTELSAT IV satellites, first launched in January 1971, have more than twelve times the communications capability of Early Bird and feature such technological innovations as the spot beam concept, which is the ability of a satellite to utilize a high gain antenna in heavy traffic areas, making possible the derivation of a significantly higher number of circuits from a limited number of transponders.

Three of the INTELSAT IV satellites presently in operation have been placed over the Atlantic Ocean, one over the Pacific, and one over the Indian. In the Atlantic, one of the satellites is called the "primary path" satellite since all of the earth stations in the Atlantic region are focused on it. The second Atlantic satellite, known as the "major path" satellite, handles high volume traffic between a smaller number of countries which have dual antennas for Atlantic traffic. The third Atlantic satellite serves as a backup for the other two. The INTELSAT IV satellites over the Pacific and Indian Oceans are each backed up by INTELSAT III satellites. The Intelsat satellites are also capable of restoring a portion of the traffic carried by transoceanic submarine cable systems in the event that one or more of these cables fail without sufficient replacement under the sea.

The next generation of Intelsat satellites, already designed, is a modified and improved version of the INTELSAT IV. Designated INTELSAT IV-A, the new satellites will have almost double the capacity of the present IV's. The new satellites will have twenty transponders each and will be capable of carrying 7,500 simultaneous telephone conversations or 20 television broadcasts. The INTELSAT IV-A's will be designed to use sixteen transponders in spot-beam mode, as contrasted with the INTELSAT IV's which are capable of using only eight transponders in spot-beam mode. The INTELSAT IV-A's will also introduce the concept of frequency reuse through spot-beam separation, a technique which permits a given frequency band to be used in different directions by different transponders and antenna beams, thereby increasing the total bandwidth available for use by a single satellite, enhancing the satellite's capacity. The first of three INTELSAT IV-A satellites is expected to be launched toward the end of 1975 and will be placed in operation as the Atlantic primary path satellite. It is anticipated that the three INTELSAT IV-A's will satisfy satellite requirements in the Atlantic region until 1978 and that the total cost of the IV-A's, including launch vehicles and launch support services, will be about $142 million.[3]

Satellite launch operations

The Intelsat satellites are launched by the National Aeronautics and Space Administration (NASA) at the United States Air Force Eastern Test Range at Cape Canaveral, Florida, pursuant to a launch and associated services contract between Intelsat and NASA. Under this arrangement, NASA furnishes its services to Intelsat on a cost-reimbursable basis, in accordance with provisions of the Communications Satellite Act of 1962. NASA is responsible for procuring the launch vehicle, for conducting preflight tests to assure launch readiness, for providing associated launch support services, and for launching the satellite into a synchronous transfer orbit. Once the satellite is in orbit, Comsat, as manager of the mission for Intelsat, undertakes the necessary operations to position and orient the satellite in geostationary orbit, test and adjust the satellite's communications subsystem, and place the satellite into the commercial operation.

Satellite monitoring and control

The satellites in the Intelsat system are monitored and controlled by four tracking, telemetry, and command (TT&C) stations around the world, and by a central technical control center in Washington, D.C. The TT&C stations — located at Andover, Maine; Fucino, Italy; Carnarvon, Australia; and Paumalu, Hawaii — acquire and track satellites

Table I — Intelsat satellite data.

*Series**	*Operationsl Date*	*Ocean*	*Circuits*		*Capacity TV channels*	*Design life*
INTELSAT I (Early Bird)	June 28, 1965	Atlantic - 1	240	*or*	1	18 mos.
INTELSAT II	Jan. 27, 1967	Atlantic - 1 Pacific - 2	240	*or*	1	3 years
INTELSAT III	Dec. 24, 1968	Atlantic - 3 Pacific - 1 Indian - 1**	1,200	*or*	4	5 years
INTELSAT IV	March 26, 1971	Atlantic 3 Pacific - 1 Indian - 1	Average 4,000	*or*	12	7 years
INTELSAT IV - A (1975)			Average 7,500	*or*	20	7 years

*Each series represents a distinct design, except for the IV-A which is a modified version of the IV.

**Originally positioned over Pacific, then respositioned over Indian.

Information in this chart derived in part from *Pocket Guide to the Global Satellite System*, Communications Satellite Corporation, March 1974, pp. 6-9, 12-14.

during launch and initial orbit; monitor the location, attitude, and systems performance of the spacecraft on station; and transmit commands to the satellites. The control center in Washington collects and analyzes the data gathered by the TT&C stations and issues commands to the satellites which are relayed through the TT&C stations. These commands are necessary for proper station-keeping, that is, the maintenance of a satellite's assigned position in geostationary orbit, which can only be accomplished by making small adjustments in the satellite's position and orientation to correct for drift and attitude perturbation. These station-keeping maneuvers are necessary because, no matter how precisely a satellite is placed in its synchronous orbit, over a period of time it will be affected by variations in the earth's gravitational field and by lunar and solar attraction, and will be pulled subtly out of its orbit. The satellite makes its adjustments in space by firing small retrorockets in the direction opposite from that which it tends to drift, in accordance with the instructions it receives from the ground and information it obtains from its own on-board sensors.

Earth stations

The Intelsat satellites in orbit around the earth are linked to the communications network on the ground by an extensive system of earth stations located throughout the world. As of March 1974, the number of earth stations operating within the Intelsat sysem consisted of 89 antennas at 70 earth stations sites in 58 different countries. Additional earth stations are expected to be added rapidly, with 23 more earth stations scheduled for operation by the end of 1975, raising the number of countries capable of communicating directly by Intelsat satellite to 76.[3] (See Figs. 1 and 2).

Since a conventional parabolic antenna can focus on only one satellite at a time, an earth station must have a separate antenna for each satellite with which it operates. Many Atlantic region earth stations have two antennas so that they can focus on both Atlantic satellites, and some European earth stations, like the Buitrago station in Spain, are equipped with three antennas so that they can communicate with the two Atlantic satellites and the Indian Ocean satellite at the same time. Unlike the satellites, which are jointly owned by the member nations of Intelsat, the earth stations are individually owned and operated by the telecommunications entities of the countries in which they are located.

In the United States, RCA Globcom is a member of the Earth Station Ownership Committee (ESOC), a consortium of communications companies which owns all seven permanent U.S. earth stations in the Intelsat system, in accordance with the Communications Satellite Act of 1962 and the requirements of a policy set by the Federal Communications Commission in 1966. These earth stations are located at Andover, Maine; Etam, West Virginia; Jamesburg, California; Brewster Flats, Washington; Paumalu, Hawaii; Cayey, Puerto Rico; and Pulantat, Guam. RCA Globcom's ownership interest in each of these stations is as follows:

Andover, Maine	10.5%
Etam, West Virginia	10.5
Jamesburg, California	10.5
Brewster Flats, Washington	10.5
Paumalu, Hawaii	11.0
Cayey, Puerto Rico	4.0
Pulantat, Guam	34.0

The earth station at Pulantat, Guam is managed and operated by RCA Globcom, which constructed the station over a ten-month period in 1969 and 1970. The station was constructed in two stages: Phase I, utilizing a temporary transportable earth station previously used by Globcom to provide temporary satellite communication ground facilities in Thailand, together with the erection of a permanent 98-ft-diameter antenna designed to withstand winds of up to 210 miles/hour, and Phase II, providing for the installation of a permanent earth station to replace the temporary facilities.[5] The Pulantat station, which became fully operational in May 1970, has proved to be one of the most reliable earth stations in the Intelsat system. RCA Globcom has also constructed and operated a transportable earth station on Kwajalein in the Marshall Islands to provide communications services for the U.S. Depart-

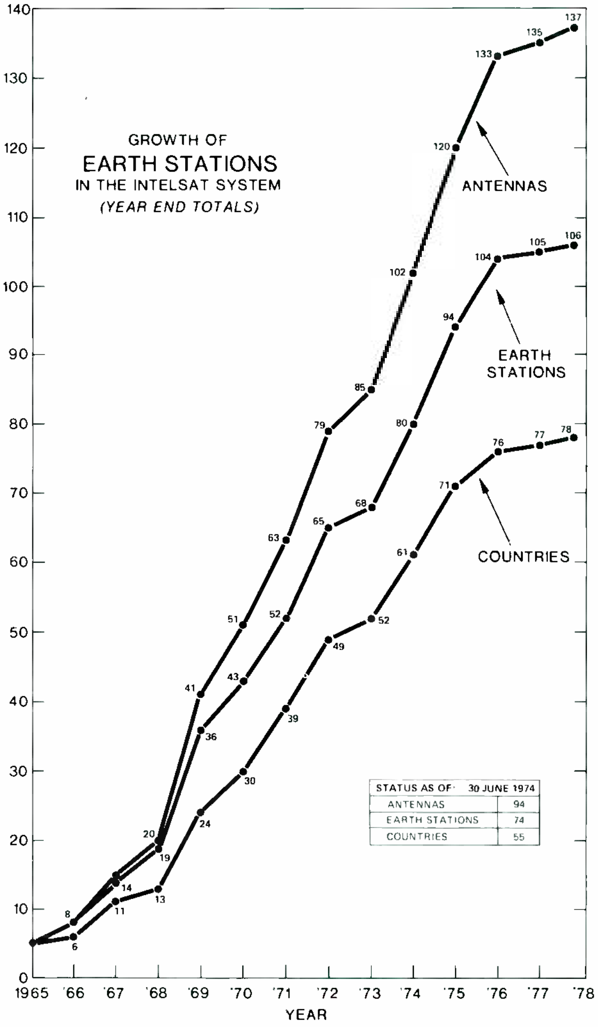

Fig. 1 — Growth of earth stations in the Intelsat system (year-end totals).

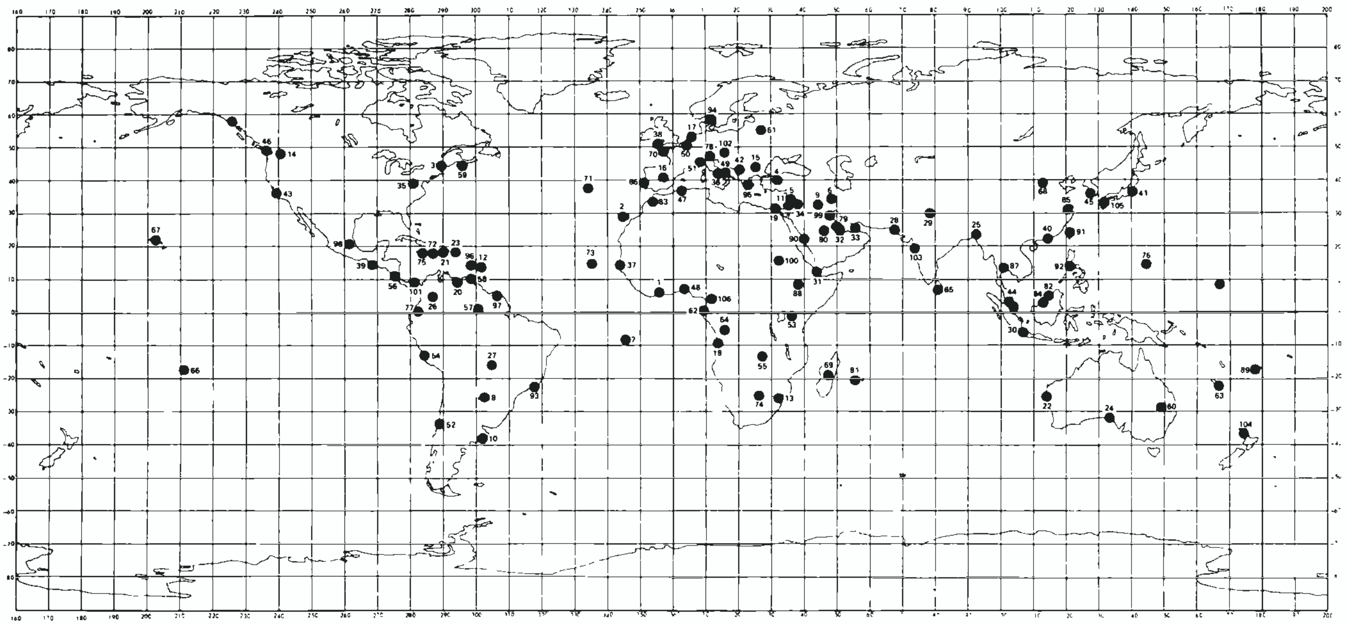

Fig. 2 — Earth station locations (1974 to 1978) — operational and planned.

ment of Defense via the Intelsat system in the Pacific. In addition, Globcom recently completed the construction of two permanent earth stations for the Peoples Republic of China at Peking and Shanghai for use with Intelsat satellites over the Pacific.

Globcom's satellite operations

RCA Globcom operates almost 300 Intelsat satellite voice circuits around the world for the provision of its global communications services. As of March 1974, Globcom operated 117 circuits in the Atlantic region between the United States and points in Europe, Africa, the Middle East, South America, Central America and the Caribbean; 165 in the Pacific region between and among the United States Mainland, Hawaii, Guam and the Philippines and points in Asia, Australia and New Zealand; and three in the Indian region between points in Europe and Asia. These circuits are used for telephone , telegraph, telex, data, leased (private-line) channels, and various other services authorized by the Federal Communications Commission (FCC). Globcom also provides international satellite television service on a rotational basis with other communications carriers.

Globcom operates voice circuits between earth stations in the United States and Intelsat satellites over the Atlantic and Pacific Oceans that are acquired from Comsat under tariffs filed with the FCC. Until very recently, all of these circuits were obtained on an individual basis, but since February 1974, RCA Globcom has been participating with other U.S. common carriers in the acquisition of the capacity of an entire transponder in a Pacific Intelsat satellite to provide service between the United States Mainland and Hawaii. The acquisition of this transponder, with the equivalent of up to 432 satellite voice circuits, has enabled Globcom to provide improved service to its customers in the Mainland-Hawaii corridor.

The circuits RCA Globcom leases and operates in the Indian Ocean region, which provide services between the United States and points in Asia, originate from earth stations in Europe rather than from earth stations in the United States. This is because of the curvature of the earth which prevents earth stations in the United States from focusing on satellites over the Indian Ocean, thus making it necessary for a carrier providing service to points in the Indian area to route its traffic in two "hops". Consequently, RCA Globcom provides service from the U.S. to Indian Ocean countries as follows: via transatlantic cable and connecting facilities in Europe to the appropriate European earth station, and then via Indian satellite to the service point in Asia over satellite capacity obtained from the European telecommunications Intelsat member which operates the European earth station.

It should be noted that most of the circuits mentioned above are in reality only "half circuits", or "up-links", between an earth station in the United States or Europe and a satellite over the Atlantic, Pacific, or Indian Oceans. In the Intelsat system, satellite capacity is subdivided into "units of utilization" of the earth station-to-satellite "space segment", with each unit of utilization equivalent to half of the through-circuit from earth station-to-satellite-to-earth station. Under the "border-to-border" concept of international telecommunications, RCA Globcom — as a United States carrier — is responsible for providing all of the necessary circuitry in the United States but only half of the circuitry in the international area. The matching half of the international segment, or "down-link", necessary to complete the through-circuit, together with all of the necessary connecting circuitry within its borders, is provided and operated by the telecommunications administration of the overseas point to which the whole circuit is directed.

In most of the areas to which RCA Globcom operates, the overseas administrations are foreign government agencies which operate the telephone, telegraph, and postal facilities of those countries. In the United Kingdom, for example, the British Post Office (BPO) acts as RCA Globcom's foreign correspondent in the provision of satellite service between the United States and the United Kingdom. The BPO, as a member of Intelsat, has an investment interest in the satellites, and owns and operates its own earth station facilities for use with

Intelsat satellites over the Atlantic and Indian Oceans.

On certain routes served by Intelsat satellites where both terminals are within the jurisdiction of the United States, RCA Globcom operates both ends of its satellite circuits. In providing circuits between the United States and Puerto Rico, and some of the circuits between the United States and Hawaii and Guam, RCA Globcom acts in effect as its own correspondent. In these areas, RCA Globcom has long been authorized to operate as a communications carrier and thus is in a position to obtain necessary satellite capacity to provide service on both ends of its routes.

RCA Globcom's communications operations are subject to the authority of the Federal Communications Commission, the regulatory agency which is charged with the duty of overseeing international and interstate communications in the United States. Before Globcom may acquire or operate any satellite facilities, and before it may offer or provide any of its communications services by satellite, RCA Globcom must first obtain authorization that such operations will serve the public interest in accordance with the Communications Act of 1934, as amended, the Communications Satellite Act of 1962, and the FCC's rules and regulations.

Technological advances

Satellite telecommunications technology has advanced dramatically over the past decade, enabling communications carriers like RCA Globcom to greatly enhance the speed and efficiency of the services they offer over the global satellite network. For example, where it was once economically unfeasible to use antennas smaller than 85 ft in diameter at earth station sites in order to receive high quality transmissions from satellites, it is now possible to receive commercial traffic at earth stations by means of antennas on the order of 33-ft in diameter. The inherent flexibility of these smaller antennas has permitted the establishment of a number of transportable earth stations at various sites for temporary and experimental purposes. Included among these are the transportable earth station RCA Globcom constructed for the U.S. Department of Defense on Kwajalein and the earth stations it has supplied to telecommunications administrations in various foreign countries, including Thailand and the People's Republic of China, to serve the communications needs of those countries while they were in the process of constructing permanent earth station facilities.

Although the broadcasting of live television programs via international satellite has been conducted for almost nine years, other transmission breakthroughs are much more recent. On May 15, 1973, RCA Globcom was a participant in the first live intercontinental stereophonic broadcast when it made available to a San Francisco radio station two 12-kHz satellite circuits between the United States and France for the broadcast of a concert by the San Francisco Symphony Orchestra in Paris. Other sophisticated transmission techniques have made it possible for communications carriers like RCA Globcom to transmit extremely high-speed data via satellite which could not economically be handled by cable and terrestrial facilities. Such data can be transmitted by using a conventional "wideband" satellite circuit with a bandwidth of 48 kHz, equivalent in bandwidth to 12 standard voice grade satellite circuits over which the data can be transmitted at rates as high as 50,000 bits/second. (Telex, by contrast, is transmitted by satellite over the far narrower bandwidth of 120 Hz at the rate of 50 bits/s, or 66 words/min.) In addition, by using newer techniques, it is possible to transmit data, as well as voice signals in digital format, over a single satellite circuit at speeds as high as 64,000 bits/s by utilizing advanced digital encoding techniques and recently developed equipment known as Single Channel Per Carrier (SCPC).

Another example of technological innovation in the transmission of satellite communications has been the development and introduction of increasingly sophisticated multiplexing equipment which makes possible the subdivision of the bandwidth of a standard voice-grade circuit into large numbers of discrete telegraph channels. These high capacity subdivision terminals, which can be used on transoceanic cables and terrestrial circuits as well as satellite circuits, employ various combinations of frequency, time, and phase division multiplex techniques to derive as many as 208 telegraph channels from a single voice circuit.[5] As an illustration of the advantages which can be obtained from the use of such high capacity subdivision equipment, a carrier can install a time-division-multiplex (TDM) system capable of subdividing a voice circuit into 88 telegraph channels for use on a satellite circuit and free as many as four other voice circuits utilizing lower capacity frequency-division-multiplex (FDM) terminals for other requirements. The carrier can then use the lower capacity FDM systems on circuits with smaller telegraph channel requirements, thus enabling it to make the best possible use of the satellite's frequency spectrum. By so doing, a carrier such as RCA Globcom can tailor the use of its multiplexing equipment to its varying requirements on the many routes it serves and provide its communications services in the most practical, efficient and cost-effective manner possible.

Conclusion

International satellite communications are still in their infancy, and yet in only about a decade of commercial operations, a host of technological and operational advances have been accomplished which have greatly enhanced man's ability to communicate on an international basis. Clearly the future holds the promise of a multitude of increasingly sophisticaed innovations in the development of satellites, ground facilities, transmission techniques, and communications services. Managers and engineers at RCA Globcom and the other RCA divisions and subsidiaries and at communications organizations throughout the world, are working full time to make new discoveries, introduce new methods of operation and improve old ones, in order to better serve the needs of all those who wish to communicate over the world's international satellite communications system.

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Monochrome and color television standards

E.M. Leyton

This paper is published posthumously for the late Eric M. Leyton. Eric was attending a CCIR Meeting in Geneva when, on February 26, 1974, he passed away quite unexpectedly. He had promised to write a paper for the *RCA Engineer* on the current state of worldwide television standards, a subject for which and with which he was uniquely familiar and qualified. A search of his files uncovered the following, and heretofore, unpublished manuscript. Although written in 1968, the paper still appeared to be very much relevant to current conditions. Thus, with the help of Ronald A. Mills of Laboratories RCA Ltd., Zurich, and several others, to update some original data since changed by intervening developments, we present this paper as a tribute in remembrance of a departed friend and colleague.

—Henry Ball, Staff Engineer, Engineering, Research and Engineering, Princeton, N.J.

FOR THE PAST FEW YEARS, there has been a considerable amount of interest in the color television systems to be used throughout the world. In writing about color systems, there is an immediate difficulty because of the lack of standardization in the meaning of the word *systems*. The International Radio Consultative Committee (CCIR) recognizes a number of different television systems and each system is clearly defined. In this paper the various methods of transmitting color television, such as NTSC, PAL, and SECAM, will also be referred to as *systems* to indicate the general scheme used that can be modified for use with different monochrome standards. It is hoped that the two meanings used for the word *system* will not be too confusing.

It has always been impossible to obtain international agreement on television standards, and it is interesting to review what has happened in the past to undertand some of the reasons for the present difficulties with standardization.

History

The first scheduled broadcasting of monochrome television, as we know it today, was started by the British Broadcasting Corporation (BBC) in 1936. Even in 1936 when television first started with only one station a single tv system was not enough. The broadcast started using two different systems on alternate days. One system, known as the Baird System, used a 250-line non-interlaced scanning raster with a frame rate of 50 Hz; the other known as the EMI system, used a 405-line interlaced raster with a frame rate of 25 Hz. Receivers were switchable for both standards and with the help of a calendar and a certain amount of manual dexterity, it was possible to obtain quite a reasonable picture on either system.

After about a year of operation, the 250-line Baird System was discontinued. The 405-line system, now CCIR system A, was retained. It has remained substantially unaltered to this day and is at present in use throughout Great Britain on all vhf channels.

Prior to 1936, there were lengthy technical discussions to decide whether vertical or horizontal polarization should be used for the radiated signals. Finally, one of the national Fine Arts Councils decided that the receiving antennas for vertical polarization were more beautiful than those for horizontal polarization, so vertical polarization was used. Much later, in the mid 50's, some stations were built using horizontal polarization to reduce co-channel interference by about 8 dB.

The direction of modulation of the vision transmitter was positive because flywheel synchronizing circuits had not been developed and automobile ignition interference was so great that, when negative modulation was used, the picture would break-up for a substantial portion of the time. If people had had radio receivers in their cars in the early 30's, negative modulation might have been chosen.

In the United States of America, television broadcasting really started on 30 April 1939, concurrently with the opening of the New York World's Fair. The standards used at this time were those recommended by the Radio Manufacturers Association (RMA). The RMA standards specified a 441-line system that had been developed by the radio industry over a number of years. It was thought by the majority of people in the industry that these standards would be adopted by the Federal Communications Commission (FCC). Contrary to this expectation, the FCC did not accept the RMA's standards and the National Television System Committee (NTSC) was formed in 1940. This Committee was charged with recommending standards to the FCC.

525-line standard

The NTSC's recommendations for monochrome television standards were accepted by the FCC in March 1941 and are now designated system M by the CCIR. The standards for monochrome recommended by the NTSC were substantially the same as the RMA standards. The only really significant difference was the number of scanning lines in each frame which was changed from 441 to 525. This change was not recommended by the NTSC until after the meetings of the panel concerned were formally closed and the NTSC had sent the FCC a preliminary copy of its recommendations.

Since the total resolution of system M, the American System, is the same as system A, the British system, the question might well be asked, "Why are the two systems different in almost every respect?" The only significant answer to this question is that the power-line frequency in the United States was mostly 60 Hz, whereas in England it was mostly 50 Hz. At the time the standards were drawn up, it was thought to be very difficult to prevent noticeable interference from the power system if the power and television frequencies were not the same. This fear has since proved to be unfounded and all the tv systems recognized by the CCIR

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Table I — Monochrome tv systems.

CCIR System	*Lines*	*Fields/s*	*Video modulation*	*Sound modulation*	*Carrier spacing Sound-to-video (MHz)*	*Color standard*
A	405	50	+	a.m.	− 3.5	6
B,G,&H	625	50	−	f.m.	+ 5.5	2
C	625	50	+	a.m.	+ 5.5	2
D,K&K1	625	50	−	f.m.	+ 6.5	2
E	819	50	+	a.m.	±11.15	4
F	819	50	+	a.m.	+ 5.5	5
I	625	50	−	fm	6.0	2
L	625	50	+	a.m.	+ 6.5	2
M	525	60	−	fm	+ 4.5	1
N	625	50	−	fm	4.5	3

are now capable of working satisfactorily when not locked to the power line. In addition, there are many geographical areas that use a 60-Hz field frequency for tv and 50-Hz power-line frequency. However, time has shown that the use of a 60-Hz field frequency is a very significant advantage of system M over all other tv systems. This is because modern technology has produced kinescopes with high levels of light output and the 60 fields/s rate gives much less flicker than the 50 field/s systems. Although people do get used to the 50-Hz flicker of European tv if the picture brightness is not too great, the 50-field system do limit the picture brightness that can be used. This is the one big advantage of the American system.

With the beginning of the second World War, in 1939, television in Europe stopped and did not get going again until well after the end of the war.

Early attempts for global standards

After the war the CCIR attemped to obtain international agreement on monochrome tv standards but this proved to be impossible. The attempt to standardize was given up completely in about 1951 when France announced, just before an international meeting on standards, that tv in France would be on an 819-line 50-field standard. As a result of the lack of standardization, there are now four different scanning standards in use:

1)405 lines (50 fields)...system A;
2)525 lines (60 fields)...system M;
3)625 lines (50 fields)...systems B,C,D,G,H,I,K,K1,L,N; and
4)819 lines (50 fields)...system E, and F.

There are also six different spacings between sound and vision carriers, namely: 3.5, 4.5, 5.5, 6.0, 6.5, and 11.15 MHz. In addition, there is the use of a.m. or fm for the audio modulation and positive and negative modulation for the picture carriers. Table I shows the important characteristics of the various systems.

At about the same time that the CCIR was trying to get agreement on monochrome tv, color tv was being investigated vigorously in the USA. After a great deal of work by industry and many demonstrations, the FCC adopted the CBS field-sequential system in 1950.

The National Television System's Committee was re-formed in 1950 because the majority of the television equipment manufacturers thought that the field-sequential system was not the best, and if agreement could be reached by all manufacturers it would be possible to have the standards changed.

The field-sequential system was not compatible with the monochrome tv system and it is difficult to see how color tv could

Eric M. Leyton, Staff Engineer, Engineering was associated with the RCA Corporation for more than twenty years and made major contributions to the development of television and television tape recording. He was actively concerned with color television systems for many years and frequently represented both the United States and RCA at international conferences on television standards. A native of London, England, he received his D.F.H. degree, the equivalent of the professional E.E., from Faraday House College of London University in 1938. Prior to joining RCA, Mr. Leyton spent six years on the staff of the Research Laboratories of Electrical & Musical Industries, Hayes, near London. During this period as head of a group engaged in the development of television transmitters, he was responsible for the design, manufacture and installation of the Kirk O'Shotts and Wenvoe television transmitters. These transmitters, later sold to the BBC, are among the most powerful in the world. Mr. Leyton was a Fellow of both the Institute of Electrical and Electronics Engineers and the British Institution of Electrical Engineers, and served as Secretary in the U.S.A. for the latter organization. He was also a member of Sigma Xi.

ever have grown in popularity with this system. Fortuitously, the war in Korea caused a shortage of copper which prevented color receivers being built at this time, so it was possible for the FCC to adopt the present NTSC system in 1953 without any public outcry from the people who had purchased field-sequential receivers.

Color television systems

The NTSC color television system, as used in the USA since 1953, was the only system used in broadcasting until mid 1967. At present, England and Germany use the PAL system and France uses the SECAM system. Again it may be asked, "Why is there not some international standardization?" Again there is no technical argument in favor of more than one system.

In the early days of NTSC color broadcasting, there were some technical difficulties resulting in unsatisfactory color pictures on certain occasions. These difficulties were all due to shortcomings of the apparatus in use at the time and have been completely overcome in modern equipment. The three important difficulties in the early days of NTSC were:

1) Errors in hue due to differential phase in equipment,
2) Errors in saturation due to differential gain, and
3) Errors in hue due to the phase of the color subcarrier burst being inconsistent in relation to the color information in the picture.

These shortcomings were, of course, known to engineers in Europe and a large number of different color systems were developed to overcome the difficulties. Very little work was done in Europe to eliminate the cause of problems in the NTSC system, but this has been done quite successfully in the United States. All the color tv systems developed in Europe were the same as NTSC except for the method of encoding the color-difference signals; they are:

1) TSC - The two subcarriers systems,
2) FAM - The frequency and amplitude modulation systems,
3) DST - The fm subcarriers system with an additional subcarrier on the color subcarrier,
4) ART - The added reference transmitter system,
5) NIR - The Russian system that is the same as NTSC except that the phase modulation, but not the amplitude modulation, of the subcarrier is omitted on alternate lines,
6) SECAM - Sequential with memory, and
7) PAL - Phase alternation by lines.

Of these seven systems, only the last two have been extensively tested by members of the European Broadcast Union (EBU), and are in use at this time. France and the USSR are using the SECAM system, while most of the other countries of Europe are using, or have stated they will use PAL.

The PAL signal is the same as the NTSC signal except that the phase of the *R-Y* component of the color subcarrier is reversed (changed by 180°) every line. The claimed advantages of this system are that it has good immunity to phase and differential phase errors, and also that ghosts do not change the color of the received pictures and are visible only as a change of brightness. The important disadvantage of PAL is the increase in cost of the home receivers. To achieve the advantages of PAL, each receiver must have a delay line (64 μs).

SECAM uses an fm color subcarrier that carries the color-difference signals sequentially *R-Y* on one line and *B-Y* on the next line. A delay line in the receiver provides the necessary storage for making *R-Y* and *B-Y* available for display at the same time. The SECAM system has greater tolerance to differential gain and differential phase than NTSC, but it also has many shortcomings compared with NTSC, the important ones being: reduced resolution of color in both the vertical and horizontal direction; poor compatibility with monochrome receivers; greater sensitivity to noise, and difficulty of mixing signals in the studio. Also, of course, the receivers must have a delay line.

The NIR system, sometimes called SECAM-IV, is the same as NTSC except that the phase of the color subcarrier is held constant at a reference value on alternate lines. The amplitude modulation of the subcarrier is the same as NTSC on all lines. The only advantage of NIR appears to be that it is not the same as NTSC, PAL, and SECAM. The NIR system was strongly recommended by a few people at the 1966 meeting of the CCIR, because they thought that it might provide a compromise to which all the countries of Europe could agree.

International exchange of programs

All the tv systems, both monochrome and color, can operate from movie film and this is still the simplest method of program exchange between all systems.

Monochrome programs can also be exchanged by video tape, microwave, and satellites between countries using the same scanning standards. In some cases there will be a reduction in picture quality because of the difference in video bandwidth between the systems.

Very satisfactory electronic standard converters are also available for converting between systems having the same field frequency, and these are used quite extensively in Europe at the present time. Satisfactory standard converters have also been built for converting between 50 and 60 field systems. Previously, optical converters that consist of a camera focused on a picture monitor were used, but they had poor resolution and also introduced substantial noise. In addition, there was usually some 10-cycle flicker output.

International exchange of color programs is more complex. Even if there were only one color system, say NTSC, throughout the world, there would still have to be six different standards for the chrominance signals if color were to be used with all the monochrome systems. These different standards are indicated by arbitrary numbers in the right-hand column of Table I. Fortunately, agreement has been reached in the CCIR that color tv will be confined to 625-line systems in Europe; thus only three color standards would be necessary if only one color system were to be used.

For exchange of color programs between countries to be accomplished easily, other than by means of film, not only must the scanning standards be the same, but the color standards must also be the same. The CCIR has obtained agreement that the color subcarrier frequency will be 4.43 MHz in Europe for the 625-line 50-field systems, but this frequency is not suitable for system "N" which is used in some South American countries, because the vision-to-sound carrier spacing is only 4.5

MHz; so, special transcoding apparatus must be used to change the color subcarrier frequency in order to exchange programs between system N and systems B,C,D,G,H,I,K and L. In addition, there may be some lesser difficulties in the exchange of programs where the same color systems, color subcarrier frequency and scanning standards are used due to differences in the bandwidths allowed for the upper sideband of the color subcarrier, which is not the same for systems B, I and L.

Exchange of programs between countries using the same scanning standards but different color systems is, of course, possible by transcoding the color information. However, this transcoding will reduce the resolution of the luminance signal to some extent, because of the filtering required to prevent the incoming color subcarrier from interfering with the outgoing signals.

Exchange of color programs between systems having different scanning standards is more difficult, though electronic conversion between 525 NTSC and 625 PAL is now becoming commonplace.

Receiver compatibility summary

Monochrome receivers designed for system N can be used on system M and *vice versa*. If NTSC is used with system N, color receivers would also be interchangeable. This is the only case where the same receivers can be used on systems having different scanning standards.

The same receivers are used on systems B and G. The only difference between these systems is the channel width (7 and 8 MHz respectively). The same receivers can be used on systems D and K. Again the only difference is the radio frequency bandwidth (8 and 8.5 MHz respectively). Receivers designed for systems B and G can be used on system H, but not the other way around. This is because system H has 1.25 MHz of vestigial sideband, whereas systems B and G have 0.75 MHz.

Because of the many different tv standards for monochrome, there are large areas of Europe where it is necessary for the viewer to have a multiple standard receiver if he is to be able to make use of all of the signals arriving at his antenna. In France he must have a receiver for systems E and L, and in the Benelux countries 4 and 5 standard receivers are not uncommon. At present, in England, programs originate as system I and are radiated on uhf. The same programs are also electrically connected to System A and radiated on vhf.

When the different color systems are added to the monochrome systems, the receiver design engineers will be busy for many years.

Table II — Sampling of international standards in current or proposed use. (Added 6/74, H.B.)

Country	*Monochrome standard used*	*Color standard used*
Argentina	N	NTSC
Australia	B	PAL
Austria	B, G	PAL
Belgium	C, B, H	—
Bulgaria	D, K	SECAM
Canada	M	NTSC
Czechoslovakia	D,K	SECAM
Denmark	B,G	PAL
Finland	B,G	PAL
France	E,L	SECAM
Hungary	D, K	SECAM
India	B	—
Iran	B,G	—
Ireland	A,I	PAL
Italy	B,G	—
Japan	M	NTSC
Korea	M	—
Luxembourg	C,L	—
Mexico	M	—
Monaco	E,L	—
Morocco	B	—
Netherlands Antilles	M	—
New Zealand	B	—
Nigeria	B,I	-
Norway	B,G	PAL
Pakistan	B	—
Panama	M	—
Poland	D,K	SECAM
Portugal	B,G	—
Rhodesia	B,G,	—
Romania	D,K	—
Saudi Arabia	B	—
Spain	B,G	—
Sweden	B,G	PAL
Switzerland	B,G	PAL
The Netherlands	B,G	PAL
United Kingdom	A,I	PAL
United States of America	M	NTSC
Union of Soviet Socialist Republics	D,K	— SECAM
West Germany	B,G	PAL
East Germany	B,G	SECAM

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Communication problems of a multilanguage company

M. Riley

When a company moves out of its traditional domestic market, its specialized advertising and sales promotion material, which has found a ready acceptance over the years, is suddenly found lacking. This communications gap, which initially seems a minor annoyance, very often becomes a major factor in an export marketing plan. Because of the many more steps involved when producing copy for foreign consumption, each one taking up time and, therefore, money, the time scales involved in the plan are increased, often by multiples of four or five. It is this aspect of the job that often leads to the frustrated cry of "idle foreigners" from the marketing people in the home office. It should be noted, however, that the man overseas will almost certainly be voicing the same feelings about the home office! A greater insight into the problems facing the novice marketeer working abroad, particularly if he is a foreign national, will lead to a far greater understanding of his plight, will remove many of the pitfalls facing both home and foreign office, and will reduce the onset of ulcers in both for a few more years.

IT IS NO USE for the company Board to make a decision to launch a product, service, or an identity without taking into account the time scale needed to produce sales literature, press literature, and advertisements. It is of prime importance that, at the outset, adequate time is alloted for implementation of a communications plan.

Developments in high-technology sciences originate mainly in the United States and therefore all data and information are in English. The situation is particularly true in electronics; even in Russia computers are programmed in English. Design engineers abroad have, by necessity, come to accept data sheets, installation notes, and technical manuals in English (the American technical magazine *Electronics* is widely accepted by many top European managers and design engineers as an authoritative mouthpiece close to the oracle of electronics knowledge), but it is a different story when material is produced for sales or marketing use. To gain acceptance, display advertising and promotional material must be in the language of the respective country, and here we come upon one of the common difficulties, namely, translation.

Translations

Many translators believe they know their particular language thoroughly, and for normal requirements they are usually right. However, a technical translation, particularly of an electronics subject, can defeat even a foreign national unless he is trained in that particular scientific discipline. Technical translation is costly, and can account for a large part of any budget; therefore, it is essential that the translator have a basic knowledge of the related technology. It is an unfortunate fact of life that a subject which is advancing as fast as electronics tends to leave the layman in its wake, and new words come into the vocabulary almost every day.

This lack of technical expertise on the part of the translator, even for a long-standing science, can result in some amazing errors. A perfect example comes from a construction machinery booklet which was translated into Spanish. The words "hydraulic ram", universally accepted in English, resulted in "water goat" on translation, leaving the reader totally bemused. The early handbooks accompanying Japanese products created various impressions on British readers, but the overall impression was one of scepticism in the company concerned. It did not take the Japanese long, however, to understand the problem, and today their literature bears no comparison to the translations of the past.

It should also be appreciated that many colloquial expressions and catch phrases used to promote a product in the United Kingdom will be quite incapable of being translated into another language and must be altered before the translator even sees the copy. The problem is usually foreseen when originating new material, but is quite often overlooked when existing copy is used in a different country. Only this year we discovered that the phrase "a load on his mind" means nothing outside the British Isles (even some Americans are puzzled by it, apparently). Since English is the world's major technical language, it seems sensible to use this as a basic working tongue. Obviously, however, care must be taken to avoid even apparently trivial idioms.

On the other hand, it is equally important to distinguish between translation errors and personal opinion. A few months ago, translated copy was sent to a European sales office for routine check. We were more than a little alarmed to be told that the translation was completely wrong. When we next visited the office to discuss the problem, it turned out that the objection was to the overall tone of the copy—it was too immodest for an essentially restrained country—and that, in fact, the translation was entirely accurate. We later met representatives from two of the national technical journals and presented them with the copy, asking them, "Is this a good translation for your

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country?" Their response was an encouraging —"Why not?"— they did not agree with the objections of the original reviewers.

Many "international" journals are starting to appear; these journals cover many industries and are written in three languages to cover their circulation areas. The advertising copy must be relevant to each country. While the copy may be in English, terminology must be simple, and must not be capable of misinterpretation by non-English readers who understand the basic Engligh language.

Many companies with headquarters in the U.S.A. are passed original American advertising material for adaptation to Europe markets. Seldom can this material be used without many alterations, for even if it were for the U.K. media, the "Americanisms" would have to be deleted, and probably the picture would need replacing. It is of no value to have a "typical" American image smiling out at the reader if the caption declares the photo to be of a design engineer from Italy. This "acceptability factor" is extremely important, not only to the reader (for the fact remains that Europeans like to deal with other Europeans, and preferably with their fellow countrymen) but to the Federal authorities in the United States where it is illegal to use models in an industrial situation unless clearly stated. If you say in your copy that Ted Smith is a tea planter, then he had better be a tea planter called Ted Smith!

Many Americans still cannot comprehend the apparent coolness with which some Europeans react to economic invasion. In contrast, many Europeans recklessly brush aside the American contribution to the unprecedented affluence of the western world in the sixties and the seventies. The pros and cons of either side are endless. It is significant then that the vast majority of U.S. companies who move into the European market do not want to be known as "American", but more as "international". This means that each advertisement, each sales brochure, and each press release has to be scanned to ensure that spelling, terminology, and graphics are related to the country in which it will appear. A company which is trying to convey an overall European identity cannot simply rely on its domestic reputation, or indeed on its domestic corporate image, to achieve its objectives. Local factors, particularly variations of national identity have to be considered and built into a recognizable overall company image.

Additional cautions

Colors may play a big part in promoting goods, particularly packaged food items. A visit to any large supermarket will bring this point vividly to the mind. English manufacturers tend to favor red as the predominant color, as it is warm and therefore comforting. Moving along the shelves, one is immediately arrested by the deep blues of the packaging containing Italian manufactured goods. Blue is a cool color, strongly fancied for hot climates, but which looks remarkably out of place in an English shop in midwinter.

Management interviews with overseas magazines are another form of communications which need particular caution. Preferably a company employee who is fluent in both languages should sit in at the interview to prevent ministerpretation by either the manager or the magazine editor. The manager should be instructed to speak slowly, and he should check that salient numbers or other data have been correctly noted. Similarly, any numbers should be followed by the units in full. This will prevent obvious mistakes, such as yards being written as meters, and so on.

Recruitment of sales personnel in the overseas market also has its problems. Apart from his mother tongue, the salesman should have a good command of the English language, as he will have to communicate with the home office at regular intervals. Translation errors when quoting for new business can be very expensive.

Conclusion

Multilanguage techniques, particularly when related to the European community, will play an increasing role in the future, and companies employing new senior marketing personnel will expect them to know most, if not all of the communications methods needed to reach these markets. Government departments in the U.K. seem to have avoided this fact, for there is no literature or guidance notes to aid the beginner in his studies, and by reading this article, it should be plainly obvious that without some form of reference, the novice will find nothing but problems.

Michael Riley, Marketing Services Manager, RCA Solid State — Europe has now been with RCA for three years, starting as European Advertising Manager. Since leaving college, his entire career to date has been in advertising and sales promotion, including nine years in consumer and industrial agencies and five years with AMP in Europe. He currently holds diplomas of the Institute of Marketing in Economics, Advertising, Market Research, and Marketing and is an elected member of the Institute of Marketing.

Technical and scientific translating

J.L. Collazo

This article discusses some of the implications and complexities of technical and scientific translation.

Editor's note: In keeping with the International theme of this *RCA Engineer* issue, Mr. Collazo calls attention to some not-so-obvious problems often created by the language barrier. The author cautions anyone having translations performed to ensure that the translator can understand the scientific environment as well as the two languages involved.

The author is Manager of Translation Services, a Corporate Staff Activity located at Clark, N.J., which provides official translations to all divisions and subsidiaries of RCA. The Translation Services activity also provides interpreters for discussions, negotiations, or conferences, with foreign visitors or customers.

WORLDWIDE need for the interlingual exchange of technical and scientific knowledge and information may be appreciated from the fact that, according to surveys carried out by UNESCO, at least 50% of the scientific literature is in languages which more than half the world's scientists cannot read. Although English is gradually becoming the accepted world language of technology, and nearly two thirds of the engineering literature appears in English, more than two thirds of the world's engineers cannot read English, and a still larger proportion of the English-speaking engineers cannot read literature in other languages. In other words, the greater part of the technical information published in the world is inaccessible to most of those who could otherwise benefit from it.

The above-described situation could be alleviated by increasing the proportion of technologists and scientists able to read foreign languages; by publishing more of the literature in widely known languages rather than in little-known languages; and by publishing in an easily learned international auxiliary language, such as Interlingua or Esperanto. However, application of such remedies would create educational problems unlikely to be solved in the foreseeable future. Therefore, we must assume that language barriers will continue to exist; that the need for translating will increase with the growth of science, technology, and international commerce; and that English will be involved (as either the source or the target language) in the bulk of the translations.

Translating and the translator

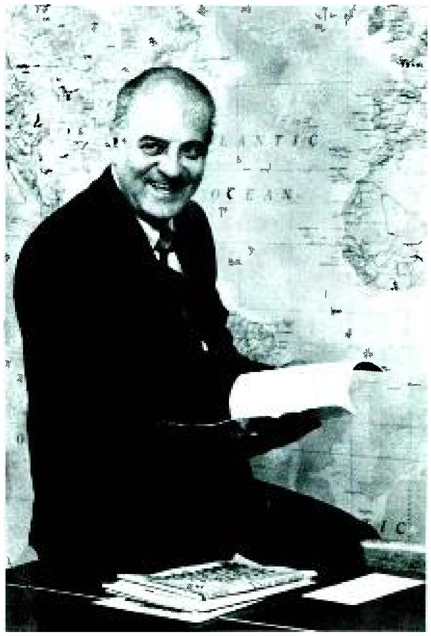
The translator can be described as a bilingual writer or editor who assimilates ideas and information by reading in one language and reissues them by writing in another language. To do this efficiently, he must meet three essential requirements:

1) He must have a good grasp of the source language and be an accurate reader in it. He should have a large recognition vocabulary to minimize the need for general dictionary consultation.
2) He must be a good writer in the target language (preferably his native language), having good facility for composition and a large active vocabulary.
3) He must master the art of accurately extracting ideas and information from the given document, written in one language, and clearly reformulating them in the required second language.

Meeting the third condition may seem a natural result of satisfying the first two, but it is not so. There are many persons who, although perfectly bilingual (in the sense that they can think and express themselves in either of two languages), cannot do satisfactory translations, simply because they lack the inborn linguistic sensitivity and/or the skill necessary to absorb another person's thoughts in one language and communicate them with accuracy and naturalness in the other. Translation skill is additional to the four main language skills (understanding, speaking, reading, writing) and largely independent from them.

Each language is the vehicle of a distinct culture and the instrument of a different system of thought, and this is the reason literal translations are ugly and inaccurate as they can be incomprehensible or laughable. In translating, the original wording is essential in absorbing the ideas; after that, it must be discarded and the ideas must be reformulated in the new frame of reference of the target language, as if they had been thought directly in it. When this is well done, the result is the "invisible" translation — the translation that does not read like one.

Javier L. Collazo, Translation Services Department, RCA International, Clark, N.J., received from the "Academia Oficial de Comunicaciones" (Cuba) the titles of Telegraphist and First-Class Radiotelegraphist (1937) and the Radiocommunications Technician diploma (1949). After passing the university entrance examinations (BS equivalency) he attended the School of Engineering (EE) of Havana University (1943-46). While in Cuba, he worked in the telecommunications field: Chief Operator and Technical Director of Cuban Wireless Corp. (1939-44); Chief Operator and Technical Supervisor of the United Press Havana Bureau (1945-47), and Traffic Manager for Radio Corporation of Cuba (1947-51). In the U.S.A. he worked as a Technical Translator and Spanish Copywriter for International General Electric (1951) and ITT (1952-54) before joining RCA (1954). He is a member of the IEEE, the ATA (American Translators Association), and PTH (Spanish Copywriters and Translators), and the author of a comprehensive "English-Spanish & Spanish-English Encyclopedic Dictionary of Science and Technology specializing in Electrotechnology, Electronics, Nucleonics, Telecommunications and related fields



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Technical/scientific translating

Technical/scientific translating involves all the complexities of general translation, plus the additional ones presented by the need to interpret specialized ideas in a specialized vocabulary (belonging to the original language) and to reformulate them in another specialized vocabulary (belonging to the final language). This is a process that requires knowledge of the subject and experience in technical reasoning on the part of the translator, particularly when the original is poorly written or insufficiently explicit and the translator must, so to speak, go out and meet the author half-way to comprehend his intended meaning.

Before the translator can restate the ideas or the information in the translation, he must digest the original text and resolve, in his own mind, any obscure statements. This takes much more than simply knowing the two languages involved; it requires familiarity with the subject matter and its basic concepts, and with the corresponding terminology in one and the other language. These conditions can only be met with the proper background and experience, supplemented as necessary by additional research and study oriented towards the specific assignment.

Texts requiring translation vary not only as regards their special subject content, but also in relation to the types of documents, examples of which are: papers and reports presenting new knowledge and descriptions of its applications; reviews and integrations of existing knowledge, in the form of articles, pamphlets, reports, and reference manuals; textbooks, popular science publications, and educational material in general; documents relating to engineering and industrial applications which concern international trade, such as catalogs and sales promotion brochures; specifications, proposals, contracts; reports on tests and analyses; and patent applications.

The type of document, the intended use of the translation, and the type of reader, are some of the factors that determine the treatment to be accorded to each assignment, and the selection of the translator to handle it.

In choosing a translator, one of the first questions is whether his product is meant for direct use, or simply as material to be processed into final form. For instance, a sales brochure on a piece of equipment, to be published in a foreign language as delivered by the translator, would require of him the combined abilities of a technical translator and of a copywriter native to that language; that is to say, he would have to be capable of both accuracy of technical interpretation and a high standard of literary presentation. The difficulty of finding these two abilities combined in one person is resolved in many cases by teamwork, that is, by getting from the translator a draft from which an editor will prepare the final copy. On the other hand, where a translation is made into English simply for the information of a staff member of an organization, the quality of presentation is much less important than speed and economy of effort.

There are many hurdles for the translator to overcome when working from English, among them:

Terms overloaded with meanings. Numerous English terms have 15 to 20 different meanings, each matched to one or more Spanish equivalents. Some terms have many meanings in a single field.

The piling up of modifiers in front of a noun. Such "conglomerates", often without hyphenation, are sometimes difficult to understand and always awkward to render in foreign languages. Examples from actual texts:

"A remarkable compact lightweight pocket-size precision-built transistor radio";

"A 10-mesh No. 23 W&M gage woven stainless steel wire cloth".

Uncommon and unexplained abbreviations. It has been estimated that new English abbreviations and acronyms proliferate at the rate of over 150 per year.

Technical slang. The translator may meet a slang term at any stage, from that of incipient use to that of generalized use and even acceptance as a standard term, as, for example, *defruiting* (the process of suppressing asynchronous returns in a radar beacon system).

Highly compressed expressions. Technical English is capable of extreme and sometimes perplexing compactness, as in *carrier maintenance* seen as the title for an article with the meaning of *maintenance of carrier-wave multiplexing equipment*. Some of these very short expressions evolve by successive simplifications until they become almost a code that only the "initiated" understands without help, like *red pipette* from *red counting pipette* from *red blood cell counting pipette*.

Pleonasms. English abounds in pleonastic expressions that have become acceptable in everyday usage. A few of the most common are: *hollow tube*, *foot pedal*, *surface area*, *free gift*. Fortunately, in translation such expressions are usually so manifestly redundant, that a translator with a modicum of experience will automatically correct them.

Ambiguity. The translator is at times confronted with an insolvable ambiguity in the text he is translating: A phrase can be read in different ways; the context does not supply sufficient clues to the intended meaning; the possible interpretations appear equally plausible or logical; and the writer cannot be reached for clarification. So cornered, the translator will usually transfer the ambiguity to the translation, rather than to risk putting his reader on the wrong track by arbitrarily opting for one of the potential interpretations. Another justification for this escape route is that the reader of the translation, perhaps in possession of background knowledge not available to the translator, may quite possibly be able to resolve the ambiguity; and if not, he will at least be able to consider the different possible interpretations. But what if the *unresolvable* ambiguity is also *untransferable*, as it would be in translating, for example, the hackneyed "Flying planes can be dangerous" into Spanish? This phrase would have to be rendered *unambiguously*, but with 50% chance of error, as either:

Los aeroplanos en vuelo pueden ser peligrosos [Planes in flight can be dangerous]; or

Pilotar aeroplanos puede ser peligroso [To pilot planes can be dangerous].

Of course, there is such a thing as the intentional ambiguity "planted" for some special reason by the source-text writer, but we are here concerned mainly with the translation of technical and scientific matter, where there should be no place for deliberate ambivalence.

False friends. Many erroneous or anglicized translations result from deceptive cognates, the so-called "false friends" among professional translators. Some English-Spanish examples are shown in Table I. Of course, the Spanish terms in the center column would present a reciprocal risk of mistranslation into English.

Conversion of units of measurement

Part of the work of translating from or into English is the conversion of English-unit quantities into metric (SI) equivalents, or vice versa. The equivalents may be supplied alone in the translation, but it is common practice to add them in brackets after the original quantities.

At times, as a compromise, the translator will simply supply (in brackets or in footnotes) the necessary conversion factors, leaving to the translation user the computation or table lookup work if the

Table I — English-Spanish false friends.

English	*Wrong translation*	*Correct translation(s)*
Actual	*actual*	*real, verdadero*
present		*presente, actual*
to anticipate*	*anticipar*	*prever, imaginar, suponer, esperar*
casualty	*casualidad*	*daño o muerte por accidente; persona lesionada o muerta por accidente; baja (soldado muerto o herido en acción*
conventional (*)	*convencional*	*común, corriente, usual, normal, ordinario, clásico, tradicional*
facilities (*)	*facilidades*	Only rarely can the English be translated as *facilidades*; the possible translations are numerous and depend on the context.
eventually	*eventualmente*	*finalmente, al fin, por fin, a la postre, tarde o temprano, un día u otro, en su día, con el transcurso del tiempo, etc.*

(*) In its common acceptation.

explicit measurement equivalents are needed.

Hopefully, the need to convert measurements will eventually disappear as the metric system is adopted for general use in the English-speaking world. This question (an important one for the translator, since such conversions represent additional work for him) has been in the news often during the last few years. In Great Britain, the conversion of industry to the metric system is nearly complete. In the United States (the only major industrial country still largely committed to the customary system of units), this most useful reform has made slower progress, but there is evidence of growing support for it.

Translator's tool chest

Regardless of how well grounded he may be in his subjects of specialization, the technical/scientific translator must own or have access to an as-extensive-as-possible reference library that includes monolingual and bilingual (or multilingual) dictionaries and encyclopedias, both general and of various degrees of specialization; textbooks and other works, both in English and in the other languages he may handle; manufacturer's or other literature on specific devices, techniques, and applications.

Also very useful are the "bilingual pairs" formed by books published in two languages. If the original version has been well translated and care was exercised in establishing the terminology in the translation, these "pairs" function ideally as specialized bilingual dictionaries, having the added advantage that all equivalent technical terms and expressions are found in parallel contexts.

Due to the fast pace of scientific discovery and technological development, and the time required for a book to be written (or updated) and published, books in general tend to fall behind rather rapidly. For this reason, the translator needs to subscribe to at least a few specialized magazines and journals in each language of interest for his work, or have access to collections of such publications.

Of the various working tools mentioned above, none is so essential and of such constant use as the technical bilingual dictionaries. Finding proper equivalents for technical terms presents many difficulties and pitfalls, for a diversity of reasons, and the research done by the dictionary compiler and embodied in his work is the translator's most effective aid. This is especially true when the compiler, having been a translator of long and rich experience, is keenly aware of the problems likely to be encountered by other translators with certain terms and expressions.

Lexicography based on agreed definitions

A number of specialized international organizations include or have affiliated to them special commissions which publish vocabularies or glossaries of terms that have been standardized in several languages by reference to agreed definitions. The International Electrotechnical Commission, for example, publishes from time to time vocabularies relating to different branches and applications of electrical engineering. In each vocabulary, the chosen concepts are carefully defined and named in French and English, and equivalent terms for each definition are given in other languages.

Although these formal international vocabularies are of doubtless importance in exercising terminological control, they are of limited value as practical tools for the translator, because each covers a relatively small number of concepts, and because of the long time it takes to publish each vocabulary. The latter difficulty is due to the working cycle used, which includes preparing a first draft; circulating it among the national committees for criticisms and suggestions; examining the comments to prepare a second draft; circulating the second draft for further comments and to gather proposals for additional definitions; and preparing the final version for publication.

Lexicography based on semantics

This is the method used to compile the vast majority of the interlingual dictionaries, usually authored by individuals for commercial publishers. The compiler using this method sets down the equivalent terms on the basis of his own familiarity with the subject fields and the meanings with which the terms are actually used in both languages.

The quality of such a dictionary depends on the knowledge and perceptiveness of the compiler, and on the thoroughness with which he has systematically confirmed and expanded his own selection of equivalents by critically consulting previous dictionaries and translations made by competent translators, and by searching the literature in the two languages. In searching the literature he will methodically compare examples of context in which the respective terms have appeared in each language, noting their relative incidence in association with particular meanings. He will also record synonyms and near-synonyms carrying different connotations and nuances of meaning. If the author is also a translator who in the course of his career has been forced to invent new terms to label new concepts, and take the responsibility for putting them in circulation he will also record such terms in his dictionary.

Linguists and translators are aware that each term has a semantic core carrying the general or central meaning surrounded by a penumbra of vagueness conveying slightly different meanings and overlapping the penumbras or fringe areas of other terms. This results in imprecision even within a single language. When referring to a concept midway between two meanings, an author may use one term and the reader understand it in the sense of another. If translation is involved, the risk of misunderstanding is compounded by the fact that only rarely do even the centers of meaning of the words equated to one another in bilingual dictionaries coincide exactly. Because of this, a bilingual technical dictionary should include a comprehensive selection of equivalent terms and synonyms, to help the translator select the expression that will achieve optimum transfer of meaning, not simply *denotation* but also *connotation*, in the specific context on hand.

To refer as an example to the specific case of the existing English-Spanish technical dictionaries (of particular interest to the author of this article), we find that many of them are poor in equivalents, that is to say, they may supply under a given entry a single equivalent when there are a few in more or less common use, or they may give two or three when there are several, perhaps up to ten or more. This deficiency is the result of scanty knowledge or insufficient terminological research on the part of the compiler, or it is due to the fact that he, setting himself up as the sole judge of good usage, included only those equivalent terms that he considered acceptable, preferable or optimum. In compiling a dictionary of this kind, the author should assemble the largest possible portion of the terminology in use, although, of course, he must discard expressions that are clearly improper or erroneous, either from the technical or the linguistic standpoint.

Some of the general criteria that should be applied in selecting or creating equivalents are: idiomatic correctness, euphony, brevity, clarity and uniqueness of meaning, recommendations of standardizing organizations, and established usage. The translator should in each case select the term with the best combination of desirable features, taking into consideration any additional factors applicable to specific assignments, such as consistency and compatibility with respect to previous translations, local or national destination of the translation, and level of technical education attributed to the reader of the translation. As an example, a given expression may be elegantly concise, while an equivalent expression may be longer but very explicit or self-explanatory; the first would be preferable if the translation were addressed to experts in the field, whereas the second would be more appropriate in an article intended for a less technical audience.

Following are some examples of English terms the translation of which presents a baffling problem or a trap to the translator not familiar with them or not having available a dictionary that will give him the proper equivalent:

Impedance volts: American transformer specialists use this expression to refer to what in all other branches of electrotechnology is called *short-circuit voltage*.

Crowbar: In addition to its traditional meaning (a tool), this term has in electronics the meaning of a *complete shortcircuit* (the condition of a power supply if a heavy piece of metal, such as a crowbar, were placed across its terminals).

Dead-reckoning: This expression is used as a short for *dead-reckoning navigation* (Spanish: *navegacion a la estima*), and is found in many technical dictionaries, but why "dead"? Originally the expression was *deduced reckoning*; through usage the first word was abbreviated to *ded* and later transformed to its phonetic equivalent *dead*.

Toll call: This expression (used in telephony) is sometimes misinterpreted as "call subject to charge" or "chargeable call", not being generally known that "toll" was originally an acronym for Transmission Over Long Lines and that it stands for *intercity*, *interexchange* or *long-distance* in expressions such as *toll board*, *toll center*, *toll line*.

Subset: The translation of this term may appear arbitrary if one does not know that it originated by the contraction of "subscriber set". *Subset* stands for *telephone instrument*, especially when installed at a subscriber's station. Synonyms: *handset*, *desk set*, *telephone handset*.

Some expressions have unexpected equivalents, completely removed from their literal translation. Consider this group with their correct Spanish equivalents:

India ink	*tinta china*
India mica	*muscovita*
India paper	*papel de bambú*
India tint	*color gamuza claro*

The following examples show how simple expressions may conceal a mistranslation trap:

1) acetate solvent
disolvente del acetato de celulosa
2) ester solvent
disolvente éster, éster disolvente
3) petroleum solvent
disolvente derivado del petróleo

In 1), the solvent *dissolves* acetate; 2) the solvent *is* an ester; 3) the solvent *is derived from* petroleum.

In translating into English any of the following equivalent expressions:

Spanish/Portuguese:
transformador diferencial
French:
transformateur différentiel
Italian:
transformatore differenziale
German:
differentialübertrager

the translator not familar with telecommunications terminology would be tempted to render it literally as *differential transformer*. This could baffle an English-speaking communications engineer who only knows the device in question as a *hybrid coil*.

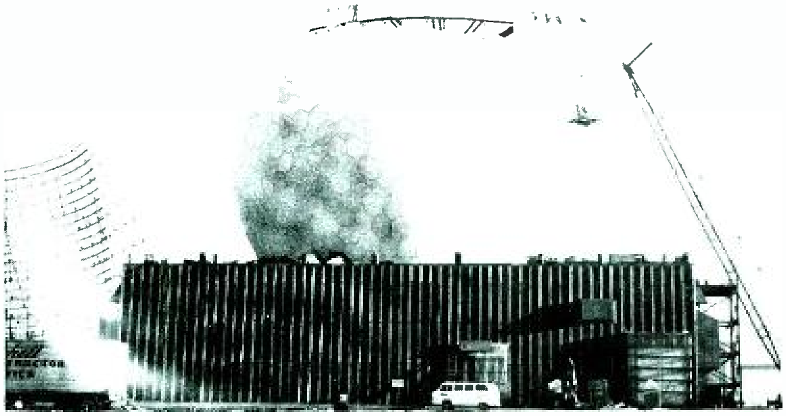
Conclusion

Far from the almost mechanical process some people imagine it to be, technical and scientific translating is a highly creative endeavor demanding knowledge, experience, skill and good judgment at every step. Specialized professional translators and bilingual dictionaries are in demand to keep pace with the rapid development and international dissemination of science and technology.

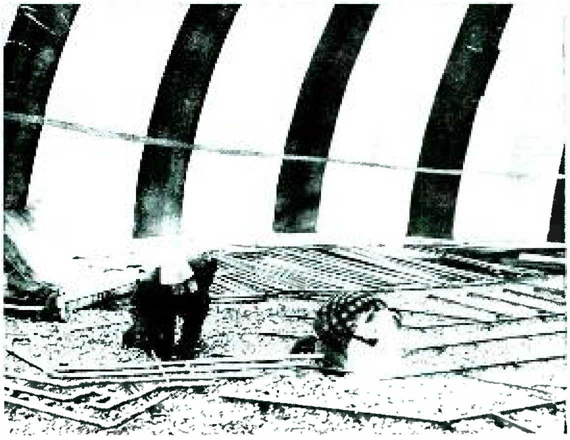
World-wide construction of facilities for ground-based electronics systems

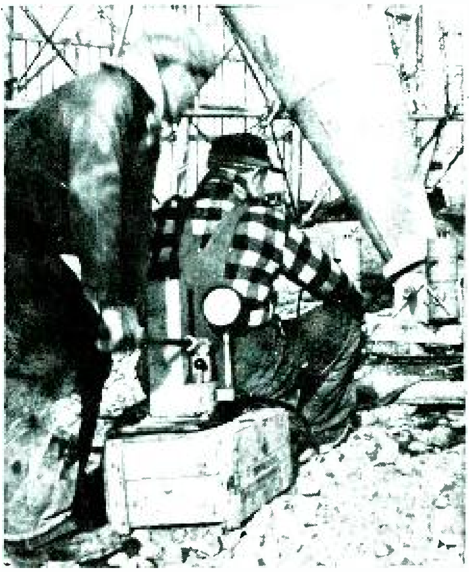
M.Rubin | A.G. Hopper

For the past twenty years, RCA's Architectural-Engineering and Construction (A/E&C) group has been involved in the design and construction of major electronic facilities around the world. These activities have involved many unique problems — ranging from construction in severe climates to concern for preservation of the environment — as well as the expected problems of cost, schedule, design, and performance constraints.



Erecting the 140-ft diameter Tracking Radar radome at the Clear, Alaska BMEWS site.





Above: View inside the air-inflated tent at the Thule, Greenland BMEWS site. Workmen are shown installing the permafrost refrigeration system under the Tracking Radar tower. Right: Prestressing anchor bolts on the rear legs of a Detection Radar Antenna at the Thule, Greenland BMEWS site. This is done to prevent movement of the rear base plate during peak design wind velocities of 185 m/h.

DURING THE 1950's, the size and complexity of ground-based electronics systems increased significantly, and RCA was faced with the problem of providing enclosures, buildings, and support facilities commensurate with the stringent requirements of sophisticated electronics systems. In many cases, the programs involved applications of electronics to navigation, missiles, satellites, space exploration and national defense, with attendant constraints and rapid activation schedules. Projects were frequently located overseas and in foreign countries, making the associated logistics and construction problems world-wide in nature. The rigors of severe climate, forbidding terrain, adverse site conditions, and remote locations simply added dimension to the challenge.

In response to this demonstrated need, RCA established a specialized Architectural-Engineering skill center to serve the entire corporation, and located this group in the Missile and Surface Radar Division, Moorestown, New Jersey. Since its inception, the Architectural-Engineering and Construction (A/E&C) Group has been actively involved in the design and construction of major electronic facilities all over the world.

Organization and design approach

The A/E&C group is staffed with professional engineers in the required facility disciplines; *i.e.*, architectural, civil, structural, mechanical, electrical, and construction engineering and management. Teams formed from this group are tailored to suit the individual needs of each project undertaken. Engineering manpower is phased into and out of the program as individual facility specialties are required, with continuity assured by designating one engineer with a key specialty as the Responsible Engineer for the project from start until completion.

Once a program is begun, the A/E&C group maintains responsibility for development of the facility from initial concept through site activation. The activity scope includes proposal preparation, site surveys, feasibility studies, facility criteria development, design and analyses, preparation of drawings and specifications, cost estimating, consultation, construction planning, and construction management.

Facilities design and construction requirements normally encountered include:

- Buildings, towers, and structures
- Heating cooling, and air-conditioning systems for personnel and equipment
- Electrical power generation and distribution systems
- Complete power generating plants, including ancillary equipment
- Fuel storage systems
- Fire alarm and security facilities
- Grounding and lightning protection systems
- Water and sewerage facilities

Murray Rubin, Ldr., Architectural-Engineering and Construction, MSRD, Moorestown, N.J. received the BCE from New York University in 1950 and the MSCE from Columbia University in 1954. He joined RCA in 1958 as a structural and foundation consultant on the BMEWS program, where he had prime responsibility for assuring the long-term structural integrity of facility and radar structure design under the severe temperature, permafrost and seismic conditions existent at the BMEWS forward sites. He is credited with several unique radar foundation designs at these sites, including refrigerated foundations, soil-cement fills, and high pressure intrusion grouting of deep sandstone lenses. From 1960 through 1962, Mr. Rubin supervised the design and construction of the BMEWS station in Fylingdales, England. He returned to this station from 1964 through 1966 as MSRD Site Manager to supervise a major modification program to the three operating radars. Prior to joining RCA, Mr. Rubin worked for the U.S. Bureau of Reclamation at Grand Coulee Dam, and for the California State Highway Bridge Department. He was associated with Dr. D.B. Steinman as Bridge Designer and Field Engineer, where he was in responsible charge of portions of such major projects as the Mackinac Straits suspension bridge. He has also had industrial building and nuclear reactor structural design experience with Blaw-Knox Chemical Plants and the Koppers Company. From 1951 to 1953, Mr. Rubin was a U.S. Army Corps of Engineers officer. He served with distinction in Korea as Engineering and Planning Officer on the staff of the 409th Engineer Brigade. Mr. Rubin is a Fellow in the American Society of Civil Engineers, and a member of the Society of American Military Engineers. He is a Registered Professional Engineer in the state of New York, and he is certified by the Department of Defense in Fallout Shelter Analysis and Protective Construction.

Abram G. Hopper, Jr., Architectural-Engineering & Construction, MSRD, Moorestown, NJ began his engineering studies at Virginia Military Institute in 1944 while serving with the U.S. Army. He received the Purple Heart during service in the infantry and returned to college after the war receiving the BSCE from Carnegie Institute of Technology in 1949 and the MS from the University of Pittsburgh in 1956. He has continued graduate study and is presently a candidate for Dr. Sc. in Applied Mechanics at Drexel University. He has taught mathematics and engineering courses at Westinghouse Technical Night School for several years, has authored several papers and patent disclosures, has served on the Chief Engineer's Technical Excellence Committee, holds Professional Engineering registrations in Pa., N.Y., and Mass. and is certified by the Dept of Defense in Fallout Shelter Analysis, Protective Construction and Environmental Engineering. His prior experience includes plant facilities engineering with Westinghouse Air Brake Co., structural design and stress analysis of naval nuclear systems with Westinghouse Electric Corp., chemical and industrial plant design with Allstates Engineering Co., and analysis of complex structural systems with Franklin Institute Research Laboratories. His nuclear experience includes work on power plant components for the U.S.S. *Nautilus* (first atomic submarine), the *Enterprise* (first nuclear aircraft carrier) and the *George Washington* (first ballistic missile submarine). Since joining RCA in 1970 he has made significant contributions to several A/E&C Group projects, including the AN/FPS-16 Instrumentation Radar installation at RADC, N.Y., the AN/TPQ-18 Transportable Radar at Kaena Point, Ha., the AN/MPS-36 Mobile Radars in W. Germany, and the OTH radars. In addition, he has been a structural consultant to RCA-Gibbsboro on tv broadcast antennas for the New York World Trade Center and the Chicago Sears Building, and to RCA-GCS on the Small Terminal Program and the Sanguine Program.

Authors Rubin (left) and Hopper.

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Supporting facilities, including offices, warehouses, shops, mess facilities, roads and parking areas

To assure that projects are completed on time, the design and construction efforts are integrated into overall engineering development program schedules; job progress and costs are monitored on a weekly basis to provide effective management control.

In general, design and construction of the support facilities proceeds concurrently with the design, development and manufacture of electronics system hardware. Consequently, the exact configuration of the electronics system is not firm at the time that facility design begins, and many assumptions and engineering judgments are made in order to proceed with facility design. As the program continues and the electronics equipment develops, the facility design must be updated and revised to maintain compatibility with the electronics equipment. On certain programs, the support facilities actually become subsystems of the electronics system, and their designs are subordinated to the electronic system requirements. Careful coordination, with due regard for performance objectives, reliability, maintainability and human factors, is always needed to achieve an optimum design and cost balance between facilities and electronics.

Foreign projects

Projects in foreign countries usually involve coordination with an agency of a host nation through the U.S. Government. Projects may be sponsored completely by the U.S., or they may be a joint undertaking of the U.S. and the host nation.

In the first instance, the A/E&C group participates in the early contract negotiations between countries to assess the impact of the customs, laws, protocol, and regulations of the host nation on the project, and to establish working relationships with the host nation's regulatory agencies. Wherever practical, host nation subcontractors for facilities design and construction are employed to the maximum extent possible, thereby directing monetary benefits from the project into the local economy.

When the project is sponsored jointly by the U.S. and the foreign country, an arrangement frequently agreed upon is for the host nation to furnish an acceptable site and supporting facilities, with the electronics system and its installation supplied by the U.S. The BMEWS site at Fylingdales, England, is an example of such an arrangement. In this instance, the A/E&C group developed and supplied facilities criteria via the U.S. Air Force to the British Ministry of Public Buildings and Works who in turn became responsible for designing the facilities, subcontracting to local builders, and providing construction management. The A/-E&C group maintained a continuous interface between the electronics groups at RCA and the host nation facility management personnel to monitor design and construction progress, perform design reviews, provide consultations, and integrate required changes into the facility as work progressed. The A/E&C group adapted RCA's normal operating procedures to accommodate and work within the contracting methods and management control techniques employed by the British. This approach maintained harmony on the job without sacrificing RCA's ability to apply selective pressures to maintain the schedule and technical objectives of the program.

In situations where the native tongue is not English, bilingual engineers are assigned to the A/E&C group's interface personnel to assure smooth operations. Where the host nation's standards dictate, site facilites are designed using the metric system.

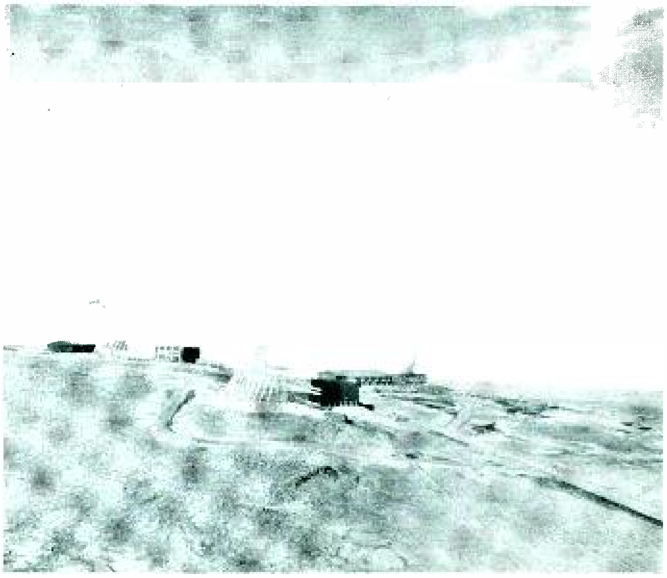
Major programs

During the 20 years that the A&E&C group has been in operation, it has played a major role in a wide variety of programs. Brief highlights of several of these are included in the following paragraphs.

TALOS land-based defense unit (TDU)

This project involved the design and construction of the prototype facility at

Typical FPQ-6 radar station, showing the two-story structure housing the radar equipment and offices, the pedestal structure supporting the 29-foot diameter antenna and the maintenance access platform.



Partial view of the BMEWS station at Thule, Greenland showing the Tracking Radar, and two of the four Detection Radar antennas. Permanent glaciers are visible in the background, beyond the fjord.

White Sands Missile Range (WSMR), New Mexico. The facility contained a series of blast-proof cells for housing missiles around the perimeter of two circular launcher enclosures, a central control structure, and support structures. Special engineering studies included blast analysis, missile assembly procedures, booster gas deflection, safety systems, and the missile fueling system.

Ballistic Missile Early Warning System (BMEWS)

BMEWS is a giant radar detection system designed and built to provide early warning of a missile attack on the United States, southern Canada, or the United Kingdom. As prime contractor, RCA provided management control and system design, and coordinated the work of over 2900 subcontractors.

The locations of the three forward sites are Thule, Greenland; Clear, Alaska; and Fylingdales Moor, England. The central control and display facility for BMEWS is located at NORAD Headquarters in Colorado Springs, Colorado. The magnitude of the undertaking is indicated by the power generation for one site alone, over ten million watts, which is enough to serve a moderate-sized city. The A/E&C group prepared facilities criteria for all of the sites, exercised design and construction surveillance, emplaced all of the electronics equipments, and integrated the power generation and distribution facilities.

Atlantic Missile Range (AFETR)

Many of the instrumentation radars installed between Cape Kennedy, Florida and the range terminus at Ascension Island in the South Atlantic are RCA radars, primarily of the AN/FPS-16 and AN/FPQ-6 category. The A/E&C group was charged with the design and construction of the associated facilities at such isolated places as San Salvador Island, Grand Bahama Island, Grand Turk Island, Antigua Island, and Ascension Island. These isolated down-range sites often demanded unusual and expeditious solutions to logistics, management and field construction problems to maintain tight activation schedules.

Pacific Missile Range (AFWTR)

Similarly, RCA instrumentation radars form the backbone of the Pacific Missile Range, with facilities from Vandenberg Air Force Base, California to the range terminus at Kwajalein Atoll in the southwest Pacific. Instrumentation radars have been built by RCA on Hawaii, Johnston Island, Eniwetok Island, Canton Island, Kwajalein Atoll, St. Nicholas Island, and at Point Arguello, Point Magu, and Point Pillar in California. These sites presented challenges as great as those encountered on the Atlantic Missile Range, requiring the building of long access roads to remote locations, the removal of mountain tops to accommodate the installations, and the construction of boresite towers 140-ft high on adjoining mountain peaks under adverse terrain conditions. Often, personnel had to commute to work by air from nearby habitable islands.

Woomera Missile Range (WRE)

Project Mercury (man-in-space) was an international endeavor, requiring joint cooperation between the governments of Australia and the United States. As part of this program, two AN/FPS-16 radars were installed in the Great Victoria Desert in South Australia, and an AN/FPQ-6 radar was later added at Carnarvon, Australia. The A/E&C group furnished design, engineering and installation data to the Australian Weapons Research Establishment, as well as engineering consultation, construction surveillance, and supervision of equipment emplacement for these stations.

Aberporth, Wales (RAE)

Two AN/FPS-16 radars were installed at this missile range in southwest Wales for the Royal Aircraft Establishment. Once again, the A/E&C group found itself working on a co-operative venture with the British Ministry of Public Buildings and Works, with the U.S. Navy designated as responsible agency for the U.S. Government.

AN/MPS-36 Radars, West Germany

Recently, three AN/MPS-36 radars were

The BMEWS Fylingdale station often finds itself playing host to distinguished visitors. Here, Prince Philip is given a briefing by the station commander Group Captain Allen Wright.

Completed Spacetrack Facility at Moorestown, New Jersey, as viewed from the N.J. Turnpike, showing the 140-foot diameter radome surmounting a three-story structure.

delivered to West Germany to counterpart agencies of our NASA and Army. Sites were prepared for these radars at Meppen, Manching, and Oberpfafenhofen. The A/E&C group participated in the site selection surveys, prepared facilities criteria, and performed design and construction surveillance.

Other United States missile ranges

In addition to the missile ranges already mentioned, facilities have been built for 18 instrumentation radars at the White Sands Missile Range, New Mexico; eight radars at the Eglin Gulf Test Range, Florida; two radars at Yuma Proving Ground, Arizona; three radars at the Air Force Flight Test Center, California; two radars at the NASA Flight Research Center, California; two radars at AEC's Tonopah Test Range, Nevada; one radar at Dugway Proving Ground, Utah; one radar at Rome Air Development Center, New York; one radar at the Naval Air Test Center, Pennsylvania; and three radars at NASA's Test Center at Wallops Island, Virginia. Many of these assignments were "turnkey," with RCA having total responsibility for delivering a complete and operating station, including the facility.

TRADEX

The TRADEX radar is a major sensor in the Pacific Range Electromagnetic Signature Studies (PRESS) program, employing an 84-ft diameter antenna located on Kwajalein Atoll. The A/E&C group prepared facilities criteria, provided design and construction surveillance, and has been providing facilities operation and maintenance consultation for the 12 years that TRADEX has been in operation.

Over-the-horizon radars

RCA has been a pioneer in the development of backscatter OTH radar systems. The A/E&C group has designed facilities for these large antenna array systems at Chesapeake Beach, Maryland, and overseas. On some of these systems, special construction materials have been applied by the facilities group to solve some rather unusual electronics problems.

Submarine communications

The A/E&C group has been associated for the last 18 years with a Navy program to communicate with deeply submerged submarines. Originally called PANGLOSS, and now termed SANGUINE, the system requires extensive burial of antenna cables and transmitter facilities over a wide geographic area. The A/E&C group has been furnishing facilities design for this program, overseeing related construction at the prototype test sites in North Carolina and Wisconsin, and assisting in the selection of suitable sites for the final system.

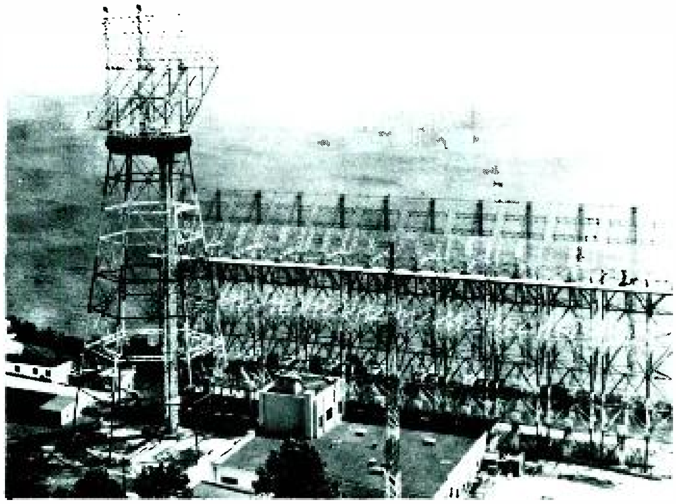
Corporate support and consultation

The A/E&C group is frequently called upon to provide specialized services and consultation to other divisions of RCA that have problems involving architecture, engineering, or construction. Some of the more recent activity of this type includes structural consultation on the design and field assembly of broadcast tv antennas for the World Trade Center and Mount Sutro, design of earth jacks and field tie-down assemblies for the shelters on the Small Terminal Program, and air conditioning and power distribution studies for a number of RCA plants in an effort to reduce energy consumption.

Unusual construction problems

On a number of the projects, RCA has had to overcome unique and challenging construction problems. Since many of the projects were classified at the time, these problems and their solutions have not found their way into the technical literature. This paper presents an opportunity to review some of them briefly.

View of the total Fylingdales, England BMEWS station, showing the three Tracking Radar Buildings, the powerhouse (right center), and the remaining support complex, in the midst of the surrounding moor.



Over-the-horizon radar constructed at Chesapeake Beach, Virginia for the Naval Research Lab.

BMEWS tracking radar antenna foundations

The BMEWS tracking radar antenna is a precision instrument, despite its 225-ton weight and 84-ft diameter, and it requires a stable base from which to operate. All three of the BMEWS forward sites involved differing and difficult foundation conditions, which had to be remedied to achieve the required antenna stability.

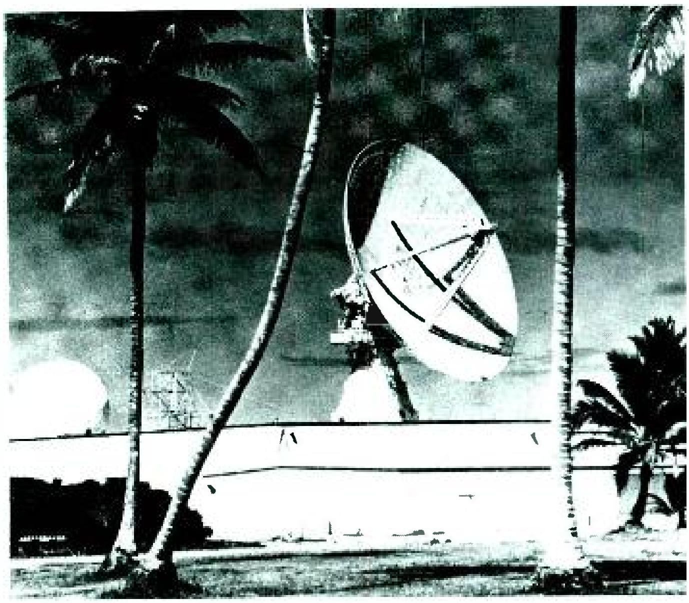
At Thule, Greenland, the site was situated on a permafrost bed 1,300-ft thick. Permafrost is a material consisting of soil granules with ice as a binding matrix, and it has a Young's modulus of elasticity of about 1,000,000 $lb_f/in.^2$. As a supporting material for the tracking radar tower, the permafrost is satisfactory, providing it is never permitted to melt. Such a condition can occur during the short Arctic summers, or as a result of heat loss from the radar buildings. At Thule, therefore, a layer of copper piping was placed on top of the permafrost at the elevation of the underside of the foundation slab, and over the entire 2,500-ft^2 base area. Refrigerated brine was pumped through this system until the permafrost (which had been disturbed due to construction) was refrozen, and construction operations then commenced.

The permafrost beneath the Thule tracking radar towers has been kept continually frozen from that day until the present. A system of thermocouples installed in the permafrost beneath the level of the brine-pipe network detects any rise in the geotherm (the 32°F isotherm) and intermittently operates the associated refrigerating equipment to maintain the ground in a frozen condition.

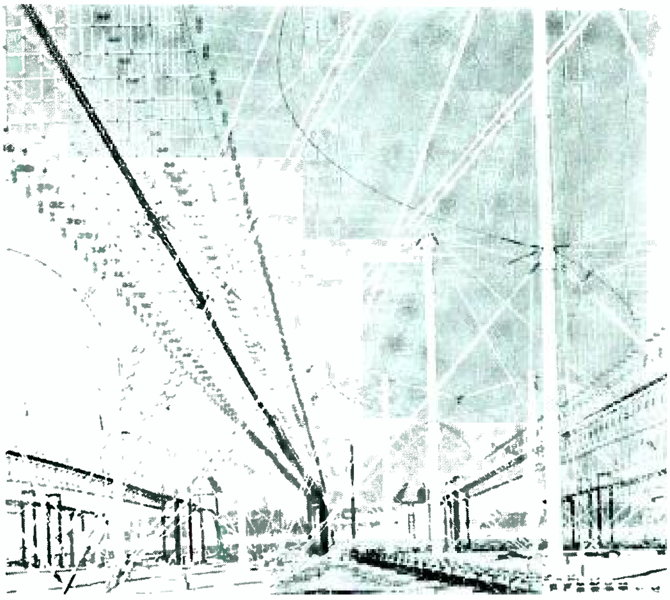
At Clear, Alaska, the foundation problem was quite different. This BMEWS site is located in an alluvial valley formed by the Nenana River, and it is also in a region of intense seismic activity. Soil borings continued to 400-ft depth without locating soil sufficiently firm to use for a radar tower foundation. The soil profile consisted entirely of loose sand and gravel. A decision was made to build a solid mass beneath the foundation sufficient in size so the tracker would act as if it were situated on rock. An excavation 100-ft in diameter and 25-ft deeper than the base of radar tower foundation was made, and the in-situ soil was reconstituted by adding portland cement, and rolling it into place in six-inch lifts. The technique is one that had been used for many years for forming base courses for rural roads but, according to Portland Cement Association, it had not previously been used in continuously applied layers to build up a solid mass. The technique worked successfully, and application was made using standard road-building equipment. At the interface with the foundation, steel dowels were employed to interconnect the tracking radar foundation with the soil-cement mass.

The Fylingdales, England site is on a desolate moor, and soil borings there showed unstable layers of alternating silts and clays (called mud-stones) to approximately 45-ft depth. At that level, a 10-ft thick layer of broken sandstone was encountered, after which the drill broke through, continued for another 125-ft through more mud-stones, at which depth boring was discontinued. The approach employed here was to strengthen the broken sandstone layer, and employ it as a base for the radar. The strengthening method utilized was the introduction of portland cement grout under pressure into the sandstone stratum over a 100-ft diameter, which served to solidify the sandstone pores and fissures. Then eight shafts, each eight feet in diameter and spaced equally around a 40-ft diameter base circle, were excavated manually to the sandstone stratum, and filled with reinforced concrete to form the base for the radar tower.

All of the BMEWS tracking-radar foundations were tested for acceptance after final assembly of the radar by rotating and elevating the radar antenna at varying sinusoidal frequencies, and determining the lowest frequency that resonated



View of the completed TRADEX facility on Roi-Namur Island, Kwajalein Atoll, showing the 84-ft diameter Tracking Radar antenna.



View of a portion of the completed OTH radar antenna at a classified overseas site. Note the horizontal and vertical fiberglass rod catenary assemblies supporting the antenna elements.

the total mass, including the foundation. The criterion for acceptance was that this fundamental frequency must equal or exceed 2 Hz. All BMEWS towers constructed to date have met this criterion.

Bomb clearing

Often, the sites assigned for the location of major radar stations are those which are not useful for other commercial or farming activities, so it has become quite normal to expect such a station to be located on a mountaintop, in a desert, or in an Arctic wasteland. On several occasions, the land assigned to the station has been that previously used as an artillery or bombing range, or one that has previously been a battlefield. In these cases, soil borings and construction must proceed in parallel with a mine-clearing effort, usually provided by the military arm of the host nation. This clearing operation can continue for as long as two years, during which time all construction activity remains confined within those boundary markers indicating areas already cleared.

Environmental impact

The A/E&C group had an early opportunity to work with environmentalists on the BMEWS-Fylingdales project. The British public was concerned with the potential impact of rf energy on bird and plant life on the moor, as well as upon sheep and hikers. The project was given ample coverage in the British press, with a number of political cartoons arising from the controversy. In the United States, Milton Caniff, the cartoonist, seized upon the British public reaction as the basis for an adventure in his "Steve Canyon " comic strip. In England, the reality of the concern of ecological groups over the project was at least equal in intensity to that displayed in the comic strip. After a number of meetings of the British Works Ministry with the various planning commissions, the following environmental impact methods were employed:

1) The entire support area was relocated beyond the crest of a hill so as not to be visible from the main road.
2) The three 140-ft diameter radomes were painted robin's-egg blue to blend with the sky.
3) A fenced-in area was utilized down-range to keep sheep and hikers out of the rf hazard zone.

At the present time, as U.S. environmental groups are becoming more active, they are making their presence felt on a number of programs. Once again, the A/E&C group finds itself working on facilities designed not only to meet functional needs, but also to satisfy aesthetic and ecological requirements.

Seismic activity

When a site is located in an active seismic zone, provision must be made in the design to assure not only that the structures and the system survive an earthquake, but also that the system accuracy will not be degraded as a result. In a major system, this usually means introducing a critical parameter measurement scheme into the design to permit rapid verification after a major earthquake, and incorporating rapid adjustment features into that same design. The largest system of this type installed thus far by the A/E&C group was on the detection radar foundations at the BMEWS site in Clear, Alaska. The antennas are fixed screens, 185-ft tall by 400-ft long, with both vertical and horizontal curvatures. Base adjustments, utilizing shim plate packs, are built into the antenna foundations to accommodate forward and rear adjustments to each vertical truss. An optical alignment system, employing pre-mounted targets and sensors, is built into each detection radar antenna, enabling rapid verification of alignment after each major earthquake. The system has been in operation for over 12 years, and has proven entirely satisfactory.

Use of construction materials as electronic components

On a recent over-the-horizon radar project, a major log-periodic antenna system had to be designed covering an area of 145 acres. Since the procurement was fixed-price competitive, the design called for use of low-cost materials in minimum quantities. In addition, a non-metallic supporting system for the antenna was necessary to avoid pattern interference.

The solution to these problems as developed by the A/E&C group employed common construction materials applied in a novel manner. Supporting poles were designed from standard 13-ft asbestos-cement water pressure pipes, epoxied end-to-end within confining asbestos-cement collars into units up to 200-ft long. At guy locations (maximum spacing 39 ft), the hollow poles were filled with concrete to provide attachments for fiberglass rod guys; 171 poles were erected throughout the antenna field to support the superstructure. Transmission feedlines and radiating antenna elements were developed from standard two-inch diameter thin-wall aluminum tubing welded end-to-end to form 1,800-ft lengths, separated periodically by dielectric insulators molded from cycloaliphatic resins.

In addition to designing the antenna system, the A/E&C group developed erection procedures which made maximum use of preassembly and subassembly work to avoid the high cost of field aerial assembly, and also supervised actual antenna erection at the site.

Conclusion

The last 20 years has seen the evolution of electronics system facilities from huge sprawling complexes to the smaller enclosures made possible by today's solid-state technology. Technical requirements for these system enclosures, however, have remained uniformly stringent, whether specified in terms of rf or acoustic isolation, survivability against the effects of nuclear weapons, ecological compatiblility, frequency- or deflection-limited structures and foundations, provision of closely-regulated no-break power systems, or in other terms. Most of the recent Government procurements have treated the facility portions of electronic complexes as major subsystems, applying rigid reliability criteria to these areas. This has necessitated specific component selection and design of redundant subystems to insure meeting the required system availability.

The A/E&C group in Moorestown has compiled an impressive record of accomplishment over the past 20 years, and it appears that the future will continue to present challenges in the devleopment of electronics facilities which are not only commensurate with the need, but which also enhance the electronics system technical approach.

Japanese data link

J.P. Gillen

Time-Division Data Link (TDDL) equipments have been developed for the Japanese Air Self Defense Forces to be used in Japan's BADGE (Base Air Defense Ground Environment) system. These programs have been coordinated with, and approved by, the U.S. Department of Defense to extend and strengthen allied Far East Air Defenses. A fall-out from these design programs has been the transfer of manufacturing technology to Japan through RCA licensing agreements with Japanese manufacturers for state-of-the-art military equipment configurations.

SINCE 1964, the Government Communications and Automated Systems Division has been providing to the Japanese Air Self Defense Forces (JASDF) equipments designed for ground-to-air digital data communications in Japan's Base Air Defense Ground Environment (BADGE) system — the air defense umbrella for the Japanese homeland archipelago. The BADGE system coordinates the detection, tracking and identification of enemy air penetration and then via digital data communication directs interceptor aircraft to an optimum tactical intercept location in countering the detected threat.

RCA had been a prime participant with JASDF and the United States Air Force (USAF) in establishing the digital data communication standards for the original BADGE system implementation. To insure operational compatibility of communications equipment on-board the interceptor aircraft with the BADGE system, close coordination between JASDF, USAF, aircraft manufacturers, and RCA was required to define system and equipment configuration requirements. Detailed definition of these requirements provided a solid base for equipment design and manufacture with minimum problems encountered in achieving the desired compatibility during flight test and subsequent operational usage.

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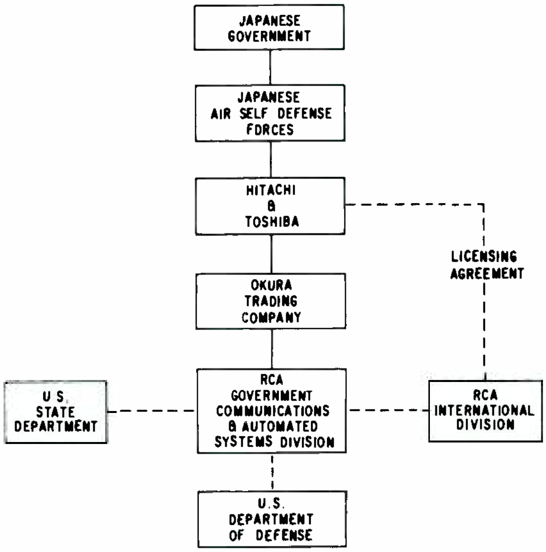

Fig. 1 — Equipment procurement channel for Time Division Data Link (TDDL).

John P. Gillen, Program Manager, Government Communications and Automated Systems Division, Camden, N.J. received the BSEE from the Polytechnic Institute of Brooklyn in 1950 and has attended graduate courses toward the MSEE at the University of Pennsylvania Moore School of Engineering. From 1950 to 1959 he was employed at the NBC Engineering Systems group where he was involved in systems engineering design and installation of NBC network audio, color tv and video tape facilities. In 1959, he transferred to the Electronic Data Processing division in Camden where his activities included computer logic and peripheral equipment design. In 1963, he transferred to the Defense Electronic Products (now G&CS) and assumed program management responsibilities for the U.S. Navy AN/USW-2 Automatic Carrier Landing data link equipment. Since 1964 he has been directly responsible for the Japanese Data Link equipment programs. These responsibilities included system design, equipment configuration and design, flight test and manufacturing for the ARR-662, ARR-670 and modified GKA-13 data-link equipments. His most recent experience includes communication system and equipment definition for the USAF Remotely Piloted Vehicle programs.

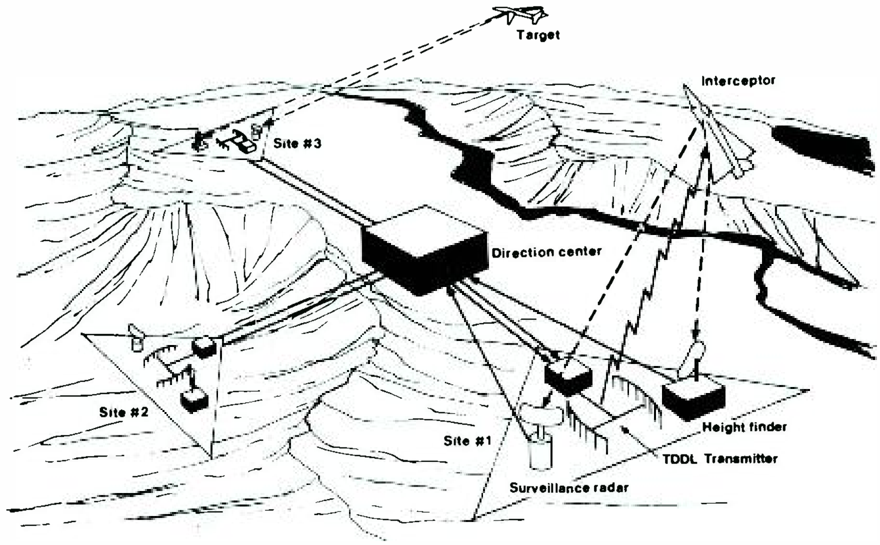

Fig. 2 — Typical BADGE direction center and communications complex.

Military equipment procurement for the BADGE system from a United States manufacturer is accomplished by the Japanese Government through a Japanese industry military equipment supplier selected by the Japanese Government with import arrangements conducted by an indigenous trading company. Equipment export arrangements are controlled by the U.S. State Department, and equipment manufacture is under the surveillance of the U.S. Department of Defense. The equipment procurement channel shown in Fig. 1 indicates the Japanese Government selection of the Hitachi and Toshiba Corporations for procurement of RCA designed communications equipments and subsequent manufacture of these equipments in Japan. After initial production at GCASD in Camden to establish manufacturing assembly and test processes, the transfer of RCA production know-how to Hitachi and Toshiba is arranged under separate licensing agreements between the Japanese companies and RCA International .

BADGE system

The Japanese BADGE system consists of stategically located ground control centers, which are interconnected for transfer of tactical information in providing for timely interception of airborne enemy threats.

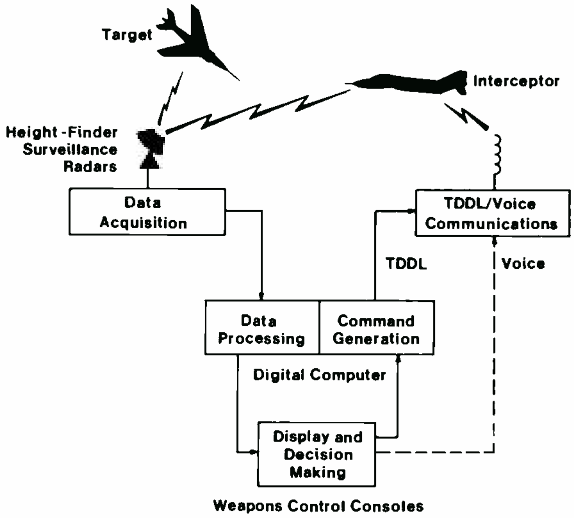

Fig. 3 — Information flow during TDDL mission.

The functional operation of a typical BADGE ground-control radar direction center and communication complex is shown in Fig. 2. Surveillance and height-finder radar data of targets and interceptors are sent to the direction center where a computer provides optimum flight path information to direct the interceptor aircraft. The interceptor command flight path information is sent from the direction center in digital format for transmission by the remote Time Division Data Link (TDDL) transmitter. The ground-to-air TDDL messages contain command and tactical information for the interceptor along with range, bearing, and altitude of the target. The typical airborne TDDL equipment receives, demodulates, and processes these message which are then converted for the radar tactical display to assist the pilot in target intercept.

System description

The basic control mode of the BADGE system is Time Division Data Link (TDDL), an automatic ground-to-air communications system using digitally coded radio transmissions. When functioning in a given operational sector, TDDL uses a single uhf channel. Within the sector, time is divided into discrete intervals and a single TDDL message is transmitted to a given aircraft using any one time interval. Each message is coded for, and received by, only one aircraft; and since only one message is transmitted at a time, multi-site transmission on a single frequency provides coverage of a large sector of operation. The duration of each message is so short that messages can be transmitted to hundreds of aircraft in less time than one voice message to a single aircraft.

TDDL messages are transmitted from complex ground control centers, which are needed to maintain control over large numbers of high speed interceptor aircraft in a large volume of airspace. In operation, all of the ground systems contain the data acquisition, data processing, and data transmission functions shown in Fig. 3. The data acquisition function includes radar equipment needed to detect, track, and identify all aircraft. The data processing function automatically processes, stores, and updates the acquired data and computes intercept commands. The data transmission portion transmits data-link command information to the TDDL-equipped aircraft. In a typical intercept

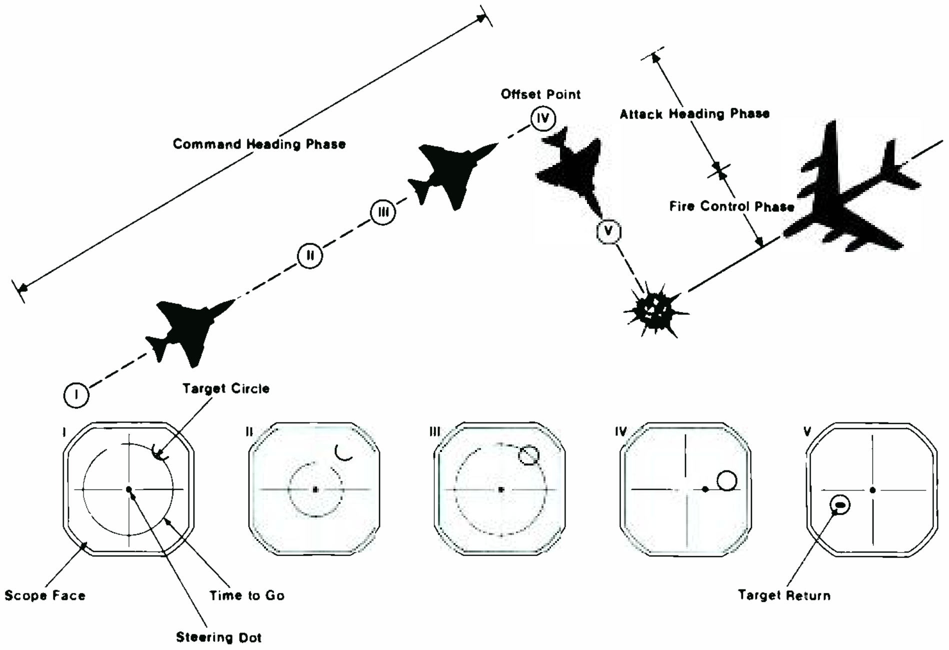

Fig. 4 — Radar display for typical TDDL mission.

mission, the following information is transmitted via data link and is processed and displayed on aircraft instruments.

Aircraft information	*Target information*
Command heading (before turn)	Target altitude
Command altitude	Target range
Command speed	Target relative bearing
Time-to-go (to turn)	
Attack heading (after turn)	

The TDDL mission directs the interceptor aircraft through a command heading phase, an offset point, and an attack heading phase to a location where the interceptor pilot can make radar and/or visual contact with the enemy threat and then execute the appropriate tactical approach. A typical TDDL mission intercept path and associated radar displays are illustrated in Fig. 4.

The ground-control centers transmit data link message to many different aircraft simultaneously on a time division basis since each message requires only 14 ms for transmission. TDDL messages are binary coded by the ground-control stations and consist of 70 bits of data. Each message contains 13 bits representing the aircraft address — 8 bits (256 combinations) define the squadron to which a particular aircraft is assigned, and 5 bits (32 combinations) designate the individual aircraft; 8192 discrete address combinations are available. If two or more TDDL-equipped aircraft are flying the same mission in formation, they may be assigned the same address, and can be controlled by a single data-link transmission. The object of the ground control system is to direct the interceptor aircraft to a point in space relative to the target where the interceptor can achieve radar or visual target acquisition and can successfully complete the mission.

An operational region, in which the aircraft receives data link messages, may comprise an entire ground environment or may be a section of larger ground environment. Time is divided into discrete intervals within the operational region. A single message is transmitted by a single transmitting site to a given aircraft during any one time interval. Depending upon the position of the aircraft at a particular instant, messages are received from the ground control equipment that is operating in the associated operational region. Two types of operation are used depending upon the size of the operational region and the range of the transmitter. Single-site operation is used when line-of-sight transmission provides sufficient range to cover the operational region and multisite operation is used when the operational region cannot be covered by line-of-sight transmission from a single transmitter.

A typical single-site transmission (Fig. 5) shows how all messages are sent in sequence on a single uhf channel. For example, assume that four different aircraft are within an operational region and that seven messages are to be transmitted to these four aircraft. As seen in Fig. 5, the seven messages are transmitted sequentially. Each message, in addition to containing the desired information, contains a binary-coded address which corresponds to one aircraft. Thus, all

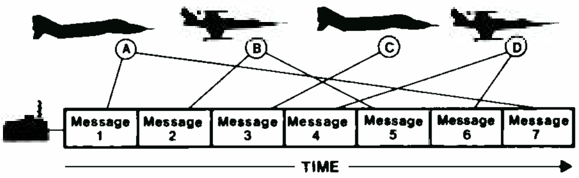

Fig. 5 — Typical single-site single-frequency operation.

messages that are transmitted are received by all four aircraft. However, only the aircraft with the address, corresponding to the message address, processes the received data. Since messages 1 through 4 are transmitted to different aircraft, each message contains a different address. Messages 5, 6, and 7 contain the same addresses as messages 2, 4, and 1, respectively. Messages 1 and 7 are transmitted to aircraft A, messages 2 and 5 to aircraft B, message 3 to aircraft C, and message 4 and 6 to aircraft D — all in a time sequence by the single transmitter.

When the operational region cannot be covered by line-of-sight transmission from a single ground TDDL transmitter site, multiple-site operation provides for complete coverage with a single uhf channel. In multi-site operation, the originator of the message is able to select the TDDL transmitter site closest to the aircraft for which the message is intended. During the next time interval, another site may be selected to transmit a message to a second aircraft. A typical example of multi-site operation (Fig. 6) shows how messages 1 and 7 are transmitted to Aircraft A by transmitter I, messages 2 and 5 are transmitted to aircraft B by transmitter II, message 3 to aircraft C by transmitter III, and message 4 and 6 to aircraft D by transmitter III.

The airborne receiver detects, decodes, checks, and stores the message data which is then processed to generate information displays for the pilot. The airborne portion consists of the antenna system, receiver, converter/coupler, power supply, and cockpit control unit. These items are coupled to the radar in the aircraft, which displays the various items of the data message to provide the pilot with the required flight-control information.

TDDL ground-to-air message structure

Each TDDL message consists of 70 message time slots, or bits indicated by a binary one or binary zero. These bits represent various types of information contained in the message. Information content includes: (a) sync recognition to enable positive data link message recognition and insure proper synchronization between ground and airborne TDDL equipments (b) aircraft address identification; (c) message type; (d) four data words; (e) control bits to provide relay control of TDDL-associated aircraft equipment. Appropriate parity check bits are included for the message type and data word.

ARR-670 data link program

During the present BADGE system expansion program to incorporate the F4E(JA) Phantom interceptor aircraft as a tactical unit, RCA proposed to JASDF an airborne ARR-670 TDDL equipment configuration (shown in Fig. 7). The F4E(JA) Phantom was designed specifically by McDonnell Douglas for manufacture in Japan. The expansion utilized existing demonstrated designs wherever possible. The RCA-designed R-662 Receiver and C-662 Control subassemblies which had been successfully integrated in previous Japanese and USAF TDDL equipped aircraft were included. Since airborne TDDL equipment interface and installation requirements vary from one aircraft type to another, certain accommodations had to be included in the ARR-670 TDDL equipment electrical and mechanical design. Interfacing this equipment set with the F4E(JA) Aircraft Weapon Systems Control, APQ-120 Radar, Central Air Data Computer and Magnetic Heading Generator necessitated a new electrical design for the Converter-Coupler and Power Supply subassemblies. A new mechanical packaging design was required for installation of the R-670 Receiver-Converter in the aircraft electronics equipment compartment. Unused space in the Converter-Coupler subassembly has been reserved for future data link system growth capability.

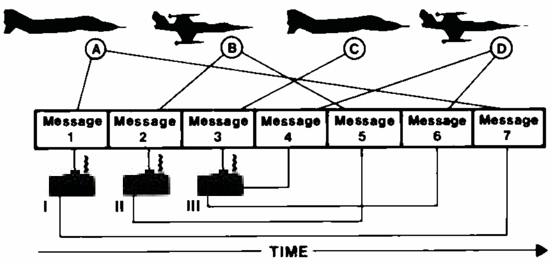

Fig. 6 — Typical multi-site single-frequency operation.

Equipment description

The ARR-670 Data Link Receiving Set consists of Receiver-Converter and Control units, as shown in Fig. 7. The Receiver-Converter contains three subassemblies, a Receiver, a Converter-Coupler, and a Power Supply.

The Receiver R-622 subassembly is a multiple channel, double conversion superheterodyne receiver tunable to any one of 1750 channels spaced at 0.1 MHz intervals from 225.0 MHz to 399.9 MHz. Any one of the 1750 channels can be selected manually and any 26 of the channels can be pre-set for automatic selection from the C-662 Control. The Receiver is designed for reception and demodulation of a.m. or FSK signals. The a.m. signal output provides voice communication to the aircraft interphone circuit and the fm signal output supplies TDDL information to the Converter-Coupler subassembly.

The Converter-Coupler subassembly processes the TDDL data for validity prior to digital computation with other aircraft information. The computed data is converted to analog form for radar display.

The Power Supply subassembly provides the necessary voltages for all units of the ARR-670 Set.

The Control, C-662, is designed for remote operational control of the Receiver and Converter-Coupler. In addition to volume, squelch, manual and automatic frequency channel control for the Receiver, the C-662 provides Address and Mode Select control of the Converter-Coupler.

Interconnections between the R-670 Receiver-Converter, C-662 Control and associated aircraft equipment are made through the airframe wiring. Since the TDDL equipment must interface with many other items of equipment aboard

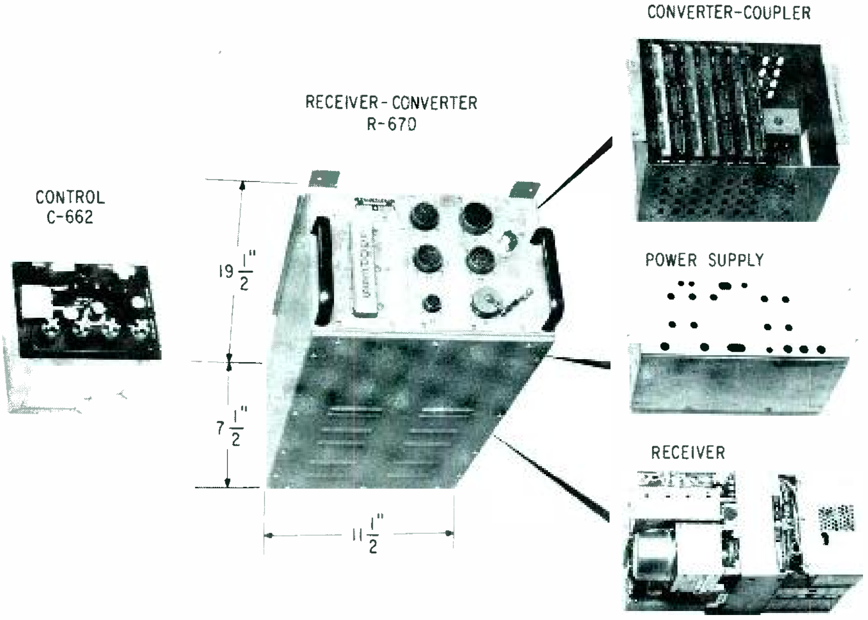

Fig. 7 — ARR-670 equipment configuration.

the aircraft (radar, air-data computer, power sources, indicators, *etc.*), interface design was a major program task.

Design constraints

Primary design thrust for the ARR-670 Data Link Receiving Set was to incorporate the required data link functions in the minimal space allocated in the F4E(-JA) aircraft. The Converter/Coupler complex logic performance requirements dictated the use of medium-scale integrated (MSI) microelectronic devices and printed-wiring multilayer boards to minimize volume. In addition, the multilayer board assembly electrical design included provisions to test board assemblies automatically under computer control during manufacturing test. MIL-E-5400 Class 2 and unique F4E(JA) environmental specification requirements necessitated emphasis in mechanical design to provide satisfactory operation in temperature, altitude, vibration and EMI.

Multilayer board design

Although multilayer board design and manufacture employs proven techniques and methods, the converter/coupler logic and analog circuit density required the use of printed wiring multilayer board interconnection methods with a higher order accuracy and precision requirements than normally encountered in printed wiring board fabrication. The technique of accurately stacking and laminating printed wiring layers to form multilayer boards with plated-through holes played a predominant role in this equipment design. The number of printed wiring layers in each multilayer board varied from a minimum of 8 layers to a maximum of 13 layers.

The density of printed interconnections with controlled characteristics was obtained by generating precision artwork compatible with production processes employed. Artwork generation was accomplished by first digitizing X and Y coordinate wiring layout data supplied by the design engineer on dimensioned gridded paper. This dimensional information was converted, via a digitizer unit, to punched-card format and then transferred to magentic tape by computer. This magnétic tape information drives an artwork generator plotter table to automatically generate the two-dimensional lines and/or points over the required plotting area. Master artwork was produced on glass to minimize variations due to temperature and humidity. Metallized mask-on-glass copies were produced from the glass master artwork for the internal layer fabrication process. These fabrication process steps are similar to producing single-sided printed wiring boards except that extremely accurate layer-to-layer registration must be maintained for the subsequent lamination, drilling, through-hole plating and finishing operations.

Automatic test

Automatic testing of printed-wiring board assemblies prior to installation in the respective subassemblies minimized testing time and identified manufacturing errors at the lowest level of assembly

The Digital-to-Digital Converter, Azimuth Difference and Altitude Difference digital logic board assemblies were automatically tested on the RCA-designed Digital Logic Test System controlled by an RCA 1600 Computer and a "Special Equipment Controller".

The Time-To-Go, Target Range and Altitude Adcon board assembly analog input/output test requirements dictated automatic testing on the RCA Automatic Communication Equipment Tester (ACET).[1] The ACET is a programmable test system with its own control system, switching system, stimuli and measuring devices. All programming control and logic operations are performed by an RCA 1600 computer with a high-order programming language to perform complete tests.

The Power Supply Rectifier and Regulator board assemblies were automatically tested on the RCA Fixit tester, a punched tape programmmed component inspection test systm.

Program status

The ARR-670 Time Division Data Link is the most recent RCA contribution to Japan's Air Defense System as part of a program that started in 1964. This latest equipment, upon completion of design and development engineering tests, was subjected to exhaustive environmental flight testing, both at the McDonnell Douglas F4E Flight Test Center in St. Louis Missouri and at the JASDF Air Proving Ground located in Komaki, Japan. Production ARR-670 units manufactured both by GCASD-Camden and Hitachi/Toshiba in Japan are now being phased into the BADGE equipment inventory.

Reference

1 Pfifferling, F. and Williamson, D.H.: "Automatic Communicaitons Equipment Tester" RCA reprint RE-17-5-19; *RCA Engineer*, Vol. 17, No. 5 (Feb/Mar 1972).

Pacific range electromagnetic signature studies (Project PRESS)

W.S. Hahn

RCA has been an active participant in the PRESS (Pacific range electromagnetic signature studies) program, which has been centered on Kwajalein atoll over the past fifteen years. Starting with initial responsibilities for TRADEX, RCA's involvement has grown to include mission planning, test execution, data reduction and analysis, and continuing radar development for the wide range of sensor systems now in use on this atoll terminus for missiles launched on the Pacific Missile Range.

Much of the project PRESS activity takes place on Kwajalein — a dot of coral sand that lies in the Pacific Ocean.

Kwajalein is an atoll, which Webster defines as "a reef surrounding a lagoon." The Kwajalein lagoon enclosed by the reef is the world's largest, with a surface area of 1,100 square miles. Its depth is generally 120 to 180 feet, with numerous coral heads approaching or breaking the lagoon surface; the ocean side of the reef plunges sharply to awesome depths in excess of 18,000 feet. As shown in Fig. 1, more than 100 small islands dot this tropical reef, which can boast of a total land area of only 3,584 acres (5.6 square miles). The three largest islands, Kwajalein (741 acres), Roi-Namur (419 acres), and Ebadon, at the extremes of the atoll account for one-half the total land area. The remainder of the islands range from little sand cays that may perhaps be seen breaking the water at low tide to several islands that could approximate 150 yards by 700 yards.

Where is Kwajalein? Its location (Fig. 1) is less than 700 miles north of the equator, making it truly tropical with temperature and humidity usually in the 80's. It is 2100 nautical miles southwest of Honolulu (about 4200 miles from San Francisco). Panama and the southern Philippines are of the same latitude, with equivalent climate.

With its highest natural point only 15 feet above sea level, it seems miraculous that Kwajalein still remains above the sea following the intense pounding it received during World War II when the atoll absorbed an average of one hundred pounds of bombs and shells for every square foot of land area.

Kwajalein, along with the rest of the Marshall Islands, limped along in history with little foreign interest other than limited trading with Spain, Great Britain, and Germany until World War II. The strategic location of the atoll, its huge lagoon, and its quiet untroubled waters made it an ideal base for naval and seaplane operations. The intensity of the struggle for control of this atoll, therefore, is understandable.

Today, on these coral isles where not a single palm tree stood after the wartime devastation, all is green and lush again in tropical finery. The atoll is now the terminus for testing missiles launched on the Western Test Range. Its offical designation is the US Army's Kwajalein Missile Range (KMR) and it is one of five national ranges maintained by the United States. Its location (5,000 miles southwest of Vanderberg AFB), its large shallow lagoon, and its complement of sophisticated radar, optical and telemetry systems, make it well suited for testing of long-range ballistic missiles, water recovery of reentry vehicles, and basic research into reentry physics phenomena. The research and study are the essence of the PRESS program. Data accumulated here contributes heavily to the development of new sensors and the evaluation of offensive and defensive weapons systems. Approximately 5,000 Americans and a similar number of Micronesians reside on the atoll. RCA employs approximately 150 people at the site on Roi-Namur, and about one-third reside with their families on the island of Kwajalein. The remainder are quartered on Roi-Namur, where the TRADEX, ALCOR and ALTAIR radars are located. Those residing on the island of Kwajalein commute 50 miles by air each day to work locations by C-54 propeller-driven aircraft.

The sensor complex on Roi-Namur is the Kiernan Reentry Measurements Site

Winfield S. Hahn, Mgr., Space Object Surveillance Identification Program, MSRD, Moorestown, N.J., received the BS in business management from Temple University in 1952. He joined the Missile and Surface Radar Division Marketing Department in 1956, responsible for coordination of all division promotional activity. From 1958 to 1960 he served on the Marketing staff of the Defense Electronic Products group, working in the areas of customer liaison, demonstrations, and conventions. Returning to MSRD Marketing in 1960 he held a variety of assignments in field marketing, marketing administration, and contract administration. He was appointed Manager, Contract Administration in 1963, and served in that capacity until 1967 at which time he became a member of the Operational Systems Dept. Marketing Staff. He joined the Strategic Systems Program Management Organization in 1969, and his first assignment was as Assistant Site Manager for RCA's activity at the Kwajalein site. During these two years, he was responsible for total site operations as the deputy to the Site Manager. In 1971 he became Program Manager for Operation and Maintenance of the TTR-4 radar system located on Kwajalein, and also performed program coordination and customer liaison duties for the PRESS Program. His recent assignment as Program Manager for the Space Object Surveillance Identification (SOSI) Data Analysis and Radar Support programs is in addition to his continuing program coordination duties on Project PRESS.

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(KREMS) named after Lt. Col. Joseph M. Kiernan, Jr., who died in a helicopter crash in Viet Nam. Col. Kiernan had previously served with ARPA (Advanced Research Products Agency) as Program Manager for the PRESS program. After his death it seemed most natural to name this site after the man who contributed so much to its beginning.

The primary KREMS sensors are the TRADEX (Target Resolution and Discrimination Experiment) radar, ALCOR (ARPA-Lincoln C-band Observables Radar) and the ALTAIR (ARPA Long-Range Tracking and Instrumentation Radar) tracking systems.

Fifteen years ago, the Missile and Surface Radar Division of RCA was awarded a study contract by ARPA involving the instrumentation of the PRESS complex on this site. The first sensor for this complex was the TRADEX system which was to be designed and built by RCA under further ARPA/Army sponsorship.

TRADEX

RCA's responsibilities on TRADEX began with site surveys, followed by design, fabrication, installation, checkout, and operation of the complete radar system.

Meticulous planning, scheduling, and coordination were necessary to assure safe delivery of 3,000 units of equipment representing 2,800,000 pounds of freight to this very remote and undeveloped site. As a result of cost effectiveness and capability studies conducted jointly by RCA and the Army, the responsibility for transportation and shipping was also awarded to RCA.

The TRADEX system became fully operational in 1962, providing the following firsts to the then existing radar field:

- First dual-frequency high-power radar.
- First tracking radar and four-dimensional (azimuth, elevation, range, doppler) resolution in a multi-target environment.
- First pulse-doppler radar with pulse compression and fine-line tracking.
- First to store coherent wide bandwidth target information at intermediate frequencies on magnetic tape.

The year 1972 was the tenth year of successful operation of this radar system, and for many of these years the TRADEX radar has been considered the prime sensor for the Kwajelein Missile Range. As time progressed, additional sensors were added to the site complex, and Project PRESS took on new responsibilities and roles.

PRESS program

The present PRESS program has two major roles. The first is to provide metric and signature data (both exoatmospheric and endoatmospheric) on test reentry vehicles (RVs) fired into the central Pacific Ocean. In fulfillment of this role, PRESS with its island sensors has provided test data on all of the experimental and operational RVs in the US inventory. In addition, PRESS has participated in the development testing of current penetration aids, such as chaff

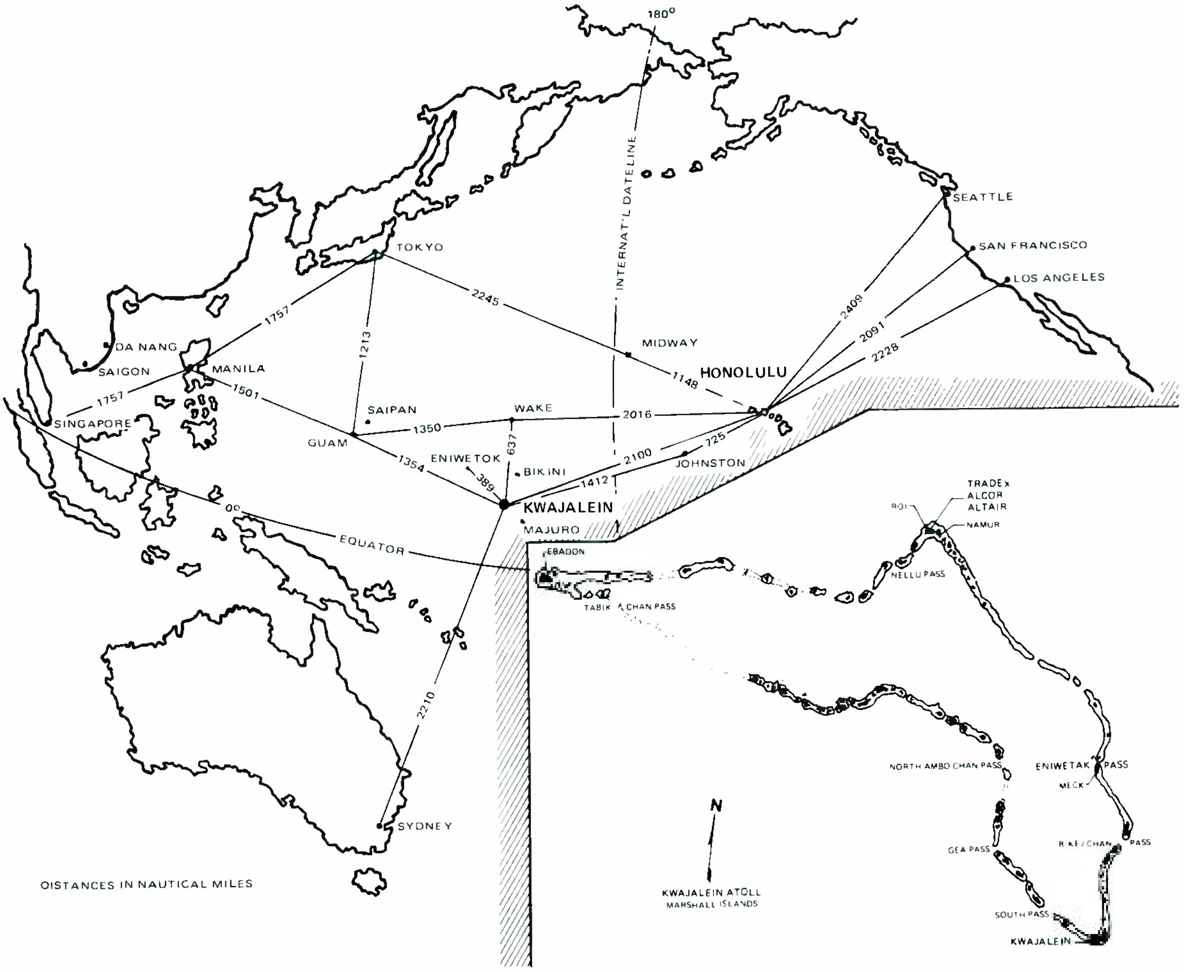
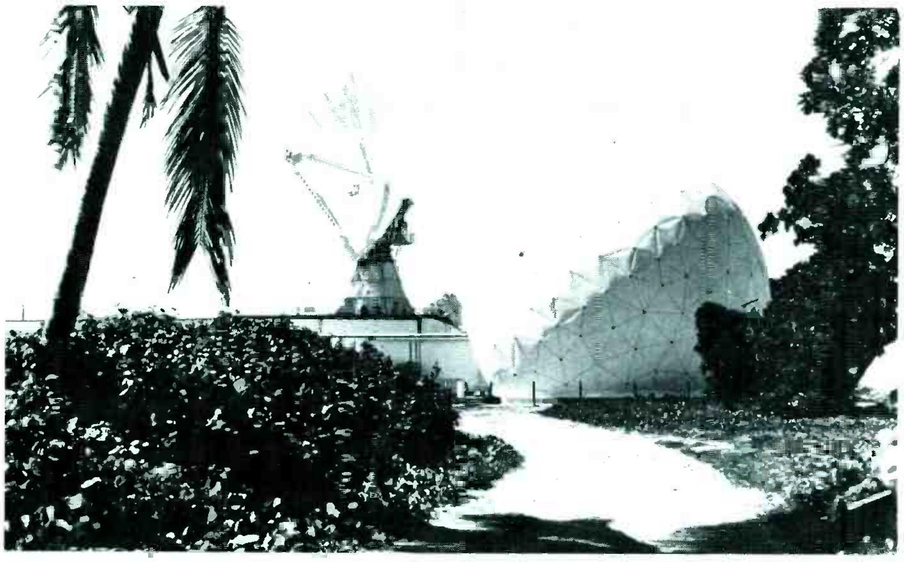
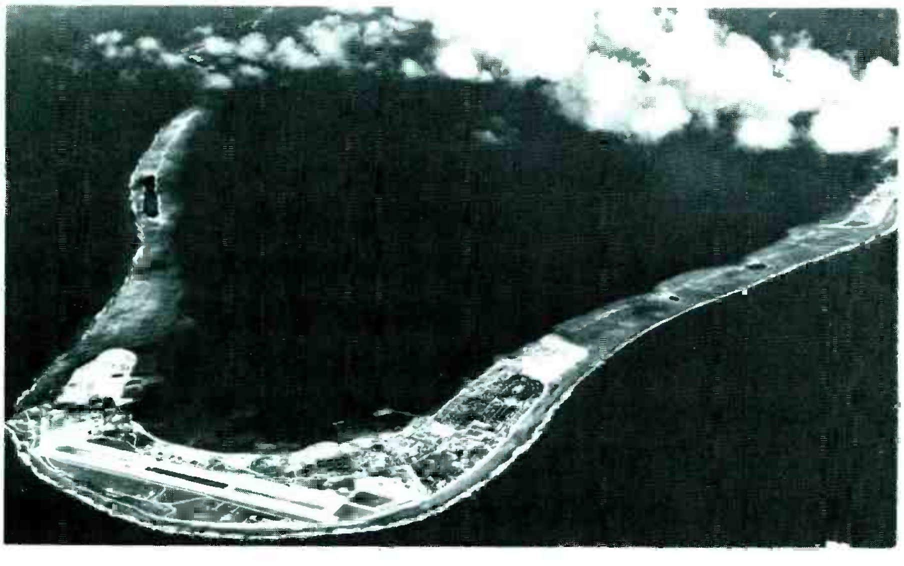


Fig. 1 — Location of Kwajalein atoll. Inset at lower right is a map of the atoll itself.



The TRADEX radar shown in position for boresighting. The ALCOR radar is to the right in the large radome. (Photo courtesy of U.S. Army.)

Aerial view of the portion of the island of Namur containing the PRESS sensors. TRADEX is in the center, ALCOR is in the radome to the left, and ALTAIR is in the background in a stored position. (Photo courtesy of U.S. Army.)



Aerial view of Kwajalein, the largest and most southerly of the atoll islands. Approximately 50 RCA families reside here (Photo courtesy of U.S. Army.)

and decoys.

The second major role is as a radar developmental test bed. From its inception, every effort has been made to keep the PRESS complex at the forefront of radar technology. New signal waveforms such as burst mode, pulse pair, frequency-agile burst, etc., have all been designed, installed and tested against real targets. PRESS has been the test site for several new signal processing techniques, such as Kalman filter trackers, doppler trackers, adaptive trackers, and bulk filtering. New radar capabilities have been installed and tested, such as dual frequency, higher power, higher frequencies, wider bandwidths, multifrequency coherence, bistatic receiver, the latest recording techniques—analog, digital and photo. In parallel with the advancement of the basic radar, data processing, and data recording capabilities, concurrent progress has been made in other areas. Among these are calibration techniques to improve data accuracy, real-time displays to improve the radar/computer/operator interaction, multi-radar data communication to provide precise pointing vectors to remotely located radars for target designation, data reduction techniques to increase the meaning of the data collected, and finally the advanced radar component development necessary to provide more stability, versatility, and accuracy in support of all of the above technical areas.

RCA has been an active participant in all aspects of the PRESS program under direction of the Program Technical Director, MIT/Lincoln Laboratory, and more recently the Kwajalein Missile Range Directorate of the Army Ballistic Missile Defense Systems Command, to do the total job of mission planning, test execution, continuing radar devleopment, and some data reduction and analysis. In each of the technical areas, RCA assigns high-level systems engineers to guide and direct the technical programs. In addition, RCA has design engineers, field engineers, administrators, and logistics specialists to support the overall goals of the program.

It is also noteworthy that a nucleus of the original design team members has been purposely held together by RCA to assure system integrity regardless of the extent of modifications made. This corporate investment in technical talent has contributed immeasurably to the successes of the PRESS program and has helped avoid system obsolescence through continuing innovative technological advances.

The breadth of the PRESS program can perhaps best be illustrated by describing some of the features of the sensors and related systems:

1) TRADEX —This was the first and the prime sensor for the PRESS program and has recently been rebuilt to reflect the latest advances in both hardware and software signal processing techniques.

TRADEX I — In its original form TRADEX was a uhf tracking radar with additional illumination at L-band and subsequently vhf. A four-coordinate tracking system provided a new dimension for resolution of targets, precise trajectory measurements, and determination of target size, rotational motion, and polarization of radar return at several radio frequencies simultaneously. A precision radar recorder, developed by RCA, retained complete raw radar data in a coherent fashion, allowing subsequent detailed measurements on targets not tracked initially.

TRADEX II — Although referred to as a modification, the changes incorporated into the TRADEX system during 1970 resulted in an almost completely new radar from both a functional and physical hardware standpoint. The current radar provides for range and angle tracking at L-band with additional illumination at S-band frequencies. It is a coherent system capable of tracking one target in angle and range and five additional targets in range only. The radar generates a 4-MW peak-power signal radiated by an 84-ft antenna. About the only hardware systems remaining even partially intact from TRADEX I were the L-band transmitter, the antenna /pedestal, and angle servo electronics. Completely new major hardware subsystems included:

- A high-power, wideband S-band transmitter.
- A dual-frequency L/S feed.
- Solid-state wideband and narrowband receivers at both L and S band.
- High-speed digitizing and recording systems for both frequencies.
- A Sigma 5 computer and associated I/O devices.
- Consoles and displays.

Throughout the hardware subsystem designs, the latest state-of-the-art techniques were employed. However, from a functional standpoint, the most significant modification to TRADEX occurred in the software rather than hardware area. TRADEX II is completely under real-time computer control. Functions provided include:

- Automatic mode control.
- Automatic waveform selection and multiplexing.
- Multi-target tracking and data recording.
- Automatic radar checkout and calibration.
- Flexibility and expansion capabilities.

Perhaps the most important of the above functions is the last one. The ability to accommodate various new system requirements rapidly has been an invaluable asset to TRADEX during the last three years.

2) AOCS (Airborne Optics Control System) — This system, although no longer active, was used to control the airborne optical sensors for PRESS by providing directing data to the optical instruments on the aircraft. It consisted of an acquisition radar, Station Keeping Radars (SKR's), digital data communications, and voice communications. The acquisition radar scanned the entire area to acquire the PRESS aircraft, and after designation, to provide area surveillance. The SKR's tracked the PRESS aircraft, providing positional information to the central computer. The digital data link transferred digital data between various ground units via dipulse links, and via a two-way radio digital data link between aircraft and ground units. Voice communications were provided between aircraft and the ground-based control centers via hf, vhf, and uhf links.

3) ALCOR (ARPA Lincoln C-band Observable Radar) — This sensor is a high-power, narrow-beam, coherent chirped C-band radar with a very good range resolution. It was designed to study very wide bandwidth observables and first became operational in January 1970. It is capable of switching rapidly from target to target during a given mission. The large instantaneous bandwidth is achieved using a linear fm signal. The receiver uses the "stretch" technique of time-bandwidth exchange to realize the effective very wide bandwidths in the signal processing. It has a peak power of 4-MW that is radiated by a 40-ft antenna enclosed in a radome. A recent modification provides a developmental all-range capability for this radar.

4) D&DE (Designation and Discrimination Engineering) The Designation and Discrimination Engineering Program at site represents a testing ground for the real-time application of discrimination techniques. These techniques can be applied in an ABM system to determine the level of threat posed by an incoming complex of radar targets. Flight test data have led to the development of designants and discriminants relating to the probability that an object is an RV. Development of techniques for linking these discriminants, for performing multiple-body tracking, and for ordering the threat in real time is the primary task for the D&DE program. The computer operates on data provided by full bandwidth channels from the radar sensors. Testing has included the use of exoatmospheric data and involves both the ALCOR and ALTAIR systems in addition to TRADEX.

5) TADCO (Timing and Data Conversion Unit) — The TADCO system provides a means of sampling data under computer control and the interface subsystem between TRADEX and D&DE hardware and peripherals. It provides communication between the D&DE and TRADEX computers and digitizes and formats the sensor analog signals for input to the computer.

6) PCC (PRESS Control Center) — The PRESS Control Center in its original configuration provided a central display for information derived by the various sensors, so that a test director was able to observe and take the action necessary to assure optimum utilization of the entire PRESS complex. The current PCC has been modified to become a real-time nerve center which provides for operator monitoring and intervention for all of the PRESS sensors and also provides the interface for all external communications. Displayed data is available from the central PRESS computer as well as from the individual dedicated radar computers and other range information sources. The sophistication of the new PCC is evident in its ability to provide computer-generated displays (in real time) of such things as angle and range offsets of trajectories of any targets tracked by the PRESS sensors.

RCA personnel on Kwajelein

The normal Kwajalein tour of duty is 18 months to two years. The remoteness of the island is too much for some, and each year a few "pull the pin" (leave before completing a tour). The majority, however, look to the assignment with eagerness and many return for a second tour. Because of the scientific nature of this mission and the experimental equipment involved, the engineer finds many challenges awaiting him. Specific missions often call for one-of-a-kind equipment modifications or a computer program change to obtain a required item of data. The opportunity to participate in the decision-making process, or to pursue the actual modifications with soldering gun in hand, is one not normally found in industry other than in a laboratory atmosphere. The personal satisfaction of watching one's own idea, decision or modification actually working in a mission in real time is difficult to equal under anything but field conditions. As a result, RCA personnel find the work extraordinarily rewarding and sustain a high level of dedication to the overall mission of the PRESS program.

Many of the innovative radar techniques developed on PRESS over the years have become everyday radar system engineering tools, thereby providing valuable corporate technology skills in these areas. RCA's long association with project PRESS remains a unique and technically rewarding experience.

World-wide instrumentation radar range

L.E. Kitchens | M.D. Wilker

RCA has been a major contributor to the development of radar instrumentation for the world-wide testing ranges that have supported the phenomenal growth in aerospace technology over the past two decades.

Lee E. Kitchens, Mgr., Digital Instrumentation Radar Programs, MSRD, Moorestown, N.J., received the BEE from Georgia Institute of Technology in 1956 and the MSEE from Villanova University in 1967. Since he joined RCA in 1956, he has been involved principally in project engineering and program management aspects of instrumentation radar programs. He served as project engineer on AN/FPS-16, AN/FPQ-6, and AN/TPQ-18 groundbased instrumentation radar programs, and later as program manager for development of a series of all-digital electronic range systems termed DIRAM (tube-type Digital Range Machine), ADRAN (transistorized Advanced Digital Range system), and IDRAN (integrated-circuit Digital Range system). Mr. Kitchens also served as program manager for the NASA Instrumentation Radar Operational Improvement Program, which provided specialized orbital acquisition and computation equipment designed to adapt missile range radar systems for operation with space program vehicles. His most recent assignment has been as Program Manager for the AN/TPQ-39(V) and AN/FPS-105 ground-based instrumentation radar systems and as equipment program director for ultra-high reliability radar development. He has also been engaged in the development of high accuracy phased-array instrumentation radars and the application of solid-state technology to radar systems.

M.David Wilker, Ldr., Systems Projects, MSRD, Moorestown, N.J., received the ME from Stevens Institute of Technology in 1949 and a MSEE from Drexel in 1959. He joined RCA in 1950 working as a mechanical design engineer at the Lancaster Tube Plant and then at Camden. In 1960 he joined the Program Management Office in RCA Moorestown, and has since been a project engineer on developments of the early AN/FPS-16, MIPIR, and CAPRI C-Band Instrumentation Radars. Since 1970 he has been program manager for the production of the AN/MPS-36 Mobile Instrumentation Radar. At the present time Mr. Wilker is program manager for the development of the Fine Line Clutter Reduction Modification for the AN/MPS-36.

Authors Kitchens (left) and Wilker.

BY THE MID-1960's instrumentation radar test ranges owned and operated by the United States literally covered the globe. The problems that arose as a result of the phenomenal progress during the late 1950's and early 1960's—especially in providing communications and control of such a large network—placed responsibilities on the engineer and scientist that were unthought of 20 years before and represent real challenges yet today. Today the electrical engineer is called on to be a physicist, chemist, mathematician optician, and astronomer if he is to function in the realm of world-wide range instrumentation.

To see how these new fields of interest have developed, one need look only at the growth pattern of the nation's aerospace effort. At the end of World War II, small, specialized missile test ranges were set up along the eastern and western coasts to test the development of air-breathing missiles. The range instrumentation needed was readily available as war surplus detection and fire control radars, such as the short range SCR-584 fire control radar.

The next phase was the development of the ballistic missile, which required a more precise, long-range, position-measuring system. In 1955 RCA developed the monopulse AN/FPS-16 radar system (Fig. 1) as a basic sensor for tracking trajectories of the missiles in use at that time. Thus began RCA's close association with the nation's test ranges, beginning with a total of fifty two AN/FPS-16 type radars, most of which are still operational at sites around the world. These radars are currently in use on ships as well as at land stations from Wallops Island, Virginia to Kauai in the Hawaiian Islands, and from Aberporth, Wales to Woomera, Australia.

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As the aerospace industry developed, so did the requirements placed on the test ranges. Missiles flew farther, necessitating expanded ranges from Florida into the Indian Ocean. As the vehicles flew higher and faster, they required sensors of greater range and precision. Accordingly, RCA developed a new generation of instrumentation radar, the AN/FPQ-6 Missile Precision Instrumentation Radar (MIPIR). With its introduction in 1963, this new radar concept (Fig. 2) provided longer range and higher precision than ever achieved before. This step up in performance was accomplished by the construction of high-precision antenna and pedestal, use of modern techniques of solid-state electronic circuitry, and the integration for the first time into the basic system of a large high-precision digital data handling system with real-time data correction. The first of these radar systems was delivered to the Air Force Eastern Test Range (AFETR) at Patrick Air Force Base, Florida on June 5, 1963. Since that time, nine more systems have been placed in operation at a wide variety of tracking stations throughout the world; moreover, as requirements have changed, both the FPS-16 and FPQ-6 radars have shown extraordinary mobility and versatility in their ability to function reliably following relocations up to halfway around the world.

In more recent years, RCA's basic instrumentation radar product line has undergone marked changes in expanded capability and flexibility, responding to the changing requirements of the various international ranges. Today RCA remains a world leader in this field.

Instrumentation ranges —requirements and applications

What, exactly, is an instrumentation

range? What are its purposes? Functions? Requirements? Essentially, an instrumentation range is an area dedicated to the measurement of objects in flight. Ranges currently in existence range in size from the inside of a wind tunnel to the circumference of the earth.

These ranges are used for the acquisition of knowledge as part of the development and test of new flight systems. The missions carried out on world-wide ranges embrace such diversified areas as testing of aircraft, missiles, bombs, and projectiles; evaluation of airborne guidance systems, and bombing systems; determination of the celestial orbits of space objects and satellites; and safety and control of satellite launches and orbit insertion operations.

All the major ranges are instrumented with one or more of three basic types of instrumentation sensors:

1) *Telemetry*, which receives and processes information gathered on-board the vehicle and transmitted to the sensor for processing and analysis.
2) *Electronic trajectory measurement* systems, active and passive, such as radar, which actively measure the spatial position of the vehicle externally by transmitting rf energy to the object and then processing and analyzing the reflection from the body.
3) *Optical/electro-optical devices*, which measure and record the characteristics of the body through the reflection of light from the object. Basically the optical devices use some form of telescope to focus the optical image of the body on a recording device such as a film camera, tv camera, or laser recorder.

The special requirements of NASA's Manned Space Flight Network resulted in a temporary, albeit long-term integration of many of the major ranges and equipments into a net of tracking and communications facilities dedicated, on demand, to the general task of monitoring and tracking the wide variety of manned space flights. Broadly, these consisted of:

1) Near-earth instrumentation facilities (fourteen land-based tracking stations, two ships, and a communications center)
2) Deep-space instrumentation facilities (three long-range tracking stations at Goldstone, California; Pretoria, South Africa, and Woomera, Australia)
3) Range and range rate network (a special net implemented primarily for scientific satellite programs)
4) The National Ranges (Air Force Eastern Test Range, Air Force Western Test Range, Eglin Test Range, and White Sands Missile Range)
5) Tracking ships (five operational tracking ships deployed in accordance with specific mission requirements)

Fig. 1 — Monopulse AN/FPS-16, radar system developed in 1955 as a basic sensor for missile tracking.

More recently, the emphasis in range instrumentation has shifted somewhat from the extreme long-range acquisition and tracking capability to specialized, highly flexible, lower-cost units capable of tracking short- to medium-range targets with extreme accuracy. Mobility and transportability are also major factors in virtually all of today's range requirements.

RCA's role in range instrumentation

RCA has made major contributions to the development of radar instrumentation for the world-wide testing ranges that elevated the ability to test vehicles from a gross measurment using war-surplus fire-control radar equipment to a highly accurate measurement using instruments specially designed for the purpose. The Air Force Eastern Test Range has summarized the use of pulsed radar for determination of the location of a site based on the use of survey satellites now in orbit:

> "Based on a comparison of results, it is noted that the short arc results yield survey adjustments which are as good if not better than the intervisible camera results Considering the data collection and processing problems of both systems, the short arc radar reductions can apparently be obtained more economically and faster than the ballistic camera intervisible results."

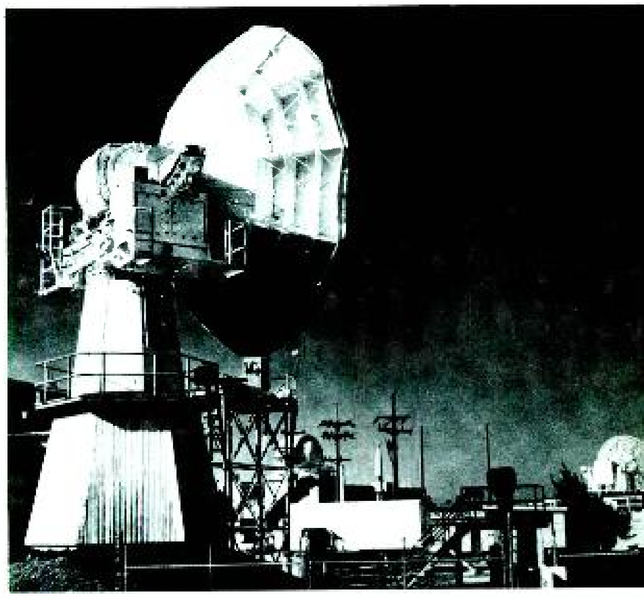

Fig. 2 — Missile Precision Instrumentation Radar (MIPIR), AN/FPQ-6, developed in 1963 to provide longer range and higher precision.

NASA has also summarized the advantage of radar for satellite gravimetric measurements:

> "C band tracking network provides the best all weather data available from any system for satellite gravimetric determinations."

AN/FPS-16

As noted earlier, RCA's first major contribution to range instrumentation started with the development of monopulse radar, providing angle and range measurement on each pulse returned from a target. Monopulse tracking, incorporated in a radar system designed as an accurate instrumentation device, was designated AN/FPS-16. This C-band radar system launched the radar instrumentation era in 1955, and the fifty two systems built have made major contributions in virtually every major rocket, missile, and space program to date. Featuring a 12-ft-diameter antenna, 1-MW peak power, and outstanding reliability, this basic radar has undergone inumerable modifications and equipment updating over almost 20 years to sustain its capability to meet expanding range requirements.

Part of this capability enhancement is the RCA-developed technique of extracting target velocity data from short pulse radar returns which is called "pulsed doppler" tracking. Further refinements have been made to the system to allow

Table I — RCA's instrumentation radar product line.

UNIT	*Angle precision mils rms*	1 M^2 range (*n mi.*)
AN/FPS-16	0.1	100
AN/FPQ-6 (MIPIR)	0.05	600
AN/FPS-105	0.2	120
AN/MPS-36	0.2	200
DIR	0.5	70

target velocity extraction and very narrow bandwidth angle acquisition and tracking in the "fine line tracking" equipment.

AN/FPQ-6

Second in line was the AN/FPQ-6 Missile Precision Instrumentation Radar (MIPIR). Based on the successful design of the AN/FPS-16, this sensor provides a nominal four-fold increase in skin tracking range, with extremely high precision of coordinate data. (Table I provides a comparative summary of features of the various RCA-developed instrumentation radars.) The basic MIPIR system includes:

- 3-MW transmitter;
- 29-ft Cassegrain antenna;
- precision two-axis pedestal featuring low friction, hydrostatic azimuth bearing and precision, direct drive;
- 19-bit single-speed encoder and digital takeoffs;
- high torque electro-hydraulic angle servo system;
- low-noise, three-channel receiver system;
- all-electronic digital range tracking unit that provides continuous, unambiguous digital data up to a maximum target range of 32,000 n mi; and
- coincident-core memory general purpose computer, the RCA 1401.

Acquisition features include a C-scope display, a video integrator, antenna scan patterns, angle-only tracking and a digital range detection system.

The AN/TPQ-18 is an air-transportable version of the AN/FPQ-6. This mobile version has all the subsystems separated and integrated into nine air-transportable all-weather shelters. Each shelter has its own air cooling, power distribution and breaker panel and can be interconnected to an adjacent shelter by a bellows-coupling walkway.

AN/FPS-105

Experience gained in developing the AN/FPS-16 and AN/FPQ-6 and the availability of new materials resulted in the solid-state, compact AN/FPS-105 radar (Fig. 3). Also called CAPRI (for Compact All-Purpose Range Instrument), this development was aimed specifically at requirements for versatility, reliability and maintainability, and offers versatile precision capability, determined by the antenna pedestal selected. The user selects only as much capability as required for present missions, retaining the ability to expand the system for future requirements.

Since its development in 1965, five radars of this class have been delivered: one on each of the two Apollo Reentry Ships, the *U.S.N.S. Watertown* (TAGM-6) and *Huntsville* (TAGM-7); one to the NASA Flight Research Center station atop Ely Peak, Nevada; one to the NASA Goddard Space Flight Center Station at Tananarive, Madagascar; and one to the U.S. Naval Weapons Center at China Lake, California.

The units have several different types of antenna pedestals, which were chosen on the basis of local tracking requirements. Because the AN/FPS-105 uses solid-state and integrated circuit design, it is extremely compact and requires less space and power than conventional systems. It is adaptable for installation aboard ship, in a trailer, or in a small one-story building.

AN/MPS-36

The need for additional flexibility in a wide variety of support missions, coupled with companion requirements for mobility and simplified operation resulted in development of the AN/MPS-36 Mobile Instrumentation Radar in 1970 (Fig. 4). This sensor features single operator control and a highly flexible, rapid set-up capability.

The radar system can be emplaced on a prepared site and provide precision tracking capability within eight hours of its arrival, utilizing the normal four-man O&M crew. No special handling equipment or cranes are required.

The incorporation of a general-purpose data processor into the AN/MPS-36 design provides many operational advantages for mission support, as well as pre- and post-mission system calibration and target acquisition.

Simultaneous digital and analog outputs are provided by the AN/MPS-36 accompanied by data for external data correction if this mode is selected, and by data

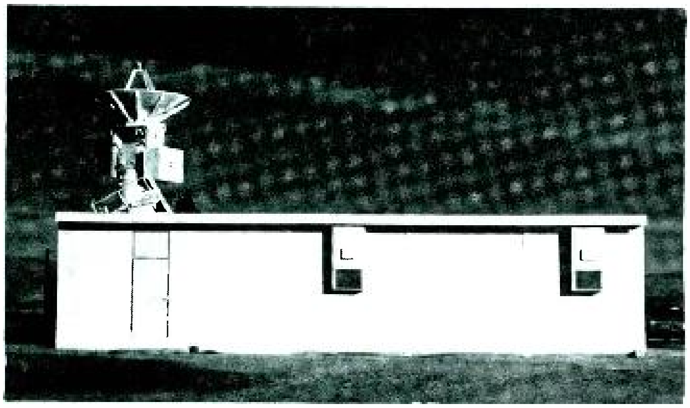

Fig. 3 — Solid-state AN/FPS-105 radar. Called CAPRI (Compact All-Purpose Range Instrument), this 1965 development was aimed specifically at increased versatility, reliability, and maintainability.

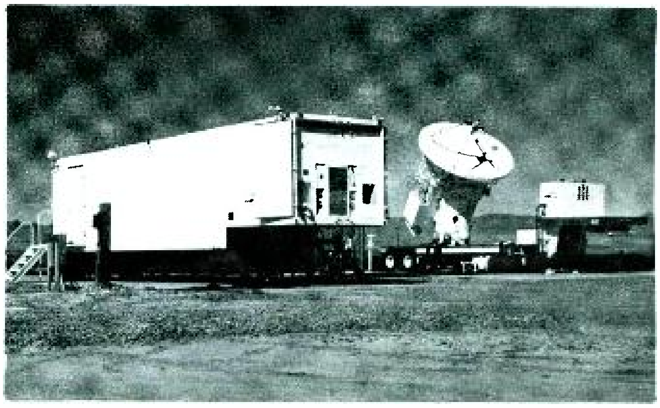

Fig. 4 — Mobile Instrumentation Radar AN/MPS-36, developed in 1970 to provide additional flexibility and mobility.

identifying key operating characteristics chosen by the operator. Radar digital input and output signals are suitable for use in single radar operation, in multiple radar chains, and provided for use with plotting boards or other devices (for which the system can be adapted for van mounting), older type radars, and analog data systems. A tape station is included in the radar for real-time recording of the digital data output.

To date, fourteen AN/MPS-36 have been built. They are located at White Sands Missile Range, Kwajalein Missile Range, Tonopah, Western Test Range, and Germany.

AN/TPQ-39

RCA's most recent range instrument is, quite simply, the result of a search for an inexpensive precision tracker with virtually automatic control that can go anywhere and perform a wide variety of functions—a universal range instrument.

Called the Digital Instrumentation Radar (DIR) when it was conceived and developed in 1972, it has since been given an official designation, AN/TPQ-39. The system, as developed, is indeed a low cost unit (well under half that of other radars in this line), highly mobile, and can be made operational almost immediately upon arrival at a site. As shown in Figs. 5 and 6, virtually everything is in a single package—even the antenna.

Fig. 5 — Digital Instrumentation Radar, AN/TPQ-39 is RCA's most recent range instrument, conceived and developed in 1972 as a universal range instrument.

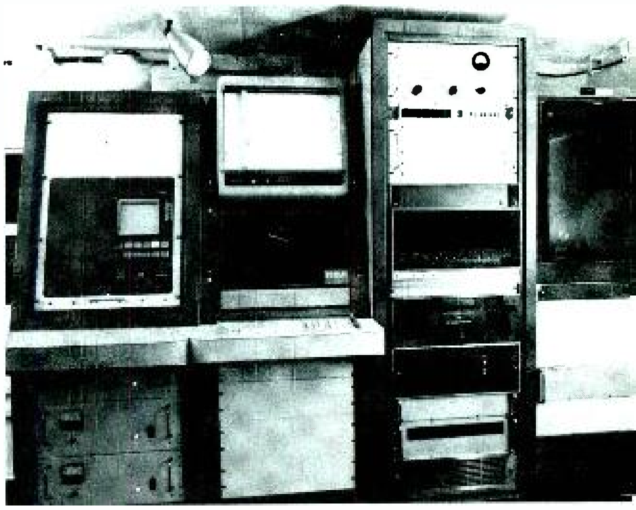

Fig. 6 — Interior of a Digital Instrumentation Radar enclosure.

The AN/TPQ-39 uses the latest techniques in computerized systems design and integrated circuitry to provide a self-contained, reliable radar that is compatible with existing range instruments. The concept enables computer software to perform functions that heretofore required highly specialized hardware. The new approach improves system reliability, reduces purchase and maintenance costs, increases flexibility of control, and permits one-man operation and maintenance.

The AN/TPQ-39 was designed from its inception to be usable throughout the world on standard available 50- to 60-Hz live power. To facilitate installation in remote or undeveloped areas, the radar enclosure serves as a broad-base platform that may be accurately leveled using built in jacks, inclinometers, and levels. Controls and displays in the equipment are interactive with the operator through a standard keyboard and alphanumeric display unit, thus providing assistance to the operator during pre-mission set up as well as during a tracking mission. This coupled with a fully automatic mode and computer-assisted setup and calibration result in a system requiring minimum operator attention.

The DIR has utilized the advantage of solid state technology to convert all radar functions that were not adaptable to software conversion into an extremely compact package. All low-level signal processing fucntions are contained on three 15-in. × 15-in. module boards that are identical to the computer electronics modules and plug into the computer main frame also. As a result of the actual design concepts used, the radar contains only four vacuum tubes: the transmitter magnetron and its hard-tube modulator, and the two cathode-ray tubes for display.

The RCA family

This family of precision radars represents part of RCA's contribution to the instrumentation ranges, and indicates the impact of RCA radars on a world-wide basis. Along with the radar equipment, of course, is a supporting network of information processing services, a strong, versatile operation and maintenance force, and a multi-pronged depot operation to keep these radars functioning.

To remain an integral part of the world's instrumentation ranges, RCA maintains close contact with the ranges and a high level of responsiviness to their needs; virturally continuous radar modifications—small and large—improves these systems to better meet the range needs. Recently, for example, laser trackers have been added to some systems to solve the basic problem of low-angle tracking; a fine-line tracking modification has been developed for the AN/MPS-36 to enable tracking in clutter.

The future of instrumentation ranges

With the changes in national policy and priorities over the years, the requirements and configurations of instrumentation ranges also undergo major modification. The slowdown of space exploration, for example, has brought a broad reorientation in range philosophy away from world-wide networks to small ranges with very specific tracking requirements. Foreign governments are also seeking to develop their own ranges, thereby broadening the scope, if not the size, of range usage. England, Sweden, Israel, Taiwan, Korea, Japan, and Germany have all been active in this area in recent years.

As the character of the ranges changes, so too do the instrumentation requirements. RCA is constantly evolving new techniques and components for application on the ranges, as well as flexible, low-cost equipment that can meet a very wide variety of instrumentation assignments. The future of the instrumentation ranges clearly includes very real technological challenges, and RCA's role remains that of sustaining its position of leadership in the field.

Computer-controlled telex

E. G. Tyndall

Telex is a world-wide telegraph network very similar to the world-wide telephony network. The major difference is that telegraphy is based on the transmission of digital intelligence, and telephony is based on the transmission of analog intelligence. In 1970 RCA Communications Systems Division undertook a contract to provide three automatic telex switches to RCA Global Communications. These three switches have been installed and are now operational. This paper describes some of the features of these switches.

E. Tyndall, Ldr. Digital Communications Equipment, Government Communications and Automated Systems Division, Camden, NJ, received the BSEE in 1963 from Union College, Schenectady, N.Y. From 1963 to 1967 he worked for the New York Telephone Company in various engineering assignments. In 1967 Mr. Tyndall joined RCA as an engineer in Digital Communications Equipment Engineering. His initial assignment was as a logician on the Interior Communications System (ICS) computer controlled circuit switch for the U.S. Navy. Subsequently, he participated in the design and development of store-and-forward message switching equipment for the AUTODIN program. In 1970, Mr. Tyndall was appointed project engineer for the design of a computer controlled telex exchange for RCA Global Communications. He presently is an engineering leader responsible for the design and implementation of a 16,000 termination telex exchange comprised of four collocated telex subsystems

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DEVELOPMENT of the Telex[1] network was begun in Germany in 1929 by Siemens.[1] Automatic telex switching was introduced into the United States by the Western Union Telegraph Company in 1958[2] RCA Global Communications, as an international carrier, switches domestic telex subscribers to the world-wide telex network. The overall coordination of the intercontinental telex network is under the control of the CCITT. [International Telegraph & Telephone Committee] This organization prepares recommendations for signalling and transmission standards which are to be adhered to by the member countries.

System organization

The RCA-developed Computer-Controlled Telex (CCT) switch (Fig. 1) was designed for an ultimate capacity of 1000 terminations. The operation of this exchange is controlled by the processor subsystem which is responsible for controlling the switching matrix, handling all of the signalling and supervision requirements of each terminator, maintaining the system configuration, keeping accurate records and monitoring the operation of the exchange for failures. The processor utilizes several peripheral devices in performing these duties. Their functions are as follows:

The Console Teleprinter (CT) is an input device from which the exchange supervisor can change program tables, change the system configuration, or request system status information. The CT is used as an output device by the processor to provide system status and system failure records.

The Computer-to-Computer Interface (CCIF) provides a direct communication link within the processor subsystem. It is used to maintain the switchover capability of the system.

The Disc Storage Unit (DSU) provides storage for all data and routines not normally resident in core memory. These include routing information, abbreviated address tables, temporary records for calls in

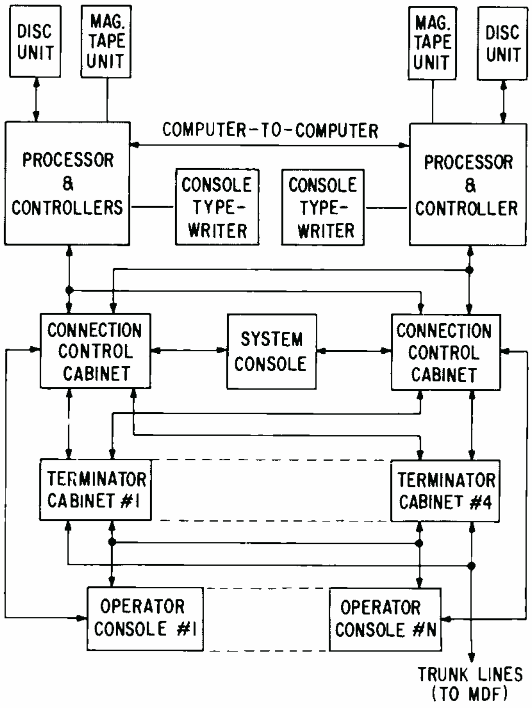


Fig. 1 — Block diagram, CCCT3/1000.

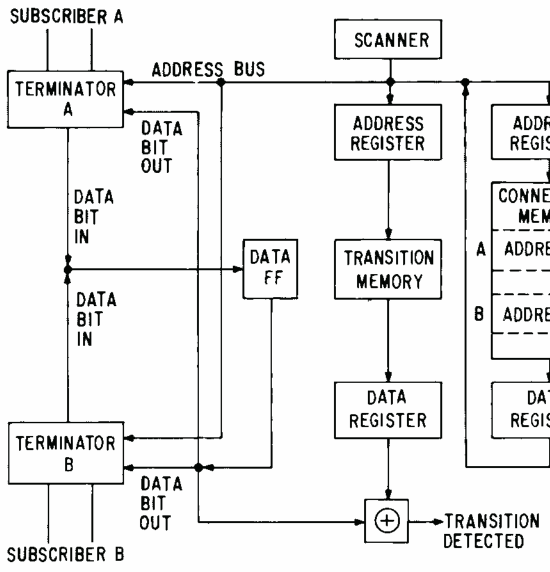


Fig. 2 — Matrix path connections.

progress and certain supervisory function overlay programs.

The Magnetic Tape Unit (MTU) stations provide a bulk record capability for the storage of individual call accounting information.

The Connection Control Cabinet (CCC) is the central equipment item of the exchange. It contains interfaces to both processors, to the terminator cabinets, to the system console and to the operator consoles. All commands from the processor to the exchange hardware pass through the CCC. All interrupts from the hardware to the processor also pass through the CCC.

The CCC contains the time-division matrix and the common logic necessary to maintain a matrix connection established by the processor. The CCC also contains receivers and senders that allow exchange of information between the processor and the line terminators.

All subscribers and trunks are terminated at a *Terminator Cabinet (TC)*. Each TC contains locations for 256 terminator plug-in modules. Each plug-in module may be a subscriber terminator or a trunk terminator. These terminators provide the level changing and regeneration required to interface the line levels to the internal exchange levels. The terminator cards also contain the logic circuitry to interface between the external line and the CCC. This includes address decoding, timing generation, and status storage flip-flops.

The System Console (SC) displays and controls the system configuration. The system configuration is sent to the SC from the processor. The SC then generates the required interlocks between the major subsystems. In addition the SC contains logic for detecting a failure of a processor or CCC. In the event of an on-line failure, the SC automatically transfers control to a standby unit.

The Operator Console (OC) in a telex system is utilized to provide directory assistance, to assist subscribers in completing calls or to interface to a manual system.

Time-division matrix

The time-division matrix (Fig. 2) differs from most time-division approaches in that data is transferred from input to output only when data transitions occur rather than at a fixed sampling rate. This approach is feasible for the telex network since a binary signal is fully defined by its transition points.

Two bipolar solid-state memories are utilized in the CCC. The transition memory (XM) contains the current data polarity (mark or space) of each terminator in the system. Each time a terminator is scanned, this polarity is updated. The connection memory (CM) contains information defining the present status of a terminator. Each terminator has one dedicated location in the CM. When a through connection exists between two terminators, the CM word for each of the two terminators will contain the address of the other terminator. This information is written into the CM by the processor when a connection is established. The following description assumes that the processor has set up a connection between terminator A and Terminator B.

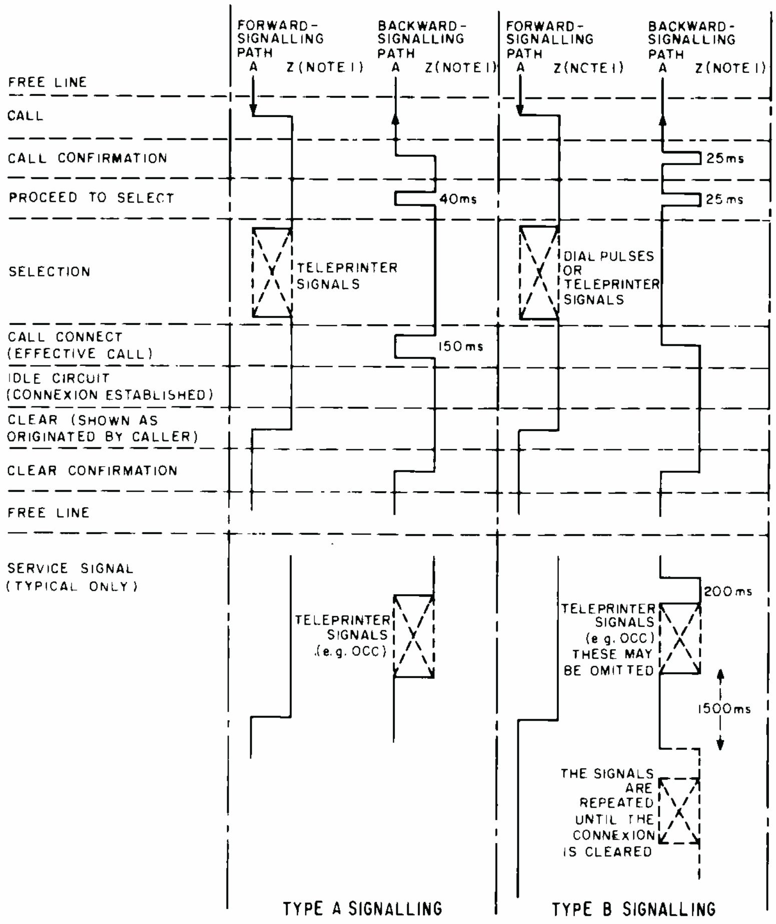
The CCC contains a scanner which sequentially addresses each of the terminators in the system. Each time a terminator is addressed, its current data polarity is read back to the CCC. This polarity is compared to the polarity stored in the XM for that line during the previous scan. If the polarities agree, no transition has occurred and the scanner then addresses the next sequential terminator. If, however, the data polarities differ, a data transition is detected and the scanner is stopped until this transition has been serviced.

Once a data transition is detected, the scanner address is used to generate a CM access for that terminator. If the scanner detects a transition from terminator A, the CM is accessed at a location corresponding to address A. The word read from the CM contains a through connect code and the address of terminator B. B's address is then gated onto the address bus and the incoming data polarity from A is passed to the output terminator B. The XM polarity for terminator A is then updated and the scanner goes on to the next terminator.

This connection is full-duplex. A transition which occurs on terminator B is passed to terminator A exactly as described in the previous paragraph. The matrix is also non-blocking since each terminator has its own CM location.

Program signalling routines

The processor program is responsible for all line signalling procedures from the detection of off-hook through to the establishment of a connection. Also the program is responsible for the line signalling procedures from the detection of a disconnect request through to the free condition of both terminators. Telex signalling procedures follow the recommendations of the CCITT. At present, Types A, B and C are in common usage throughout the world. Types A and B were derived from existing electromechanical exchanges. Type C signalling is a fast signalling system based entirely on the exchange of teleprinter signals, the timing of which permits the best features of the two existing systems to be retained.[3] Fig. 3 shows a com-



NOTES: 1. THE CONVENTIONS USED TO INDICATE POLARITIES OF SIGNALS ARE:
A = START POLARITY
Z = STOP POLARITY

2. THE DURATIONS INDICATED FOR THE SIGNALS ARE NOMINAL.

Fig. 3 — Principles of CCITT, Type A and B, signalling.

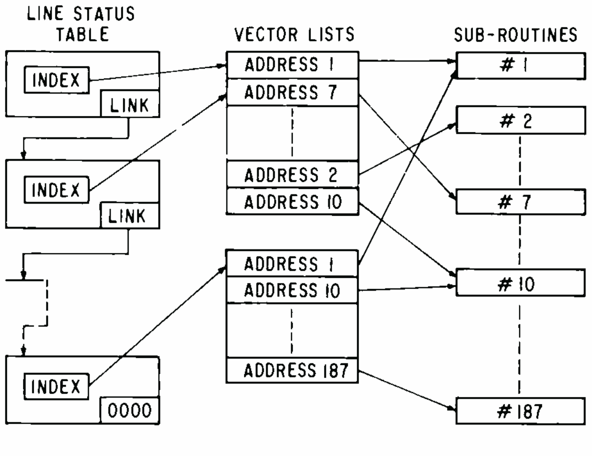


Fig. 4 — Telex line scan.

parison of types A and B signalling.

Although all countries follow the CCITT recommendations, there is considerable variation in how these procedures are LST entries for all of the other terminators in the signalling mode. At periodic intervals, the program steps through these linked LST entries. This process is called the Line Scan Routine (LSR). A terminator is linked into the LSR when an off-hook is detected and unlinked when a through connection is established. A terminator is also linked into the LSR when a disconnect request is detected and unlinked when the line is returned to its free condition.

The signalling routines for each group (country) are divided into many segments or subroutines. A subroutine may simply switch the output line from space to mark. Another subroutine might receive dial pulses and time for interdigit pauses. A third subroutine may just time a specified interval. Most of these subroutines are common to all of the signalling diagrams. To generate a signalling program for a specific country, the addresses of these subroutines are placed in a vector list. The program then sequentially steps the terminator through the vector list. When this process has been completed, the terminator is unlinked from the Line Scan Routine.

The Line Status Table (LST) for each terminator contains an index word (address) which points to a location in its assigned vector list. The initial setting for this index is determined by the type of signalling class mark for the terminator. Once this index is set, the program continually enters the same subroutine during the LSR until the index is incremented to the next step. Each subactually implemented. One of the installed RCA exchanges contains over 30 different variations of these three basic signalling types. In general, the variations from country to country are minor. These minor variations have had a major influence on the way the signalling programs were implemented in software.

Fig. 4 shows how the Telex Line Scan program is structured. This program is responsible for all signalling subroutines. Each terminator has its own dedicated Line Status Table (LST) in core memory. When a terminator is in the signalling mode, its LST address is linked to the routine is responsible for incrementing the index pointer when its task is complete.

If, for example, the task of a subroutine is to decrement a line timer, then the routine would decrement a count in the LST each time the LSR was entered. When the count reaches zero, the vector index is set to point to the next step. The data base for each of the routine segments is contained in the LST entry so that a routine as just described operates completely independent of any other line in the system. This allows the routine to be used over and over by each line without any resetting or initializing of the routine.

This generalized approach to the signalling programs has several definite advantages. It conserves core memory since the same subroutines are shared by all of the signalling diagrams. It reduces the amount of coding required since the common subroutines are shared. It allows for minor variations between countries. Finally, it greatly simplifies the addition of new signalling procedures to the system. A new signalling variation can generally be implemented by making a new vector list of existing subroutines. Therefore, no new coding is required.

Fault detection and automatic switchover

The RCA Government Communications and Automated Systems Division has implemented several fully redundant communications switches for the US government. These switches utilize 'ghosting' techniques which allow switchovers to occur without any loss of information. In each of these cases, the processor was designed with special features to implement this 'ghosting' technique.

The Computer-Controlled Telex switches utilize commercially available processors to perform a commercial function. With this in mind, the following criteria were established for any automatic switchover of redundant equipment:

1) All calls which are being established (in signalling mode) at the time of switchover are to be cleared back to their free state.
2) All calls which are through connected at the time of switchover are to be maintained in that state. At the time of switchover, not more than one character should garble in a through connection.
3) No billing or accounting information for any call will be lost during switchover.

These criteria were met by utilizing a 'shadowing' approach instead of the more complex 'ghosting' techniques. This 'shadowing' approach utilizes a computer-to-computer interface (CCIF) provided by the minicomputer manufacturer. The CCIF is used to pass all pertinent information from the on-line processor to the standby processor. This information is used by the standby processor to update its program tables.

Three types of transfers are made as follows:

1) Initialization – When a processor is brought into standby, all of the current on-line tables are transferred to the standby processor.
2) Connection – Once a processor is in standby, the on-line processor transfers connectivity information to the standby system. Three transfers are made during a normal call. One when the off-hook is detected, one when the through connect is established and one when the disconnect occurs.
3) Line status changes The exchange operator can issue commands to the on-line processor which affect a terminator's status. When this occurs, the same command is passed to the standby system so that its tables can be updated.

The standby Connection Control Cabinet (CCC) is not kept updated. When a CCC switchover occurs, the on-line processor initializes the new on-line CCC. This is accomplished with a write CM block instruction which allows the processor to write each CM word sequentially. A fully implemented CCC can be initialized and placed on-line in less than five milliseconds.

A switchover can be manually initiated by the exchange operator or automatically initiated by the exchange itself. In either case, the unit going on-line must previously have been in the standby condition. The unit which had been on-line goes to an off-line condition so that 'ping-ponging' cannot occur.

The exchange will generate an automatic switchover when a fault is detected. The exchange hardware detects two major types of faults which can generate switchover.

1) A power failure of an on-line processor or CCC is detected by the System Console and switchover is initiated.
2) The on-line program is required to generate 'program alive' signals (commands) to the System Console each time the Line Scan Routine is entered. If the System Console logic detects that two successive signals have been missed, automatic switchover to the standby processor is initiated.

The exchange software also detects two major types of faults which can generate a switchover.

1) Failure of an on-line peripheral (disc or magnetic tape) will generate a switchover to the standby system. This approach was required since peripheral switches were not available with the minicomputer.
2) Failure of the on-line Connection Control Cabinet will generate a switchover to the standby CCC. This condition is detected by diagnostic programs within the on-line processor.

Future CCT systems

The successful implementation of these original CCT switches has led to the development of a complete line of automatic telex exchanges to be marketed on a world-wide basis. These new CCT switches have several new features which were not available in the original switches. Briefly, these are as follows:

1) Expanded capacity the switch capacity has been increased to 4000 terminations.
2) Small exchanges switches in the 100- to 500-line range have been developed without a Connection Control Cabinet. The switching function is accomplished within the processor itself.
3) Mixed data rates new CCT switches will handle data rates from 50 to 1200 baud. Several baud rates may be mixed in one system, but switching is allowed only between terminals of the same speed.
4) Mixed line codes new CCT switches will handle either synchronous or asychronous data with 5, 6, 7, or 8 data bits.

For future requirements, RCA is presently exploring the feasibility of store and forward switches with code and speed conversion, collocated exchanges with out-of-band signalling and several other telex related projects.

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Visual capacity— an image quality descriptor for display evaluation

R.W. Cohen | I. Gorog

A new quantitative descriptor can be used to compare human appreciation of different displays at any viewing distance. This quantity, called "visual capacity" because of its analogy to the information capacity of a communication channel, can be thought of as the total number of edges that can be perceived by an observer located at a given distance from the display. The calculation of the visual capacity involves only a single integration of a function that includes the modulation transfer characteristics of both the display and human visual system. The important general properties of the visual capacity include the existence of an optimum viewing distance for a given display. Furthermore, at a given viewing distance, the visual capacity at first rises rapidly as the bandwidth of the display is increased but eventually saturates if the bandwidth is increased indefinitely. As specific examples, we calculate the visual capacity as a function of viewing distance for ideal color kinescopes and for two real kinescopes for which MTF data was available. We find that the optimum viewing distance for an ideal kinescope operating under standard U.S. bandwidth limitations is approximately four picture heights, but the optimum viewing distance for the two real kinescopes ranged between five and seven pictures heights.

To compare the performance of competitive display devices and to establish quantitative rules to aid in developing new display systems, a mathematical model of image quality has long been of interest. Even though the significance of the modulation transfer function (MTF) in describing the performance of imaging systems has been recognized for sometime,[1] no widely accepted index of image quality has been developed thus far. One can now attempt to develop a useful quality descriptor, because precise measurements of the spatial frequency response of the human visual perception system have recently been obtained.[2].

A number of recent extensive studies of imaging-system performance have included the modulation transfer characteristics of both the imaging system and the human observer. For example, a detailed series of studies was carried out with the aim of describing display performance when the viewer is searching for specific information,[3,4] *e.g.*, detection, recognition, and identification of targets in aerial photographs. The descriptor developed for this purpose is the *Modulation-Transfer Function-Area* (MTFA), defined as the difference between the display system's modulation transfer function (MTF) and the modulation transfer function required by the human observer for threshold detection, integrated over all frequencies where the system MTF exceeds the required threshold. Even though considerable success has been reported in correlating photo-interpreter performance with display MTFA, the MTFA concept was developed specifically for use with images that have a signal-to-noise ratio of the order of unity, and its applicability to very high signal-to-noise ratio systems is uncertain. (Commercial television has $S/N \approx 40$ dB.) Another image evaluation method has been recently developed by researchers at the Sony Corporation.[5] They define an overall system-cum-observer MTF by multiplying the display MTF and the human-visual-system MTF together, and then use this overall MTF to calculate the average perceived gradient of the rising portion of the response to a step-function input. A major shortcoming of this approach is that it completely ignores the ringing that may follow the rising portion of the step response. More importantly, it places undue emphasis on brightness; for a given viewing distance, the average gradient is constant if both the spot size and the brightness are increased by the same multiplicative factor. This conclusion suggests that if sufficient brightness can be produced, soft edges are acceptable — a result that contradicts the results of all pertinent perceptional measurements.[6]

We present a new mathematical formalism for image quality and display performance evaluation. We define a new descriptor, called the *visual capacity*, which is a measure of image sharpness. It is equal to the number of transitions that a human viewer can perceive along one line of a display with a series of unit-step input excitations. As defined, the visual capacity of an ideal flat-bandpass display at the optimum viewing distance is equal to the horizontal resolution expressed in terms of the number of resolvable tv lines, and it satisfies the expected scaling law with respect to bandwidth and viewing distance. Furthermore, when the visual capacity is maximized with respect to some experimentally adjustable parameter, the display/viewer system is optimized with respect to signal-to-noise ratio.

Rigorously, the human visual perception system is highly non-linear, and, therefore, its MTF can be defined only for a given background brightness in the limit of zero contrast. Only further research in perception can establish the practical contrast range of applicability of any descriptor, including the human MTF and the visual capacity, obtained through a linear systems-analysis approach. In general, all real physical systems are described by non-linear equations. However, there is ample evidence that results of practical significance can be obtained by first-order perturbation calculations that involve the linearization of the describing equations.

The visual capacity is expected to be an accurate measure of the comparative performance of displays having identical size, operating at identical color temperature and brightness, and having different MTF characteristics. Furthermore, it is expected to be useful in selecting the economically optimum display size and bandwidth for a given application. All calculations in this paper concern themselves with the evaluation of the display device itself; the optimization of the customary band-limited drive signals is not treated here.

Concept of visual capacity

To understand the concept of visual capacity, it is useful first to review some basic tenets of communication theory. The information-carrying capacity of an electrical communication channel is directly proportional to the bandwidth of the channel. The system capacity is, by definition, the amount of information that can be transmitted through the system per unit time. Information is defined as the base-two logarithms of the number of discrete states the system can assume.[7-9] For example, if a telegraph system is capable of handling only two-level pulses and the maximum transmission rate is N pulse/s, the system can assume 2^N discrete states in a one-second interval, and, by definition, its information capacity is $C = N$ bits/s. Similarly, if the maximum transmission rate a channel can handle is N pulses/s, each of which can be of a height chosen out of n possible levels, the information capacity of the channel is $C = N \log_2$ bits/s. In these two examples, the number of pulses the system can handle is determined by the system's speed of response. The number of pulse height levels is set by the transmission code chosen. (Naturally, the maximum number of permissible levels is determined by the available signal-to-noise ratio, or the acceptable transmission error rate.)

In general, the channel capacity is given by

$$C = \alpha B \qquad (1)$$

where B is the effective bandwidth of the system and α is a proportionality constant that describes the details of the information coding. The bandwidth is a measure of the system's speed of response. More explicitly, assume that the system is composed of an information encoder, a transmitter, a transmission line, a receiver, and a decoder. Furthermore, define the various systems components in such a way that the speed limitations are set only by the transmitter, the transmission link, and the receiver. Then the response time, τ, observed at the receiver output as a result of a unit-step excitation of the transmitter is related to the bandwidth by

$$B = \beta/\tau \qquad (2)$$

where β is a proportionality constant that involves the exact definition of the risetime and the shape of the pass-band. Therefore,

$$C = \alpha\beta/\tau \qquad (3)$$

If the bandwidth (or the risetime) is a function of some experimentally adjustable variables, then the maximum information transfer is achieved when the bandwidth is maximized (or the risetime is minimized) with respect to these adjustable variables.

Denote the time duration alloted to transmit a message by T. We define the total information capacity associated with a message, C^I, as the amount of information that can be transmitted through the communication channel in time T. Then

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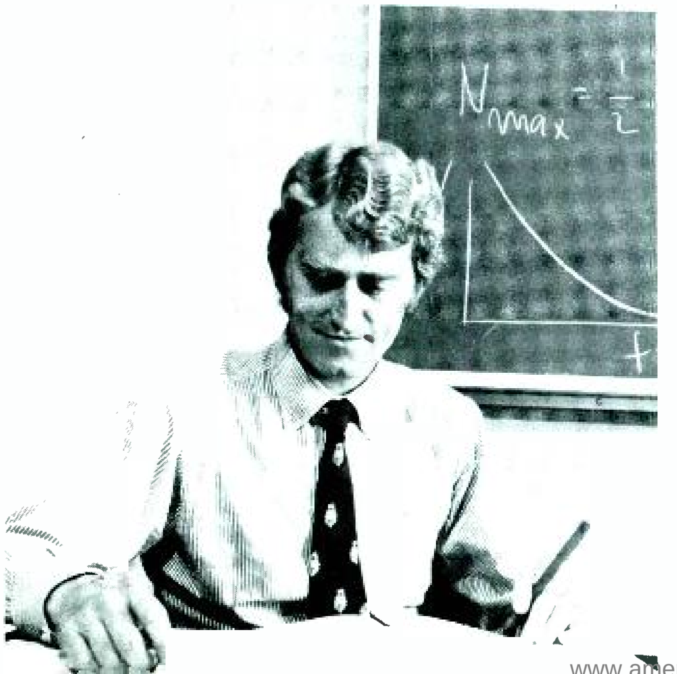

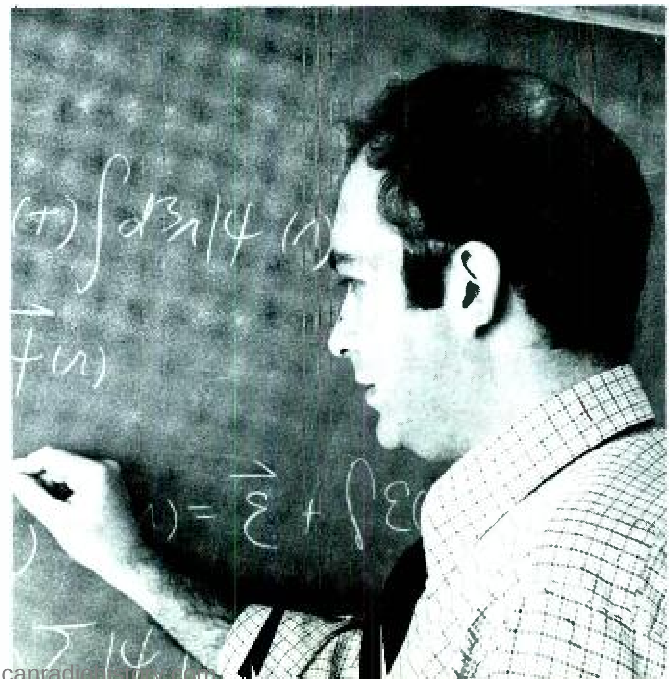

$$C^T = CT = \alpha\beta T/\tau \qquad (4)$$

By analogy with the concept of the channel capacity, C, we define the visual capacity, C_V, of a display system as the amount of visual information that a human observer (limited by the finite spatial frequency response of the visual system) can perceive per unit length of display. Then visual capacity is proportional to the effective spatial bandwidth of the system composed of the actual display and the human visual system.

If the display comprises non-isotropic elements, the visual capacity of the display will also be non-isotropic. An ideal, two-dimensional, diffraction-limited optical imaging device has isotropic visual capacity; as a result of the inherent scanning process, a television kinescope display does not have isotropic visual capacity. Also, it is known that the frequency response of the human visual system is anisotropic; it is optimum in the horizontal direction.[10] The calculations presented in this paper are one-dimensional, aiming primarily at the comparison of the horizontal response of various television displays. Therefore, the question of anisotropy will not be of further concern here.

We shall show that visual capacity is a function of viewing distance and that, by calculating the viewing distance where the visual capacity of the display is maximum, one can determine quantitatively the optimum viewing distance of any display device with a given spatial frequency response. Conversely, for a given viewing distance, one can calculate the visual capacity as a function of the frequency response of the display. Clearly the visual capacity will be a monotonically increasing function of display bandwidth. However, for large bandwidth, the display costs are expected to increase faster than the display bandwidth but, as we will show in the following sections, beyond some bandwidth value the visual capacity increases more slowly than the bandwidth. Therefore, it may be possible to calculate an economically optimum bandwidth for a given viewing distance.

A convenient way to carry out the calculations discussed above is to start out from the perceived step-function response, expressed in terms of the viewing angle. Define the quantity,

$$\sigma = \int_{all\ \theta} (dE/d\theta)^2 d\theta = 1/\theta_e \qquad (5)$$

where θ is the viewing angle, and E is the perceived response as a function of θ when the input to the display is a unit-step signal. The quantity σ is a function of viewing distance and has the dimension of inverse viewing angle. We define θ_e to be the perceived effective angular width of the transition from black to white at an edge.

We can now write the equations for the visual capacity, C_V, that are analogous to Eqs. 1,2, and 3 for the channel capacity. Denote the spatial bandwidth of the perceived information by B_V and the perceived width of the edge transition by x_e. Then

$$C_V = \alpha_V B_V = \alpha_V \beta_V / x_e \qquad (6)$$

where

$$1/x_e = 1/(r\theta_e) = \sigma/r \qquad (7)$$

and r is the viewing distance.

In the limit $r \to \infty$, the visual capacity is determined by the optical limitations of the human visual system. The angle θ_e approaches a constant value, θ_e^{∞}, determined by the resolution limit of the human visual system. In this case, the transition width $x_e \to \infty$, and the visual capacity $C_V \to 0$. (Clearly, if we go too far from the display, we cannot perceive any detail, and, therefore, the visual capacity is zero). In the limit $r \to 0$, the system is display bandpass-limited,[11] and θ_e increases monotonically faster than $1/r$ because the human visual system lacks low frequency response. (See next section). Thus, again $C_V \to 0$. (In the close-up viewing range, we throw away information-transfer capacity because the peak of the eye's response function now falls at spatial frequencies where the display device has a reduced response).

By analogy with the total information capacity associated with a message of time duration T, we define the total visual capacity of a display, C_V^T, as the amount of visual information a human observer can perceive when he views a display of linear dimension w. In a television display, w is the length of a scan line; *i.e.*, it is the width of the raster displayed. Then, from Eqs. 6 and 7

$$C_V^T = C_V w = \alpha_V \beta_V w/x_e = \alpha_V \beta_V w/(\theta_e r) \qquad (8)$$

Now note that w/r is the viewing angle subtended by the display at the observer's eye. Thus, the total visual capacity is proportional to the viewing angle of the display divided by the perceived angular extent of an edge transistion. Since, for a given display, w is a constant, the optimum value of C_V^T occurs at the same viewing distance as the optimum C_V. Therefore, in order to calculate the performance of a given display as a function of viewing distance, one can use either C_V or C_V^T. However, to compare the performance of various displays, C_V^T is clearly more appropriate.

In Eqs. 3 and 4 we have indicated that the absolute value of the information capacity of a communication system depends on the coefficients α and β. These can be determined if the details of the information coding and the exact definition of the risetime are specified. To calculate the analogous coefficient, α_V and β_V for the visual capacity, we would require precise knowledge of the human visual perception process; *i.e.*, we would need to know exactly for which features of an image the visual system searches, and precisely what is the physical nature of the "output". Because the required details of the perception process are not known, we need two auxiliary assumptions, or definitions, for the calculation of the absolute value of C_V^T.

First, we assume that the most important features of an image are the transitions between different brightness levels. Therefore, for the purposes of our calculations, we define visual capacity as the number of countable black-to-white transitions, and we set $\alpha_V = 1$. (The analogous communications channel is then a simple two-level telegraph system, for which $\alpha = 1$).

The second assumption involves the setting of an absolute scale for the MTF of the human visual system. In the next section, we shall show that the perceived angular width of a transition can be calculated from the known frequency response characteristics of the display and of the human visual system. A difficulty arises because the absolute scale factor of the human visual system's response curve is not known; as a matter of fact, without an auxiliary definition, one can not assign, even conceptually, an absolute scale factor to a perceptional quantity. A possible way to overcome this difficulty is to assign a scale factor in a self-consistent manner in terms of the known number of countable edges in an appropriate limiting case. [The scale factor and the precise definition of the transition width are intimately related. For the electrical analog (Eqs. 2,3,4), the effective risetime is τ/β. We can set $\beta=1$, provided that τ is properly scaled.]

Two known limiting cases appear useful for the calculation of the required scale factor. They are:

1) When the viewing distance is sufficiently large, the perceived angular extent of a transition, θ_e^x, is determined only by the modulation transfer characteristics of the visual system and is independent of the MTF of the display system. Measurements on visual acuity indicate that θ_e^x is probably determined by noise considerations. For a unit-contrast circular black test object, log θ_e^x = [*constant* − 0.5 log (*background luminance*)];[12] the slope of 0.5 is in agreement with fluctuation theory.[11] A value of θ_e^x ≅ 1 minute was measured at 1 ft-lambert luminance; extrapolation of the same data suggests a value of $\theta_e \cong 0.1$ min at 100 ft-lamberts. Earlier measurements, aimed at establishing television scanning standards and, therefore, performed with line patterns, indicate a value for θ_e^x in the range of 0.5 to 2 min.[14]

2) When the display system has a flat response up to a maximum spatial frequency component f_m and has zero response for higher frequencies, the maximum number of transitions that can be displayed is $2wf_m$. If we assume that, at the optimum viewing distance, a human observer with normal vision can perceive all these transitions, we can conveniently choose the scale factor for the visual response in such a way that, at the optimum viewing distance and for the flat response display, $C_V^T = 2wf_m$. Using this method of normalization in the next section, we find that $\theta_e^x = 1.84$ min.

For our calculations, we have chosen the second of the above two methods of normalization. The primary reason for this choice was that this method of normalization is consistent with the human visual system's subjective MTF curve used for the detailed calculations in the next two sections.[15] Also, as a result of this method of normalization, the total visual capacity of a flat-response television display viewed at the optimum viewing distance is equal to the maximum number of tv lines (*i.e.*, twice the number of line pairs) that can be displayed. However, it is important to emphasize that the assignment of an absolute scale factor to the perceptional response curve in the context of our calculations is only a matter of convenience and not an essential requirement for describing such properties as the dependence of C_V^T on viewing distance and display MTF.

Mathematical formulation and general properties

We have defined the visual capacity in terms of the perceived visual response to sharp edge inputs. Therefore, we begin our calculation by considering the application to a display of an input signal consisting of a perfectly sharp step-function input signal of magnitude ΔV, superimposed on a dc level, V_o. As a result of this input excitation, the displayed image consists of an edge transition superimposed on a uniform, bright background field. We assume that $\Delta V/V_o << 1$, so that both the display and the human visual system can be treated by linear response theory. The step input is imaged by the display and viewed by an observer located a distance r from the display. Both of these processes affect the original signal in a manner described by the transfer functions of the display and the human visual system (*HVS*). If x denotes the length coordinate on the display screen in a direction perpendicular to the displayed edge, the corresponding angular coordinate for the observer is $\theta = 180\ x/\pi r$, measured in degrees-of-vision. We define the psychophysical response function, $E(r,\theta)$, that describes the perceived response to a unit-step input signal. The meaning of the unit-step input is as follows: We define the brightness units such that the change in brightness on the display screen in going through the edge transition is unity.[16] The function $E(r,\theta)$ is proportional to the perceived brightness at a viewing angle θ, measured with respect to an arbitrary axis, when the observer is located a distance r from the illuminated region. In the following analysis, $E(r,\theta)$ will be taken to be dimensionless. We can do so provided care is exercised in the establishment of a scale for the transfer function of the *HVS* that is consistent with the psychophysical experiments. Our method for assigning such a scale was discussed at the end of the previous section. The corresponding value of the required normalization factor of the *HVS* response function will be calculated later in this section.

The perceived sharpness of the edge can be defined in a variety of ways. The simplest, mathematically convenient definition is in terms of the integral,

$$\sigma(r) = \int_{\text{all }\theta} [\partial E(r,\theta)/\partial\theta]^2 d\theta \qquad (9)$$

Since E represents the (dimensionless) perceived response to a unit-step input, Eq. 9 suggests that the quantity $\sigma(r)$ can be thought of as the reciprocal of the effective viewing angle over which the transition from the darker to the lighter region is achieved. A few simple analytic examples, using assumed forms for $E(r,\theta)$, should convince the reader that Eq. 9 for $\sigma(r)$ is indeed a reasonable choice for a definition of sharpness. We encourage the reader to do so, for it will give him a feel for the definition. We merely note here that, if $E(r,\theta)$ has no ringing or overshoots (a condition that cannot be met by any signal that is filtered by the MTF of the human visual system), Eq. 9 can be rewritten in the form

$$\sigma(r) = \int [\partial E(r,\theta)/\partial\theta] dE(r,\theta) \qquad (10)$$

where the integration proceeds over all values of $E(r,\theta)$. It follows from Eq. 10 that the display that produces the largest gradient $\partial E(r,\theta)/\partial\theta$, averaged over the entire range of $E(r,\theta)$, has the largest value of $\sigma(r)$ (see Fig. 1). It is reasonable to assign the sharpest edge-producing capabilities to this display. When $E(r,\theta)$ displays ringing, the definition of $\sigma(r)$, Eq. 9, includes some "spurious sharpness" because of the inability of the integration to distinguish the sign of $\partial E(r,\theta)/\partial\theta$. (Fig. 1 includes an example of a function $E(r,\theta)$ that would produce

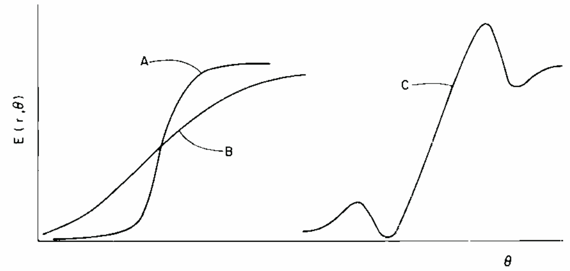

Fig. 1 — Examples of edge transitions. Transition A has a larger value of $dE/d\Theta$ for every value of E than transition B, so that, according to Eq. 10, it has a larger value of the sharpness function. Transition C is an example of a transition that has "spurious sharpness" because the oscillations of E contribute to the sharpness function defined in Eq. 9.

spurious sharpness). However, we have found that the error introduced by including spurious sharpness is small[17] in cases of importance. Moreover, it is not clear to what extent oscillations in $E(r,\theta)$ may actually enhance the subjective appreciation of sharpness. Therefore, we have adopted Eq. 9 for our definition of sharpness and have employed it throughout our calculations.

The visual capacity, $C_V^T(r)$, was defined as the total number of edges that can be perceived by an observer from a position located a distance r from a display. Thus, it is equal to the angular width subtended by the display divided by the apparent angular width of a single edge. Then from Eqs. 7 — 9, (with $\alpha_V = \beta_V = 1$),

$$C_V^T(r) = (180\,w/\pi r)\,\sigma(r)$$

$$= (180w/\pi r) \int_{all\ \theta} [\partial E(r,\theta)/\partial\theta]^2 d\theta \quad (11)$$

Here w is the width of the display in a direction perpendicular to the impressed edges. Eq. 11 can be expressed in terms of the modulation transfer characteristics of the display and the *HVS*. Let $R(\omega)$ denote the modulation transfer function (MTF) of the display, where ω is the angular spatial frequency on the screen, *i.e.*, the Fourier compliment of the coordinate x. We denote the MTF of the *HVS* by $O(\nu)$, where the quantity $2\pi\nu$ is the Fourier compliment of the angular coordinate θ. Therefore, $\nu = \omega r/360$ and is measured in cycles/degree-of-vision. With these definitions, it is a straightforward exercise in Fourier analysis to express the integral in Eq. 11 in terms of the transfer functions $R(\omega)$ and $O(\nu)$.[22] The results for $\sigma(r)$ and $C_V^T(r)$ are

$$\sigma(r) = 2 \int_0^\infty |O(\nu)R(360\nu/r)|^2\, d\nu \quad (12)$$

$$C_V^T(r) = (360w/\pi r) \int_0^\infty |O(\nu)R(360\nu/r)|^2\, d\nu \quad (13)$$

From Eqs. 12 and 13, we see that the perceived sharpness and the visual capacity are proportional to the integral of the square of the magnitude of the combined MTF of the display and the *HVS*. The importance of the quantity,

$$\int_0^\infty |R(\omega)|^2\, d\omega$$

the area under the square of the system MTF curve, has been recognized in connection with signal-to-noise aspects of imaging[1] and with decision theory.[18] Also, several researchers[19,20] have considered quantities related to C_V^T as a measure of the quality of photographic film reproductions.

Before discussing the properties of $C_V^T(r)$, we shall describe briefly the properties of $O(\nu)$, the modulation transfer function of the human visual system. The human visual response has been measured at various levels of adaptive luminance by means of ingenious psychophysical experiments.[21] The solid curve in Fig. 2 represents the $O(\nu)$ for high brightness levels obtained from the experiments of Davidson and of Campbell and Green.[2] The basic features are 1) a lack of dc response (we do not perceive intensity changes if they are sufficiently slowly varying); 2) a peak of $O(\nu)$ at $\nu_o = 8$ cycles/degrees-of-vision (this peak is responsible for the famous Mach Bands observed at edge transitions); and 3) a rapid decrease of $O(\nu)$ at high spatial frequencies (the result of the physical-optical limitations of the lens-eyeball-retina system). We find that $O(\nu)$ is well represented in the range $0.3 \lesssim \nu \lesssim 40$ by the simple Pade approximant

$$O(\nu) = \frac{0.6367}{(\theta_e^\infty)^{1/2}} \; \frac{(\nu/\nu_o)}{1 + 3.436(\nu/\nu_o) - 4.123(\nu/\nu_o)^2 + 2.562(\nu/\nu_o)^3}$$

$$\nu_o = 8 \text{ cycles}/\textit{degrees-of-vision} \quad (14)$$

where θ_e^∞, as described in the previous section, is the perceived width (in degrees) of a single edge transition in the limit of large viewing distance. That is, the function $O(\nu)$, given by Eq. 14, is normalized such that the sharpness $\sigma(r)$ approaches $1/\theta_e^\infty$ as $r \to \infty$

$$\lim_{r\to\infty}\sigma(r) = 2\int_0^\infty |O(\nu)|^2 d\nu$$

$$= 1/\theta_e^\infty \quad (15)$$

To obtain Eq. 15, we have employed in Eq. 12 the relation

$$\lim_{r\to\infty} R(360\nu/r) = R(O) = 1$$

Eq. 14, our approximation for O(ν), is represented by the dashed curve in Fig. 2.

We now enumerate the general properties of C_V^T. We begin by noting that there exists a characteristic angular spatial frequency, ω_m, measured on the display screen, that characterizes the rate of roll-off of $R(\omega)$. This characteristic frequency may be determined by components of the display itself, such as a kinescope, or by inherent limitations of the rate of input information, such as those imposed by the television broadcast standards. The characteristic frequency ω_m and the frequency $\nu_o = 8$ cycles/degree-of-vision, for which $O(\nu)$ has a maximum, determine a fundamental unit of viewing distance,

$$r_o = 360\,\nu_o/\omega_m \quad (16)$$

If $r >> r_o$, the *HVS* limits the value of C_V^T,

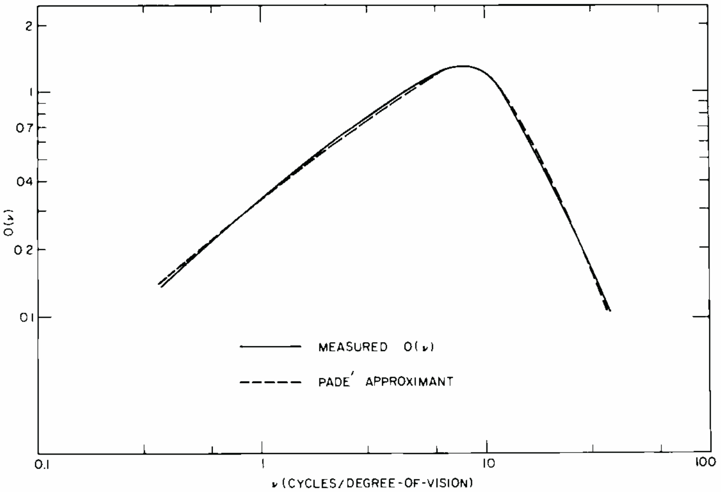

Fig. 2 — The modulation transfer function of the human visual system as a function of spatial freuqency in cycles/degree-of-vision. The solid curve represents the experimental results (Davidson, Ref. 2). The dashed curve represents the approximation Eq. 14, with the resolution limit of HVS at 0.03065 degree. The ordinate scale is chosen such that $O(11.9) = 1$.

whereas for $r << r_o$, the limitations of the display imaging capabilities dominate the total visual capacity. Intuitively, one expects the optimum value of C_v^T to be obtained at the viewing distance for which the characteristic display frequency ω_m corresponds approximately to the peak in the MTF of the *HVS*, *i.e.* $r \sim r_o$. Indeed, this turns out to be the case. In the following, we outline successively the properties of $C_v^T(r)$ in the regimes $r >> r_o$, $r << r_o$, and $r \sim r_o$.

1. *Far-field viewing* ($r >> r_o$)

In this limit, the display MTF, $R(360\nu/r)$, in the integrand of Eq. 13 may be replaced by unity, so that $C_v^T(r)$ is given by

$$C_v^T(r) = (180\,w/\pi\theta_c^{\infty} r),\ r >> r_o, \qquad (17)$$

where we have employed Eq. 15 for θ_c^{∞}. The physcial meaning of Eq. 17 is that, at large viewing distances, the visual capacity is simply the angle subtended by the display divided by the apparent width of a single edge transition, as determined solely by the human visual system.

2. *Near-field viewing* ($r << r_o$)

Here, only the low frequency ($\nu << \nu_o$) contributions to $O(\nu)$ are important in determining the visual capacity. Thus, we need to retain only the term proportional to ν/ν_o in Eq. 14 for $O(\nu)$. Eq. 13 then yields, after transforming the variable of integration to angular spatial frequency on the display screen,

$$C_v^T(r) = 0.1290\,(w/\omega_m^2\,\theta_c^{\infty})(r/r_o)^2 \int_0^{\infty} \omega^2 |R(\omega)|^2\, d\omega,\ r << r_o \qquad (18)$$

From Eq. 18 it is seen that, in near-field viewing, $C_v^T(r)$ increases as the square of the viewing distance, with the magnitude determined by the area under the curve of $\omega^2|R(\omega)|^2$, thereby emphasizing high spatial frequencies. This result can be understood by considering that, when we view an image from such small distances that all spatial frequencies produced by the display lie below the peak in the response of the *HVS*, we would be quite capable of perceiving detail that is, in fact, not being produced by the display. In this case, visual capacity is increased either by increasing the high-frequency response of the display or by moving further away so as to bring the peak of the response of the *HVS* within the effective passband of the display.

3. *Optimum viewing* ($r \sim r_o$)

We have reasoned intuitively that the visual capacity should possess a maximum when $r \sim r_o$; *i.e.*, at that distance for which the characteristic frequency ω_m of the display corresponds approximately to the peak of the response of the observer. Detailed calculations for actual color kinescope MTF's, described in the following section, show this conclusion to be true. A simple example of practical interest is a display with a flat response ($R(\omega) = 1$) below a maximum angular spatial frequency ω_m and zero response above ω_m. Then, Eq. 13 simplifies to

$$C_v^T(r) = (360w/\pi r) \int_0^{r\nu/r} O^2(\nu)d\nu \qquad (19)$$

Straightforward differentiation of Eq. 19 yields the following equations for the optimum viewing distance, r_{opt}, and the total visual capacity at r_{opt}:

$$\left\{[xO^2(x)]^{-1} \int_0^x O^2(\nu)d\nu\right\}_{x=r_{opt}\nu_o/r_o} = 1 \qquad (20)$$

$$C_v^T(r_{opt}) = (\omega_m w/\pi)\, O^2(\nu_o r_{opt}/r_o) \qquad (21)$$

Numerical solution of Eq. 20, using Eq. 14 for $O(\nu)$ and Eq. 16 for r_o, yields the result for the optimum viewing distance,

$$\begin{aligned} r_{opt} &= 1.485\, r_o \\ &= 4277\ \omega_m \end{aligned} \qquad (22)$$

This result verifies our intuitive reasoning that $r_{opt} \sim r_o$. Furthermore it satisfies the expectation that the optimum viewing distance should vary inversely as the maximum spatial frequency produced by the display. For conventional American tv standards (active scan time of 52.368 μs and a screen aspect ratio of 4:3) and for an ideal kinescope with a standard 3.5-MHz cutoff, Eq. 22 predicts that the optimum viewing distance is 4.95 times the picture height. In the next section, we shall see that departures from ideal behavior shift r_{opt} to higher values.

Combining Eqs. 21 and 22, the total visual capacity at the optimum viewing distance is given by the simple expression

$$C_v^T(r_{opt}) = (\omega_m w/\pi)\ O^2(\nu_{opt}) \qquad (23)$$

where

$$\begin{aligned} \nu_{opt} &= 1.485\ \nu_o \\ &= 11.9\ \textit{cycles/degree-of-vision} \end{aligned} \qquad (24)$$

Thus, as one would expect, $C_v^T(r_{opt})$ is proportional only to the maximum frequency produced by the display and the total width of the display; the quantity $O^2(\nu_{opt})$ is a constant, characteristic of *HVS*. This result allows us to normalize $O(\nu)$ in a consistent manner. As discussed at the conclusion of the previous section, we choose to set the value of the total visual capacity at the optimum viewing distance equal to the total number of tv lines, $\omega_m w/\pi$, that can be produced by a system with a flat response below a maximum angular spatial frequency ω_m. This convention establishes the value $O(\nu_{opt}) = 1$, and the vertical scale of the curves of $O(\nu)$ in Fig. 2 is so chosen. The assignment of an absolute value for $O(\nu)$ for any value of ν allows the determination, through Eq. 14, of θ_c^{∞}, the perceived angular width of a single edge at large viewing distances. Our choice, $O(\nu_{opt}) = 1$, establishes the value of $\theta_c^{\infty} = 1.84$ min. This value lies within the range found in early measurements of visual acuity on line patterns.[14] It should be emphasized again that the choice of a scale for $O(\nu)$ affects only the absolute value of $C_v^T(r)$ but does not affect its behavior as a function of display MTF or viewing distance.

The particular viewing distance $r = r_o$ also has a special significance. It can be easily verified from Eq. 19 that, for a flat passband of width ω_m, $\partial C_v^T/\partial\omega_m$ has its maximum value at $r = r_o$. Thus, for a given viewing distance, the visual capacity is most sensitive to changes in bandwidth when the bandwidth satisfies the condition $\omega_m = 360\nu_o/r_o = 360\nu_o/r$.

Application to kinescopes and facsimile reproduction systems

To illustrate the application of the concepts described in the preceding sections, we have applied Eq. 12 and 13 for the sharpness function $\sigma(r)$ and the total visual capacity $C_v^T(r)$ to real imaging systems.

Figs. 3 and 4 are curves of $C_v^T(r)$ and $\sigma(r)$, respectively against viewing distance in units of picture height, *h*, for various color kinescopes. The curves labeled *ideal kinescope* were computed using a response function $R(\omega) = 1$. The curves designated *American monochrome standards* represent the maximum achievable $C_v^T(r)$ and $\sigma(r)$ if the entire

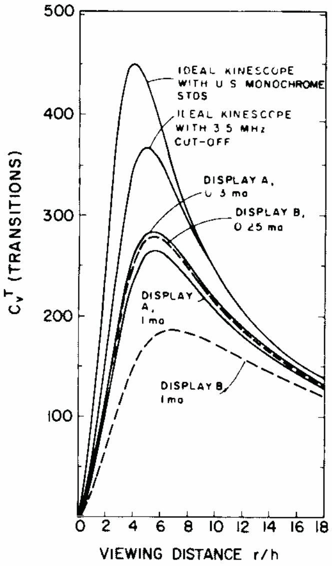

Fig. 3 — The total visual capacity as a function of viewing distance in units of picture height. Curves are shown for an ideal kinescope with two types of bandwidth limitation and for two commercially available kinescopes. The values of the beam current are indicated in the figure.

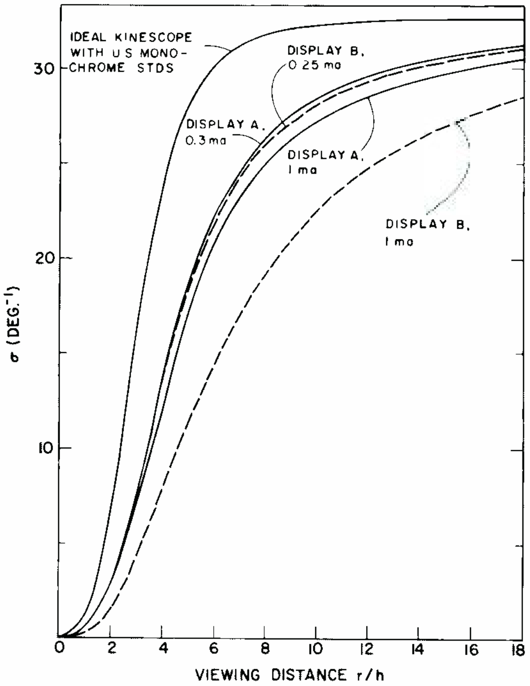

Fig. 4 — The edge sharpness as a function of viewing distance in units of picture height. Curves are shown for the same ideal and actual devices as in Fig. 3.

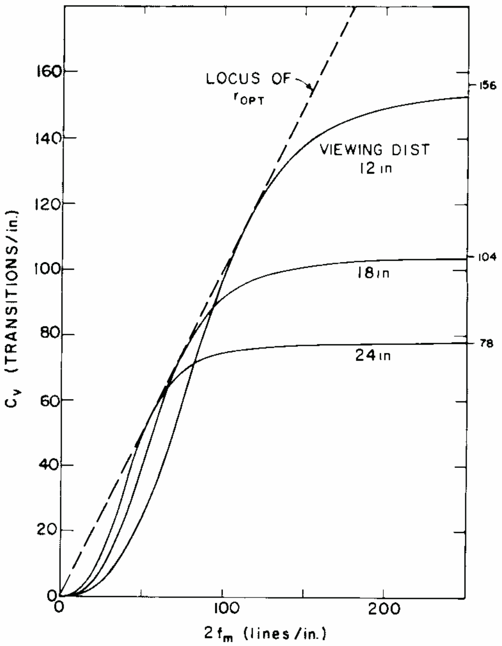

Fig. 5 — Visual capacity as a function of resolution, in units of lines/inch, for an ideal facsimile system. The viewing distances are indicated in the figure. The dashed line represents the locus of points through which all curves of visual capacity *vs.* resolution pass when the viewing distance is optimized. The numbers in the right hand margin represent the values of visual capacity for infinite resolution corresponding to the values of viewing distance given in the figure.

monochrome bandwidth were available for luminance signal reception. Therefore, these curves represent the ultimate picture performance under the present standards. In the calculation of the curve in Fig. 3 designated *ideal kinescope with 3.5-MHz cutoff*, the bandwidth was limited to 3.5 MHz in accordance with the current U.S. practice. Thus, this curve represents the best possible performance with the present practice of receiver design. The curves labeled *display A* and *display B* were calculated using the measured MTF's for a single electron gun of two wide-angle, small-screen kinescopes at the indicated values of the beam currents. The MTF's were determined only at the screen center, and the curves in Figs. 3 and 4 were calculated assuming the kinescope spot profiles to be invariant across the face of the screen. A cutoff at 3.5 MHz was employed in the calculations of $C_v^T(r)$ and $\sigma(r)$ for both kinescopes.

As discussed in the previous section, all the curves of $C_v^T(r)$ in Fig. 3 show the same characteristic behavior: the curves rise rapidly at small viewing distance, achieve a maximum, and approach far-field behavior, Eq. 17, at large viewing distances. For the curves calculated assuming an ideal kinescope, the value of the total visual capacity at the optimum viewing distance, $C_v^T(r_{opt})$, corresponds to the maximum number of tv lines that can be displayed for the appropriate bandwidth. For the curves calculated using real kinescope MTF's, it is seen that: 1) the values of $C_v^T(r_{opt})$ are substantially decreased from the ideal values, 2) the optimum viewing distance is shifted to larger values, and 3) the sensitivity of $C_v^T(r)$ to changes of viewing distance near r_{opt} is greatly decreased due to the increased width of the peak. These effects are especially strong at high beam currents, and they agree with our intuitive feeling concerning the nature of image quality.

Figure 5 is a plot of visual capacity, $C_v = C_v^T/w$, as a function of the resolution in lines/inch, $2f_m$, of an ideal facsimile reproduction system for various viewing distances. The curves were calculated using Eq. 13 assuming an ideal system response $R(\omega) = 1$ below a maximum angular spatial frequency, $\omega_m = \pi(2f_m)$. The dashed line represents the line for which $C_v = 2f_m$; *i.e.*, the visual capacity equals the maximum density of displayed lines. According to the discussion of the previous two sections, this can occur only when $r = r_{opt}$. Thus, the line $C_v = 2f_m$ represents the locus of points through which all curves of visual capacity against resolution pass when $r = r_{opt}$. From Eqs. 21 and 22, with $O(v_o r_{opt}/r_o) = 1$, it can be shown that the calculated curves are tangent to the lines $C_v = 2f_m$ when $2f_m = 1361/r_{opt}$. In the limit of infinite resolution, $2f_m \rightarrow \infty$, C_v saturates because of the limitations of the human visual system. The saturation values for each value of viewing distance considered in Fig. 5 are given in the right hand margin of the figure. From Fig. 5, it is seen that, for viewing distances greater than 12 in., only small gains in visual capacity can be achieved by going beyond approximately 100 to 150 lines/inch in an ideal facsimile system.

Conclusions

We have derived a new descriptor which can be employed to compare human appreciation of different displays at any viewing distance. This quantity, called *visual capacity* because of its analogy to the information capacity of a communication channel, can be thought of as the total number of edges that can be perceived by an observer located at a given distance from the display. The calculation of the visual capacity involves only a single integration of a function that includes the modulation transfer characteristics of both the display and the human visual system.

The concepts developed in this paper can be considered as an extension of the work of O.H. Schade[1] and J.L. Harris.[18] Schade has found that visual evaluation of image sharpness correlates well with the noise equivalent passband, N_e, which he defined as the integral of the square of the MTF. Harris has shown that the probability of the correct binary decision increases with increasing N_e. In this paper we have proved that a rigorous mathematical relationship exists between the sharpness of a reproduced edge as perceived by an observer and the integral of the square of total display-observer MTF. The visual capacity, which we have defined in terms of the perceived edge width, is a generalization of the concept of N_e to the perceptional level.

The important general properties of the visual capacity include the existence of an optimum viewing distance for a given display. Furthermore, at a given viewing distance, the visual capacity at first rises rapidly as the bandwidth of the display is increased but eventually saturates if the bandwidth is increased indefinetly. As specific examples, we have calculated the visual capacity as a function of viewing distance for ideal color kinescopes and for two real kinescopes.

We found that the optimum viewing distance for an ideal kinescope operating under standard U.S. bandwidth limitations is approximately four picture heights, but the optimum viewing distance for the two real kinescopes ranged between five and seven picture heights. Furthermore, we found that, whereas the visual capacity was essentially identical for the two real kinescopes at low beam currents, the performance at high beam currents differed considerably in the two tubes.

Also, we carried out calculations to investigate the dependence of visual capacity on resolution, at various typical viewing distances, for facsimile systems. We found that, for an ideal facsimile reproduction system viewed at distances greater than approximately 12 inches, only a small gain in visual capacity can be achieved by going beyond a 100 to 150 line/inch system.

We anticipate that the visual capacity can be a useful tool for translating the modulation transfer characteristics of a display into such readily appreciated quantities as optimum viewing distance and the number of edges actually perceivable by an observer. As such, it can assist in the establishment of performance specifications for new displays, as well as in the comparative evaluation of present day systems.

Acknowledgment

It is a pleasure to thank G.D. Cody for helpful suggestions during the course of this work. We are also grateful to F.W. Herold for providing the kinescope MTF's and whose eloquent description of problems in color television ultimately stimulated this work.

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16. All incoherent optical imaging systems and scanning beam displays have a maximum response at dc. [See, *e.g.* Cohen, R.W., and Gorog, I., *J. Opt. Soc. Am.*, (Sept. 1973)] Therefore, for such systems $R(0) = 1$ and $R(\omega \neq 0) < 1$. Assume that the input is a step function of step height ΔI, superimposed on a dc level, I_0:

$$Input = I_0 + \Delta I\, U(x)$$

$$= I_0 + \Delta I \int_{-\infty}^{\infty} \frac{d\omega}{2\pi}\, u(\omega) \exp(i\omega x)$$

where $U(x)$ is a unity step function, $u(\omega)$ is the Fourier transform of $U(x)$, and we assume unity magnification between input and output, *i.e.* x is the appropriate distance coordinate on both the display screen and at the input. Denote the brightness gain factor of the display by G. The output on the display screen is described by

$$Output = GI_0 + G\Delta I \int_{-\infty}^{\infty} \frac{d\omega}{2\pi} R(\omega)u(\omega)\exp(i\omega x)$$

It follows directly from the properties of $U(x)$ and $R(\omega)$ that at $x \to -\infty$, the output $= GI_0$ and $x \to \infty$, the Output $= G(I_0 + \Delta I)$. We now choose our brightness units such that $G\Delta I = 1$, and, therefore, the change in brightness going through the displayed edge transition is unity.

A complete television display, consisting of electronic signal processing circuits followed by a scanning beam display, does not necessarily have $R(0) = 1$ (Incomplete dc restoration.) We write $R(\omega) = R_e(\omega)\, R_b(\omega)$, where the subscripts e and b refer to electronic system and the scanning beam, respectively. We normalize the response functions in such a way that $R_b(0) = 1$, and, within the finite pass band of the beam, we set the maximum of $R_e(\omega)$ equal to unity. The output that results from the step function excitation can then be written as:

$$Output = GI_0R_e(0)\, R_b(0) + G\Delta I \int_{-\infty}^{\infty} \frac{d\omega}{2\pi}\, R_e(\omega)R_b(\omega)u(\omega)\exp(i\omega x)$$

In the absence of dc restoration $R_e(0) = 0$, and at $x \to +\infty$, the output $= 0$. Without any loss in mathematical precision, we can again set $G\Delta I = 1$. However, in order to assure that, in the calculation of C', the system is linear, now we have to assume that there is sufficient background brightness to allow the perception of the edge transition to be treated as a perturbation.

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21. The frequency response of the human visual system has been measured by methods that involve: i) threshold detection [O.H. Schade, "Optical and Photoelectric Analog of the Eye" *J. Opt. Soc. Am* Vol. 46 (1956) p. 721] ii) brightness matching [Lowry, E.M., and DePalma, J.J. "Sinewave Response of the Visual System I. The Mach Phenomenon", *J. Opt. Soc. Am.* Vol. 51, No. 7 (1961) p. 740. Bryngdahl, O.: "Characteristics of the Visual System: Psychophysical Measurements of the Response to Spatial Sine-Wave Stimuli in the Photopic Region," *J. Opt. Soc. Am.* Vol. 56, No. 6 (1966) p. 811, and Kay and chesters, Ref. 11], and iii) contrast matching (Davidson, Ref. 2). All of the above measurements, except that of Hay and Chesters, were aimed at measuring the one-dimensional sinewave response. Hay and Chesters measured the transfer function for circular detail. The results obtained by the various experimenters are all in rough agreement; however, there is considerable variation in numerical detail. In general, matching measurements are believed to be more appropriate for determining the frequency response than are threshold measurements. Furthermore, the data taken by Davidson, Ref. 2, is expected to be the least contaminated by the measurement method itself. For a more detailed comparison of the various methods of measurement, see Cornsweet, Ref. 6, pp. 330-342
22. This analysis was included as an Appendix in the original manuscript of this paper and is available from the authors

Basic, highly maintainable airborne video tape recorder/reproducer

P.F. Muraco

The AN/USH-17 family of airborne video recorders is described in this paper. The basic USH-17 can be used to record and reproduce the display signals for an airborne forward-looking multimode mapping radar, while simultaneously recording the output of another wideband electro-optical sensor as well as voice and digital data. The USH-17 embodies state-of-the-art video recording techniques, coupled with modularity and packaging concepts that provide simplicity of maintenance as well as reliable operation; yet size and weight have been reduced so that the unit can be operated in small attack aircraft. Other versions of the basic equipment have been adapted to other wideband dual-channel airborne recording applications.

Paul F. Muraco, Ldr., Recording Equipment Operations, Government Communications and Automated Systems Division, Camden, N.J., received the BSEE in 1966 from Ohio University. He attended the University of Pennsylvania where he completed course requirements for the MSEE in 1970. Following his graduation, he was employed by RCA on the development training program. On completion of this program, he joined the Recording Equipment Operations Engineering Staff as a design engineer. His responsibilities since that time have included subsystem checkout and acceptance testing of various video recorders, design of a universal power supply and subsystem electronic design, integration system test, and acceptance tests of the AN/TSH-5. In 1970 and 1971, Mr. Muraco was assigned as Project Engineer for the final design, testing and field support of the AN/USH-17 airborne recorder/reproducer system for the Navy A6 aircraft. Assignment included design of radar multiplex and demultiplex subsystem for the AN/USH-17 Recorder/Reproducer. In 1972, Mr. Muraco was promoted to Engineering Leader and is responsible for the ADVISER family of Video Recorder/Reproducers. He is currently responsible for the ADVISER Production Recorder, the TPR-10 Portable Color Recorder/Reproducer, and actively supporting the AN/USH-17(V) production program.

RELIABILITY and maintainability are important parameters in military equipments. Reliability of electronics equipment has been developed to the point where nearly any desired level of reliability can be achieved in design. Magnetic recording equipments, however, consist of extensive electromechanical systems, and the reliability of such systems has frequently not met the expectations of the user or the designer. An even more frustrating aspect of the equipment from the user's standpoint has been that failures are difficult to repair.

Providing a sharp contrast with past magnetic recording equipment is the highly maintainable airborne video tape recorder/reproducer shown in Fig. 1. The AN/USH-17 (V) video recorder/reproducer, can be described as a high performance, dual-channel wideband airborne video recorder/reproducer capable of withstanding severe environmental exposures.

Initial application of the USH-17 has been the Navy's A-6A, A-6C and A-6E family of carrier-based attack aircraft. The USH-17 provides for the simultaneous recording and reproducing of forward-looking radar, an electro-optical sensor channel such as LLTV (low light level tv) or FLIR (forward-looking infrared), digital data, and audio information.

Specifically the USH-17(V) was designed to record and reproduce two wideband (6-MHz) channels and two narrowband auxiliary channels. Wideband channel A accepts the radar video, radar display vertical and horizontal sweep waveforms, and intensity/range gate signals for a forward-looking ground mapping multimode radar, such as the AN/APQ-92 or AN/APQ-148.

Channel B accepts any tv-type composite video signal with horizontal line rates of 10 kHz or greater.

Auxiliary Channel I accepts 25k bit/s digital data. Such data consists of aircraft status information, range, altitude, heading, *etc.* Auxiliary channel II contains audio data, such as aircraft ICS or vhf communications outputs.

The USH-17(V) was designed with three major goals in mind: (1) high performance; (2) high reliability; and (3) a high degree of maintainability. In addition to these basic goals, this program was treated at RCA as an opportunity to show that a video recorder could be designed that field personnel could satisfactorily utilize, maintain, and keep operational with a high system availability factor.

The goals were attained by adherence to a basic design philosophy called functional modularity.

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The basic USH-17 was developed for Naval Air Systems Command under the technical direction of the U.S. Naval Air Development Center.

Table I — AN/USH-17 parameters.

Size	23-3/4 × 12-1/4 × 4-3/8
Transport unit	
Electronics unit	23-3/4 × 13-1/4 × 4-1/2
Weight	100 lbs inc. aircraft mounting structure
Operating environments:	
Temperature	−30°C to +55°C
Altitude	70,000 ft
Humidity	to 95%
Vibration	Mil-E-4300, curve I
Explosive atmosphere, salt spray, sand and dust	In accordance with MIL-E-5400/MIL-T-5422
Temperature (storage)	−62°C to +95°C
Shock	MIL-E-5400/MIL-T-5422
MTBF	150 to 350 hrs, depending on environment
$M_{CT\ (max)}$	40 min.

Performance	*Environment*	*Std. conditions*
Wideband channels		
Signal-to-noise ratio	34 dB	36 dB
Risetime	120 ns	120 ns
Overshoot	10%	10%
Amplitude linearity	7.5%	7.5%
Time displacement error	±350 ns/ms	±200 ns/ms
Distortion and crosstalk	−35 dB	−35 dB
Aximuth position accuracy (radar sweeps)	±4°	±2°
Range linearity (radar sweeps)	±7%	±5%
Narrowband channels		
Voice frequency response	±3 dB	±3 dB
Voice S/N ratio	30 dB	30 dB
Digital (30-bit words)	25 kb/s at 500-Hz word rate	

Further, design to MIL-E-5400 construction and environmental requirements and to MIL-STD-461 EMI standards was of equal importance. The degree to which the goals were met is shown partially in Table I.

Construction

Basically, the USH-17(V) is made up of three replaceable assemblies: a transport unit, an electronics unit, and a remote control unit.

The Transport Unit (Fig. 2) contains all the necessary electromechanical modules to move tape. It also contains sufficient electronics to handle the low level playback signals and to supply the record currents to the wideband heads. Fig. 3 shows the completeness of the modular design. All units are plug-ins with their own captive hardware. Little effort is needed to replace a defective module. At most, three hold-down fasteners are used for a module. The nine printed-circuit electronics cards are also plug-in modules. The transport interconnect board (mother board) is a replaceable printed-circuit card. Maximum effort was used to make all interconnections by printed circuits, thus eliminating large harness wiring, a welcome deviation from the familiar "rat's nest" approach.

Heater pads are located under all motor assemblies to insure that the temperatures at the motors remain above 0°C when the recorder/reproducer is operative at low temperatures. The heaters are cycled *on* and *off* by independent temperature sensors in the transport. There are two *identical* reel module assemblies. The reel assembly consists of a dc motor, brake assembly, a reel hub, and the hold-down mechanism.

The master erase assembly contains the erase head, that erases across the entire tape, tape guidance post and compliance arm.

The scanning station is a rotary headwheel panel. It uses a 2-phase motor which is driven synchronously. Eight video heads are placed 45° apart, and rotary transformers couple the rotary heads to the electronics. The scanning station uses a "dry" tape guide (*i.e.*, without vacuum as used in standard ground based equipments) to establish the proper head-to-tape contact. The use of the "dry" guide makes the recorder

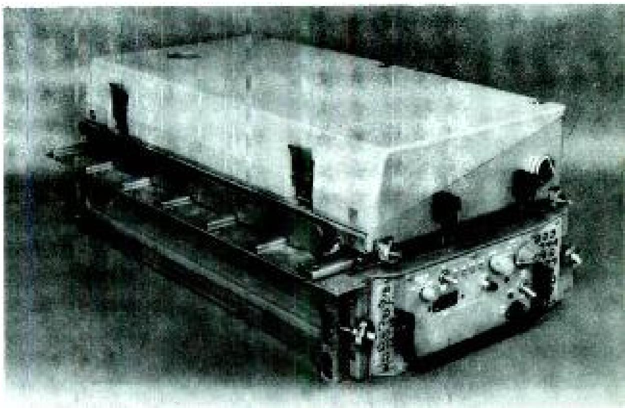

Fig. 1 — AN/USH-17(V) video recorder/reproducer.

Fig. 2 — AN/USH-17 transport unit.

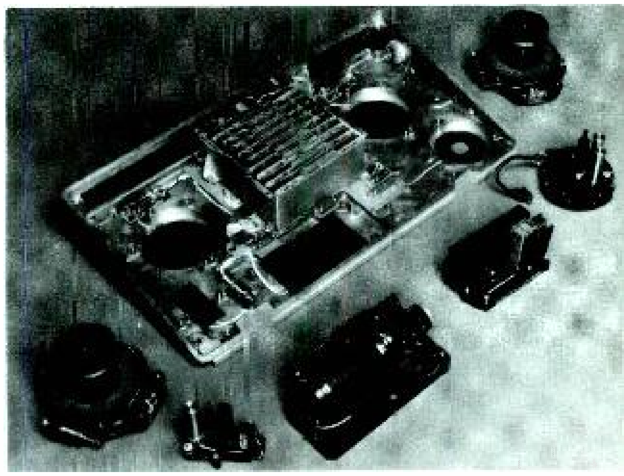

Fig. 3 — AN/USH-17 transport modules.

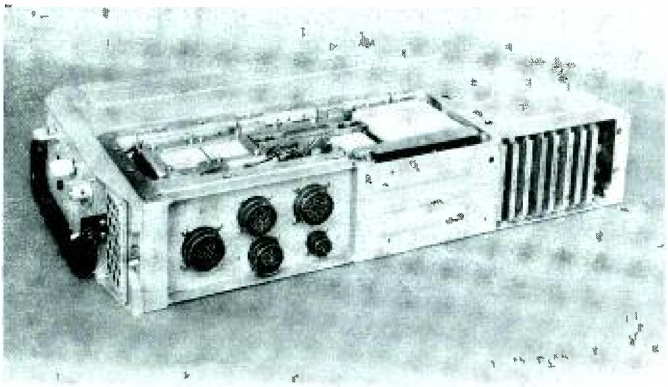

Fig. 4 — AN/USH-17 electronics unit.

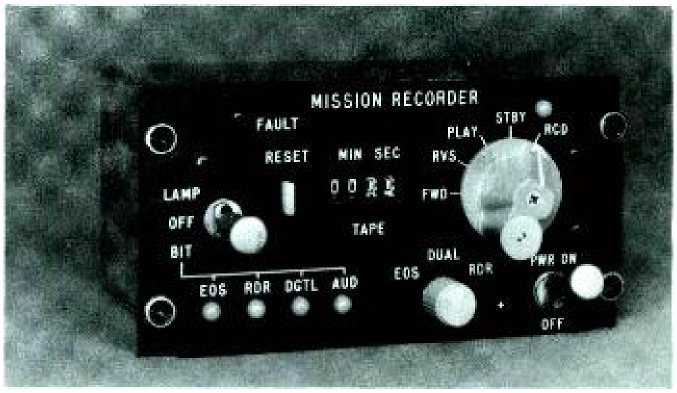

Fig. 5 — AN/USH-17 remote control.

performance independent of atmospheric pressure up to approximately 80,000 ft. Hence, no pressurized case is required and tape may be transferred as in a normal room environment. The video scanning station is easily replaceable and is refurbishable. The modularity concept allows for minimum down time due to worn video heads.

The auxiliary module contains the audio and digital erase and record/reproduce heads and all associated electronics needed to record and reproduce two auxiliary channels longitudinally on tape.

The capstan assembly contains a dc capstan motor, capstan tachometer amplifier, tape guidance posts, and the takeup compliance arm.

The electronics unit (Fig. 4) contains all the necessary motor drive circuits, servo electronics, control circuits, video and fm processing circuits, radar processor circuits, BIT (build-in test) controls and circuits, digital record and play electronics, 400-Hz power supply, and all necessary operator controls and indicators. The electonics units contains printed circuit plug-in modules and the 400-Hz power supply, which is a completely self-contained replaceable plug-in subassembly.

Functional details

The video and fm circuits, both radar video and sensor video, are processed in a similar manner. After amplification and preemphasis, these signals modulate an fm carrier which is then recorded on tape. In playback, the individual heads are commutated together to reconstruct a continuous video signal. Demodulation and video processing follow.

The sweep processor circuits serve to process the radar display x and y deflection signals and the intensity/range gate. The modulated sweep analog inputs are sampled within the USH-17, and values for each are stored as width-modulated pulses. The pulse-width modulated information, along with radar mode indication and sync pulses, are time-division multiplexed with the radar video signal.

Two basic control systems are used in the USH-17: the operational controls and the "protectors" or fault-sensor controls. The operational controls provide the operations of record, playback, standby reverse, forward, and BIT sequence.

The fault-sensor controls are designed to protect the recorder from damage if operation is attempted with specific abnormalities. For example, the sensor controls will shut down the recorder if any of the four motors stall or if the tape breaks.

The BIT function records special test signals on all four channels. In playback these signals are "looked" at and a determination is made as to the *go* or *no-go* status of each channel. Indicator lights on the control panel will illuminate if a *no-go* condition exists. The BIT function is automatically cycled through record, reverse, play, signal and analysis, and standby.

The remote control unit (shown in Fig. 5) contains all the necessary control functions to operate the AN/USH-17(V) from a remote position (*i.e.*, cockpit). When the remote unit is connected, the local controls are not operational.

Compatibility

The USH-17(V) uses a transverse scan technique of recording which is identical to the scanning techniques used by the commercial tv broadcaster and in all RCA instrumentation video recorders. Tapes made on the USH-17(V) may be reproduced on most of these recorders. The USH-17(V) will also reproduce any recording made on another USH-17(V). Compatibility of electronics and electromechanical modules as well as recorded tapes has been extended to other RCA airborne and ground instrumentation recorders.

Applications

Applications for the USH-17(V) recorder/reproducer are many in number:

1) Bomb damage assessment in-flight or at a later time.
2) Target recognition.
3) Reconnaissance/strike—the ability to identify and strike.
4) Event recording.
5) High data rate digital recording.
6) Crew training.
7) General mission recording.

With the USH-17(V), in-flight playback is possible or, if desired, the tape can be replayed upon returning to the carrier or base. In this latter situation, one package, the tape transport, is removed from the aircraft and mated with an electronics unit for quick playback and evaluation of a mission.

The mission recording may be played back as often as necessary. Tapes may be stored for future viewing, or hard-copy photographs can be taken of radar and satellite signals. The playback can be viewed on a display identical in format to that of the in-flight display. Digital quantities can also be replayed and displayed on a read-out similar to the cockpit display.

The USH-17 system also may be used with a peripheral "frame storage unit" (FSU) to provide "stop action" or "frame freeze" readout of a selected frame of data. This can be used with satellite or radar imagery. This is very useful for detailed viewing of recorded imagery and can be a valuable tool in target identification and bomb damage assessment.

Several prototype USH-17's have been in service at Naval Air Stations and on-board Navy aircraft carriers for periods up to 20 months. The AN/USH-17(V) is now in its second year of full production. To date, approximately 50 units are operational in the field. The equipments have had an outstanding record of success and have been well accepted by the users.

ADVISER 62

An extension of the USH-17 recorder/reproducer is called the ADVISER VMTR which was developed for the U.S. Air Force. The ADVISER VMTR's are to be used in an airborne data collection and analysis system. This unit (Fig. 6) required re-packaging of the basic USH-17 (V) electronics unit to provide a servoed headwheel for improved time-base stability. It consists of two wideband 6-MHz channels and two auxiliary channels. The power supply is a plug-in unit. Various power supply options are available with the ADVISER for use with three-phase 400-Hz, single-phase 400-Hz, single-phase 60-Hz, or 28 Vdc. The complete ADVISER Transport Unit and 90% of the printed-circuit cards used in the electronics unit are identical to those used in the USH-17 system. Complete interchangeability and commonality is preserved.

ADVISER 152

A future extension of this is the 15-MHz ADVISER recorder/reproducer. RCA, under contract to the USAF, has expanded the video bandwidth of the two-channel ADVISER to 15-MHz/channel. The recorder/reproducer is a basic ADVISER VMTR and therefore has the highest possible degree of commonality with the USH-17(V) system. With this bandwidth extension, the ADVISER family of VMTR's will address a wide range of recording requirements using a common logistics support base.

TPR-10

From the basic ADVISER, a new product line of commercial VMTR's has evolved — the TPR-10 (NTSC, PAL or SECAM) recorder. The TPR-10 is a compact, portable VMTR built for the production of studio-quality video tapes on location, where conventional recorders cannot reach. The TPR-10 is a complete recorder/reproducer with full-track erase, dual audio-recording channels (program and cue), monochrome or heterodyne color playback, and a system of self-generated test signals (self test) for a complete record-playback confidence check.

STAR

The star is a single-channel record-only version of the USH-17 (Fig. 7) developed by RCA as a small low cost video tape recorder. The unit consists of a single package containing all the necessary electronics to record a single video channel. A small power supply is also required. The unit contains all the same electromechanical and printed-circuit modules used in the USH17(V). Reproduce is performed by playing back STAR tapes on a compatible reproducer or by connecting the STAR to a small, portable playback unit. Again the highest degree of commonality with the USH-17 is maintained.

Conclusions

The commonality which RCA maintains in the ADVISER family results in a significant system cost savings. Operational and logistical advantages accrue through the use of the same standard transverse-scan tape, the same support equipment, and the same operator and repair crew training.

In addition to the applications and uses mentioned, other versions of the USH-17 are under evaluation for use in various patrol, attack-fighter, and bomber-type aircraft, and in special weapon systems.

Additional applications are for high data rate digital instrumentation recording applications, video storage and retrieval systems, and numerous shipboard and ground data collection systems.

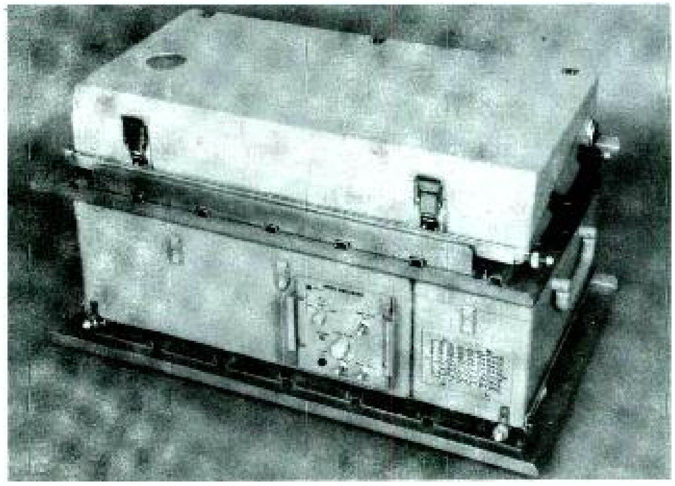
Fig. 6 — ADVISER wideband tape recorder/reproducer.

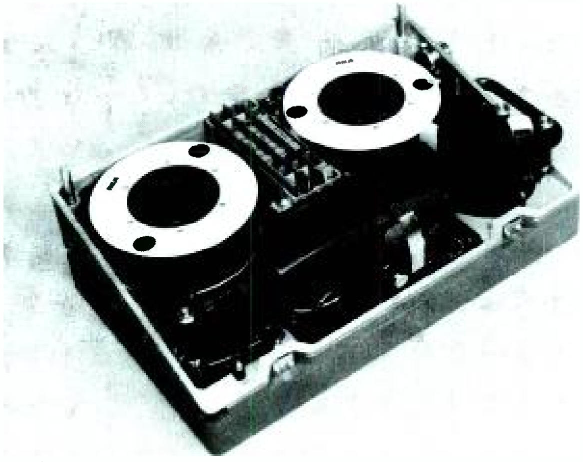
Fig. 7 — STAR single-channel record-only unit.

Philosophy and design of acoustic surface-wave filters

Dr. D.H. Hurlburt

In the last decade, acoustic surface waves have ceased to be a laboratory curiosity and are being used to perform a variety of sophisticated signal processing operations with greatly reduced size, improved performance and lower cost.[1,2] One of the most widespread and versatile applications has been in the realm of filters, both dispersive and non-dispersive. The dispersive filters are characterized by a group delay which is a function of frequency and can be used to compress or expand a "chirped" pulse.[3] The non-dispersive filters have essentially zero variation in group delay with frequency and are used as bandpass filters.[4] This paper presents some of the basic principles involved in the design of these filters. The procedures involved in the design of a specific filter follow from an understanding of these basic principles and will not be dicussed in detail.

MOST acoustic surface-wave devices are based on the so-called Rayleigh mode of propagation. This mode, named after Lord Rayleigh who showed that such a mode could exist,[5] is characterized by both longitudinal and transverse components of particle motion. The relative phases of these components are such that the individual particles follow elliptical paths in a plane that is parallel to the direction of wave propagation and normal to the surface of the material. The particle displacements decay rapidly with distance away from the surface such that more than one-half the energy is contained within a wavelength of the surface. To date, the majority of useful devices have been based on the propagation of Rayleigh waves on the surface of a piezoelectric substrate; however, there is growing interest in the generation and propagation of acoustic surface waves in layered structures.[6,7] The basic principles described in this paper are applicable to either situation.

The interdigital transducer

The interdigital transducer (IDT) has become the accepted method for both the generation and detection of acoustic surface waves.[8] Fig. 1 shows an IDT located on the highly polished free surface of a piezoelectric substrate material. An acoustic surface wave is generated by the application of a differential voltage to the adjacent fingers of the IDT. The resulting electric fields between the fingers produce a deformation in the piezoelectric substrate. If the voltage across the fingers is rapidly varied, the continuously varying deformation between the fingers will generate a wave that propagates away from the source of the disturbance, as shown in Fig. 2a.

The process of detection operates in the reverse fashion. Since the substrate is piezoelectric, the propagating wave, which represents a displacement of the material from its equilibrium position, carries with it regions of positive and negative charge density and an attendant electric field. When the propagating wave passes under an IDT, the fingers are charged alternately positive and negative, producing a current in the load, as shown in Fig. 2b. To those readers familiar with antenna theory, the interdigital transducer can be considered an acoustic analogue of the "end-fire array".

There are four parameters which specify an IDT. They are:

1) Center-to-center spacing of adjacent fingers, L;
2) Width of the individual fingers, d;
3) Overlap of the adjacent fingers, W; and
4) Length of the transducer, D.

The spacing, L, determines the frequency at which a given pair of adjacent fingers will "resonate". This occurs at that frequency, f_0, for which L is one-half an acoustic wavelength. Thus, if the velocity of propagation is v,

$$f_0 = v/\lambda_0 = v/2L$$

The ratio d/L determines the spatial harmonic content of the applied electric field, and thus the harmonic frequencies at which the transducer will also resonate. If, for a given finger pair, $d/L = 0.5$ which

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is the most common case, that finger pair will resonate at f_0, $5f_0$, $9f_0,\cdots$, *etc.*[9] However, the degree of surface-wave excitation at the harmonic frequencies will be very small. The overlap, W, can be used to control the bandpass characteristics, as will be shown, in addition to scaling the transducer admittance. The length, D, determines the bandwidth of the transducer, in conjunction with, W. The problem facing the designer of a surface-wave filter is one of adjusting the above parameters to give the desired frequency and phase response.

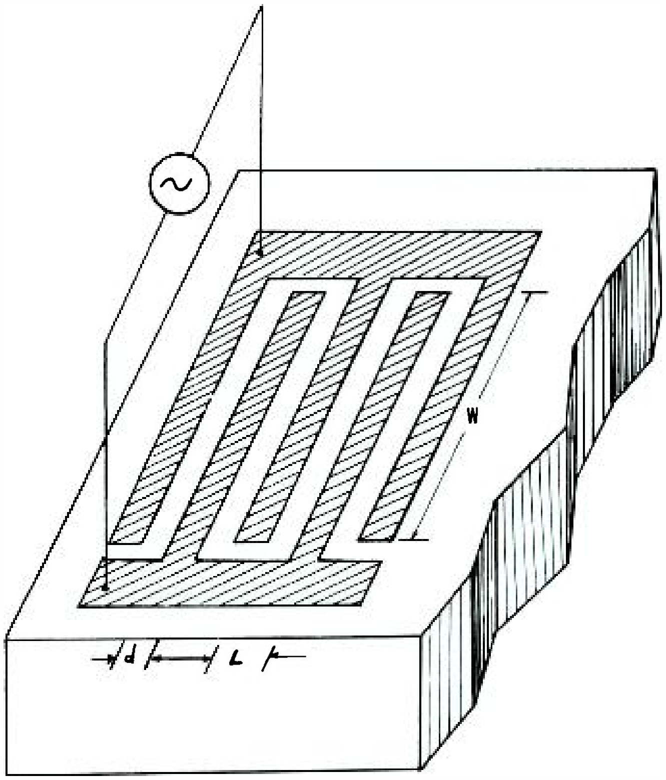

Fig. 1 — Interdigital transducer on a piezoelectric substrate.

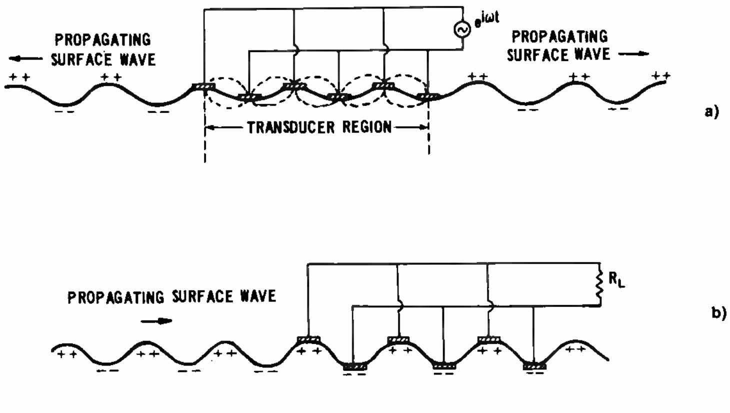

Fig. 2 — a) Generation of acoustic surface waves; b) Detection of acoustic surface waves.

Time response and transfer function

Consider the situation that occurs when a very brief voltage impulse is applied to an IDT. Within the transducer, the material is instantaneously distorted to form an acoustic impulse which is an image of the electric field within the transducer. Once generated this impulse will propagate across the surface of the material with velocity v. The time length of this impulse will be t_0, given by

$$t_0 = D/v.$$

Fig. 3 shows this acoustic impulse for two different IDT's. In Fig. 3a, the overlap of the adjacent fingers in the transducer is uniform; whereas, in Fig. 3b the overlap varies, known as "apodization".

Now suppose that the acoustic impulse passes under a single pair of interdigitated fingers whose spacing L' is approximately equal to that of the source transducer and whose overlap is sufficient to span the maximum width of the incoming acoustic impulse. As mentioned in the previous section, an acoustic wave will be accompanied by an alternating charge density. Thus, the current which flows between the two fingers of the output transducer and hence the voltage across the load will be proportional to the width of the acoustic impulse as shown in Fig. 4. Thus, it is apparent that the time response $f(t)$ for the generating IDT can be written

$$f(t) = g(t)\ W(t).$$

The function $g(t)$ is of constant amplitude and alternates in phase with a period $\Delta t = 2L/v$, while $W(t)$ is the overlap function of the generating transducer in the time domain. It is well known that the frequency response $F(\omega)$ of a network is the Fourier transform of its time response and thus the frequency response of the generating transducer is

$$F(\omega) = (\tfrac{1}{2}\pi)^{1/2} \int_{-t_0/2}^{t_0/2} g(t)\ W(t)\ e^{i\omega t}\,dt$$

The finite limits on the integral reflect the fact that the generating transducer and hence its corresponding acoustic impulse are of finite length. In the frequency domain, this affects the passband ripple and the filter selectivity. All of the parameters which determine the IDT appear in the above expression for the frequency response. The parameters W and D are involved explicitly ($t_0 = D/v$), while d and L determine the form of $g(t)$.

Conversely, the time response of a single IDT when its frequency response is known is given by

$$f(t) = (\tfrac{1}{2}\pi)^{1/2} \int_{-\infty}^{\infty} F(\omega)\, e^{-i\omega t}\, d\omega,$$

and it is easily shown that a single IDT can only have the properties of a bandpass filter. The design of bandstop filters using acoustic surface waves must be based on the design of various bandpass filters operating in conjunction with one another.

Since any acoustic surface-wave filter requires both an input and output transducer which are separated by some distance, D_0, the transfer function $H(w)$ for a surface-wave filter will involve both IDT's and the delay line separating them. It can be shown that, providing one of the transducers is of a uniform overlap equal to or greater than the maximum overlap of the other transducer, the time response of the two transducers is the convolution of their individual time responses,[10]

$$h(t) = \int_{-\infty}^{\infty} f_1(\eta)\, f_2(t-\eta)\, d\eta$$

Thus, $h(w)$, the transfer function for the two transducers is the product of their individual frequency response functions

$$h(\omega) = F_1(\omega)\, F_2(\omega).$$

This same result can also apply if both transducers are apodized, providing special geometry is used in the design of the filter.[11,12] If the delay line separating the transducers has a transfer function $h_3(\omega)$, the overall transfer $H(\omega)$ can be written

$$H(\omega) = F_1(\omega)\, F_2(\omega)\, h_3(\omega).$$

In the strictest sense, the transfer function $H(\omega)$ must include a loss factor to represent the bi-directional loss of each IDT, the losses resulting from the finite resistance of the transducers and propagation losses (including diffraction and beam steering). In most cases, however, these will be essentially constant over the bandwidth of the filter and can be treated as a constant scale factor.

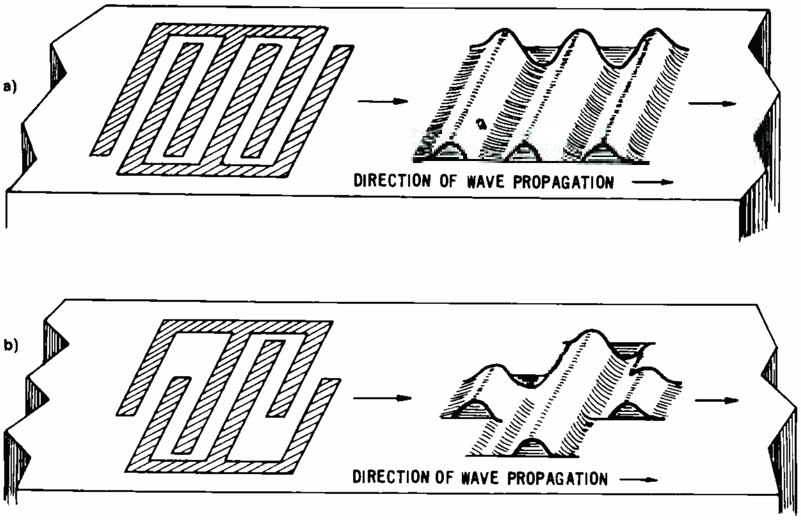

Fig. 3 — a) Impulse train for an IDT of uniform overlap; b) Impulse train for an apodized IDT.

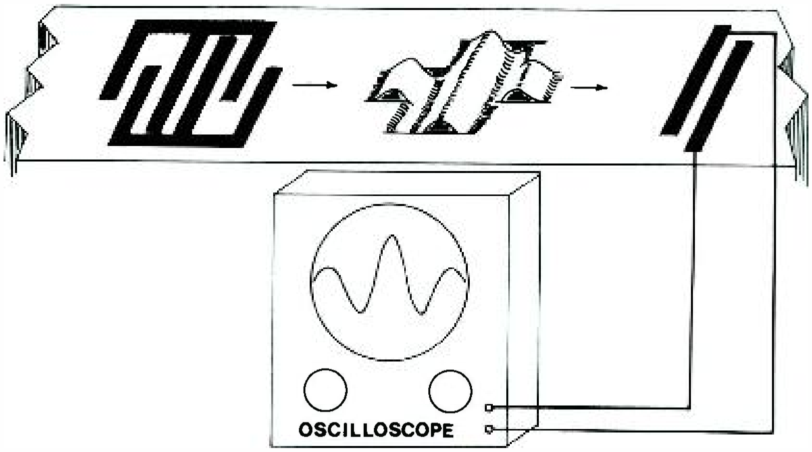

Fig. 4 — Illustration of the measured time response of an apodized IDT.

Thus, the transfer function of the delay line can be represented by a phase shift $\gamma(\omega)$, and $H(\omega)$ can be written

$$H(\omega) = |F_1(\omega)|\,|F_2(\omega)| \exp\{i\,[\gamma_1(\omega) + \gamma_2(\omega) + \gamma_3(\omega)]\}$$

in terms of its magnitude and phase. Another factor, to be mentioned briefly, is the effect of mismatch loss at input and output. This is related to the characteristics of the matching networks between the source and the input IDT and the load and the output transducer. Because of the impedance transformations that are usually involved, this term may have both a magnitude and phase term. This can be an annoying problem, as will soon be apparent, but since it represents something which can be controlled separately from the acoustic behavior it will not be considered further.

Group delay and phase shift

The group delay of a network is

$$T = -\,\partial\gamma_o/\partial\omega$$

where γ_0 is the total phase shift of that network. Therefore, in the case of an acoustic surface-wave filter, the group delay will be

$$T = -\frac{\partial}{\partial\omega}[\gamma_1(\omega) + \gamma_2(\omega) + \gamma_3(\omega)]$$

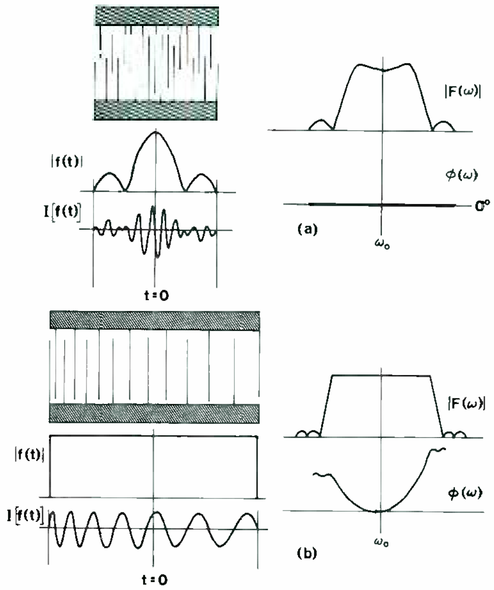

Fig. 5 — Two common IDT configurations with their associated time and frequency response.

The phase shift γ_3 is

$$\gamma_3 = -\omega t'$$

where t' is the time delay between input and output transducers. Since we have used symmetric limits for the time responses of the individual transducers

$$t' = D_0/v$$

where D_o is the center-to-center spacing of the input and output transducers. (We are assuming wave propagation on the surface of a piezoelectric substrate without a layer so that v is independent of ω). Thus the group delay becomes

$$T = D_o/v - \frac{\partial}{\partial\omega}[\gamma_1(\omega) + \gamma_2(\omega)]$$

and is entirely dependent upon the phase characteristics of the input and output transducers. (It is at this point that any phase shift resulting from the matching networks becomes a problem for this will also enter into the overall group delay.)

Relationship between the transducer and its time response

In general, the transfer function $H(\omega)$ as well as the frequency response functions $F_1(\omega)$ and $F_2(\omega)$ will be complex. This does not present any problems of interpretation for we are accustomed to considering both amplitude and phase when considering the frequency response of a network. When the time response is calculated from the frequency response, it will always be complex, even if the frequency response is purely real. Again, the interpretation is the same; however the determination of the transducer configuration from the time response may not be obvious.

As shown in Figs. 1, 2, and 3, the way in which the fingers of the IDT are connected implies that the relative phasing of each finger can only be 0° or 180°. This relative phasing is preserved in the time response for a given transducer. Conversely, if the time response is known, the fingers are located at those points in time where the relative phasing is 0° or 180°, *i.e.*, when the imaginary part of the time response vanishes. The physical spacing of the fingers is determined by the required time spacing and the acoustic wave velocity. The length of the fingers is determined by the magnitude of the time response at the appropriate time intervals. The "polarity" of the fingers, or to which side of the transducer they are connected, is given by the slope of the imaginary part of the time response at those points where Imag $[f(t)] = 0$.

Fig. 5 shows the magnitude and imaginary part of the time response for two commonly used transducer configurations and their respective frequency response characteristics. The transducer illustrated in Fig. 5a has a singularly important property. Since the magnitude of the time response is symmetric and the imaginary part asymmetric, the real part must also be symmetric. (A function of this type is often referred to as a "Hermitian" function.) For a time response of this nature, the frequency response is purely real and the phase shift is 0° or 180° only. Thus, a transducer of this form has inherently zero group delay, and is a fact worth remembering when faced with the problem of designing an acoustic surface-wave filter.

Generalized design approach

The most common situation facing the filter designer is to design a particular filter, given the required behavior in the frequency domain. From the standpoint

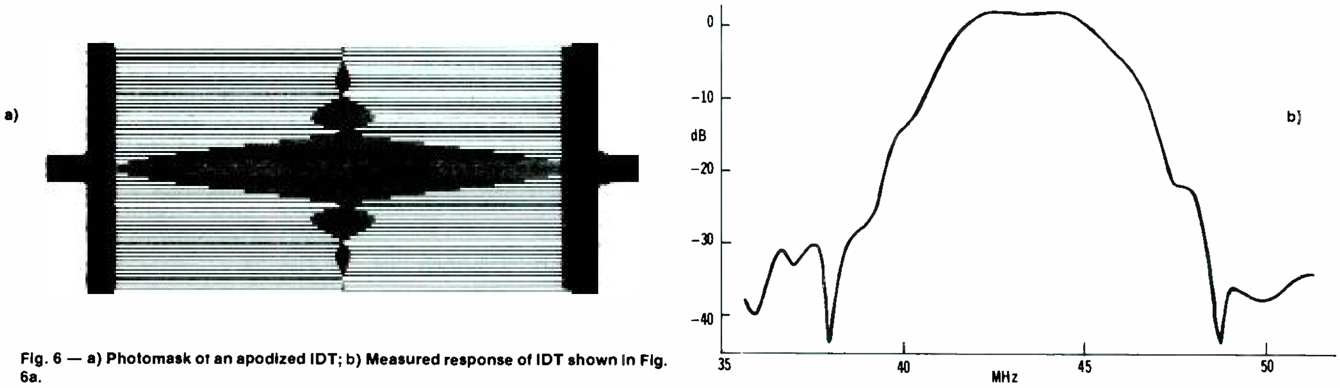

Fig. 6 — a) Photomask of an apodized IDT; b) Measured response of IDT shown in Fig. 6a.

of an acoustic surface-wave filter, one must know the magnitude of the desired frequency response and the group delay characteristics. Perhaps the most common case is that of a filter with constant group delay, a non-dispersive filter. It was shown in the preceeding section that transducers which have "Hermitian" time responses have a zero group delay characteristic; thus for a filter of constant group delay, both input and output transducers are usually chosen to be of this type. Since, without special geometry, one IDT must have a constant overlap, only one apodization function need be determined. The complete time response can be calculated from the inverse Fourier transform of the frequency response, using a digital computer and a fast Fourier routine. The calculated time response will be of semi-infinite extent, and thus it must be truncated to satisfy the physical size requirement of the IDT. This truncation will affect the filter selectivity as well as adding ripples to the passband, and the designer must decide where truncation can occur without significantly altering the frequency response. The frequency response of the truncated response can be evaluated by the direct Fourier transform. After truncation, it is possible to modify the calculated time response to correct some minor deficiencies.[10]

The magnitude of the time response represents the relative length of adjacent fingers while the imaginary part determines the spacing and polarity of the fingers in the IDT. The physical separation of the fingers, L, is determined by the time separation Δt and the wave velocity. Fig. 6 shows an apodized IDT which was designed for preliminary studies into acoustic surface-wave i.f. filters for tv applications and its measured frequency response using an output IDT with only a few fingers of constant overlap.

When designing a filter with variable group delay, one can start with the desired delay characteristic and work back through the necessary phase response to the time response. However, in most applications where such a filter is desired, the desired time response is already known, and the transducer design is specified as described previously. Fig. 7a shows the design of a dispersive filter using an IDT of constant L as a detector. In this instance, the spacing of the output IDT is chosen to resonate at the center frequency of the dispersive transducer and the length of the transducer is chosen to cover the bandwidth of the dispersive IDT. Fig. 7b shows a doubly-dispersive delay line, in which the input and output transducers are mirror images. This approach doubles the dispersion for a given transducer geometry, but at the expense of twice the material.

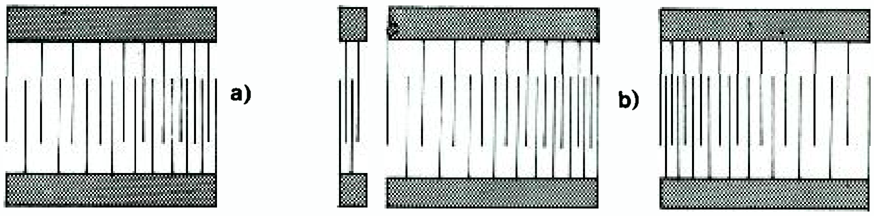

Fig. 7 — a) Single dispersive filter; b) Doubly dispersive filter.

Practical problems

In the preceeding discussion the straightforward concepts that determine the basic filter design have been discussed. However, no such discussion would be complete without some mention of the pitfalls facing the designer when faced with a real-life situation. The response curve of Fig. 6b indicates that the behavior of the filter is not as good as theory predicts. This results from a variety of problems, many of which are second-order effects that accumulate in a long transducer array until they are no longer negligible. Some of these problems are the variation in wave velocity between the metallized and unmetallized regions of the IDT, internal reflections from the fingers, triple-transit echoes, and bulk-wave generation. In all cases, there are techniques for handling these problems of which the designer must be aware. The problem of velocity variations and internal reflections are corrected by the addition of "dummy" electrodes[13] and the use of split electrodes, respectively. Triple transit can be reduced by the use of specialized geometries[15] and, though the nature of the generation of bulk waves is still largely unknown, techniques are available for eliminating their effect on the output signal.[11,12]

Conclusion

Acoustic surface-wave filters can be designed to fulfill a large variety of requirements. The basic design procedure is straightforward and is based on the Fourier transform relationship between the time and frequency response on the interdigital transducer. In the design of an actual device, the designer must be aware of practical problems which alter the basic approach and the methods of correcting for them.

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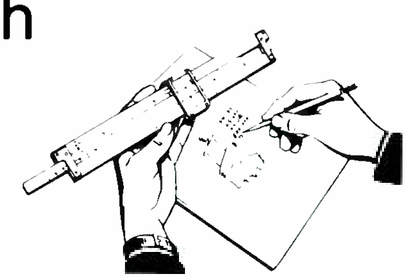
Engineering and Research Notes



CA3096E and CA3099E extended range voltage-programmable timer

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Designers frequently have a need for a "universal" timer circuit in which the timing-cycle can be varied linearly over an extended range, preferably by simple linear variation of a control-voltage. The schematic diagram of such a voltage-programmable timing circuit is shown in Fig. 1. It employs two ICs: a CA3099E, programmable comparator, and a CA3096E, npn/pnp transistor-array. During the timing-cycle, the output signal at terminal 3 of the CA3099E is a logic 0 (an internal transistor can sink a load-current of 150mA into terminal 3).

Capactior C is the timing-capacitor, and is charged through a constant-current source transistor, Q4. When it is charged to a potential such that the voltage on terminal 14 of the CA3099E exceeds that on terminal 13, the comparator changes state and terminal 3 goes "high" (logic 1), interrupting the load current. When switch SW1 is moved to the "reset" position, transistor Q1 is driven into conduction, thereby discharging C and resetting the logic output of the CA3099E to 0. The timing cycle is reinitiated when SW1 is turned to the "time" position.

Constant current flow through transistor Q4 (to charge C) is established by means of diode-connected transistors Q2, Q3, and Q5, which are connected in a "current-mirror" circuit and driven from terminal 5

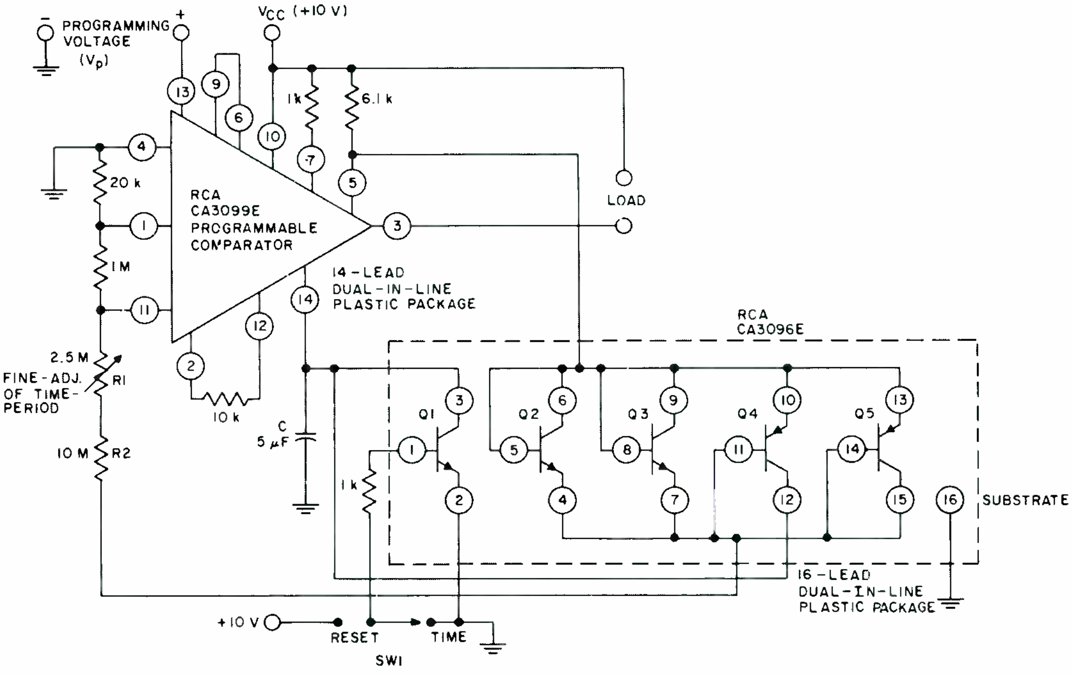

Fig. 1 — Voltage-programmable timing circuit.

(internal Zener-regulated) of the CA3099E to force current-flow through transistors R1 and R2. Consequently, the magnitude of current flow in Q4 (to charge C) is essentially determined by the total resistance of resistors R1 and R2. With a potential of +1 V on terminal 13, the timing cycle, T is approximately:

$$T = C\,(R1 + R2)/3.5 \quad \text{[seconds]}$$

Thus, *e.g.*, T is 15 seconds when C is 5μF, R1 is 1 megohm, and R2 is 10 megohms. This time-period can be extended linearly by applying an increasingly positive programming voltage (V_p) to terminal 13. Fig. 2 shows a plot of the time delay as a function of programming voltage for the timing circuit using the circuit constants shown in Fig. 1. These data show that the time-delay can be programmed to vary linearly, approximately as 1.15 $T\,V_p$, when V_p is varied over the 1- to 7-V range. The current needed to supply terminal 13 is low; *e.g.*, only 30nA of current is required when V_p is 7 V. Timing accuracy is comparatively insensitive to changes in supply-voltage (V_{cc}); measured data indicates a typical change in time-delay of only 1.5% when the supply-voltage is varied over the range from 9 to 12 V. Similarly, the time delay only varies approximately 3.5% when the temperature of the ICs is varied from 0 to 70°C.

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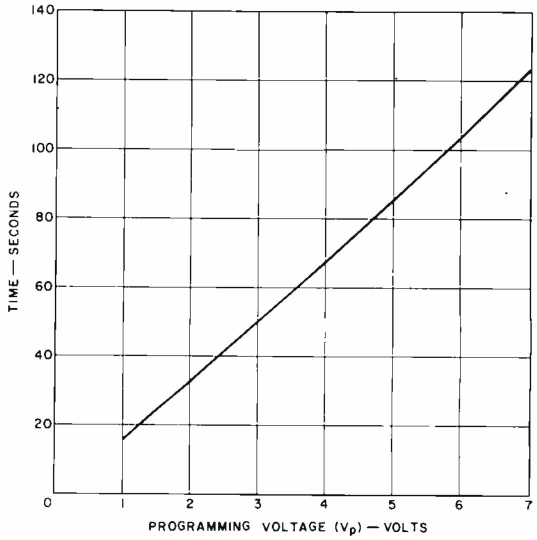

Fig. 2 — Time delay as a function of programming voltage.

"Turn-on" reset-pulse circuits

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A turn-on reset pulse circuit is a circuit for providing an output pulse for resetting counters, registers, and the like to a given condition upon application of system power. Such circuits are also useful for providing an automatic reset signal after momentary power interruptions.

In the circuits of Figs. 1a and 2a, the RC differentiator or integrator connected across the power supply terminals is also coupled to a suitable threshold detection circuit, shown as an inverter in these Figures. If the RC time constant is selected to be relatively long compared with the system power supply time constant, the waveforms of Fig. 1b and 2b result. This is the signal which may be employed as a reset signal.

Complementary symmetry MOS logic gates (COS/MOS) are particularly suitable for use as threshold detectors in this application because of their high noise immunity, high input impedance, and very

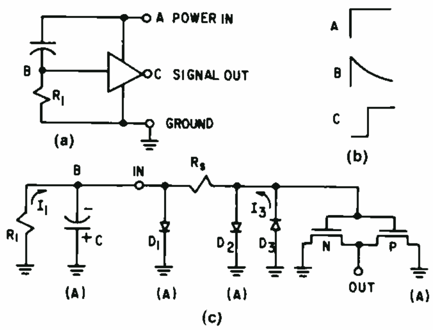

Fig. 1 — Resetpulse circuit.

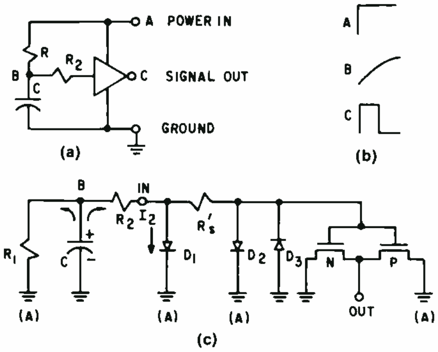

Fig. 2 — Reset-pulse circuit.

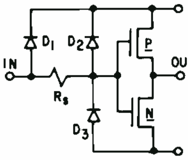

Fig. 3 — Inverter.

low power consumption. A precaution must be taken, however, when implementing the circuits of Figs. 1a and 2a with COS/MOS logic elements. Manufacturers of such logic circuits customarily include some form of gate-oxide protection circuitry and this should be considered in designing the RC integrator or differentiator.

Fig. 3 shows the inverter of Figs. 1a and 2a in more detail. Note the gate-oxide protection circuit comprising diodes D_1, D_2 and D_3 and series resistor R_S. The current through these diodes must be limited to 50 mA for safe operation; therefore, the design of the circuits of Figs. 1a and 2a must be such as to insure that this condition is met.

If a low impedance power supply is connected to the circuit of Fig. 1a and the power is turned *off* after a period of operation, the equivalent circuit shown in Fig. 1c results. Since point A, which was previously at a positive potential is now at ground level, the charge stored in capacitor C produces a negative voltage at node B which forward biases protective diode D_3. Since the value of series resistor R_S is typically 500Ω, current I_3 is limited to a safe value even if the capacitor is charged to the rated absolute maximum voltage of the COS/MOS logic gate. Thus, in the circuit of Fig. 1a, any practical value of resistor and capacitor may be used without danger to the gate-oxide protection circuit of the COS/MOS logic element.

A different situation obtains, however, with regard to the integrating type of turn-on reset circuit shown in Fig. 2a. The equivalent circuit, under the conditions previously described, is shown in Fig. 2c. Here, it is seen that the charge stored in capacitor C produces a positive voltage at node B. Diodes D_1 and D_2 are both forward biased. Diode D_2 is protected by the action of series resistor R_S (typically 500Ω) but diode D_1 is not. Therefore, it is necessary to include an additonal series resistor R_2 between node B and the logic element input terminal as shown in Fig. 2a. A value such as 500Ω will provide the necessary protection. As in the circuit of Fig. 1a, any practical value of resistor R_1 and capacitor C_1 may be used.

An inverter has been shown for simplicity in Figs. 1a and 2a; however, other logic gates such as *exclusive or*, *nor* and *nand* gates, as examples, are equally suitable for this application. Using such gates, one or more other leads to the gate may be employed for applying other input signals to the gate for independently producing reset signals, as required.

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COS/MOS linear amplifier with feedback tone and volume controls

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Solid State Division
Somerville, N.J.

The circuit shown in Fig. 1 uses only two sections of RCA's CA3600F, leaving one section available for an additional function. The first stage is a Baxandall tone-control circuit which features ± 15-dB bass and treble boost-and-cut at 100 Hz and 10 kHz, respectively. Standard linear-taper potentiometers are used throughout. The output is biased at one-half the supply voltage through the resistive path in the feedback network, and allows the circuit to function at supply voltages from 5 to 15 V.

Since the input current to the CA3600 is, for all practical purposes, zero, there is no dc current through the controls, and they will not become noisy.

The maximum volume gain is set by the ratio R2/R1; with the values shown it is about 12 dB. The circuit will handle inputs up to about 200-mV rms without overloading.

Reprint RE-20-3-25| Final manuscript received March 15, 1974.

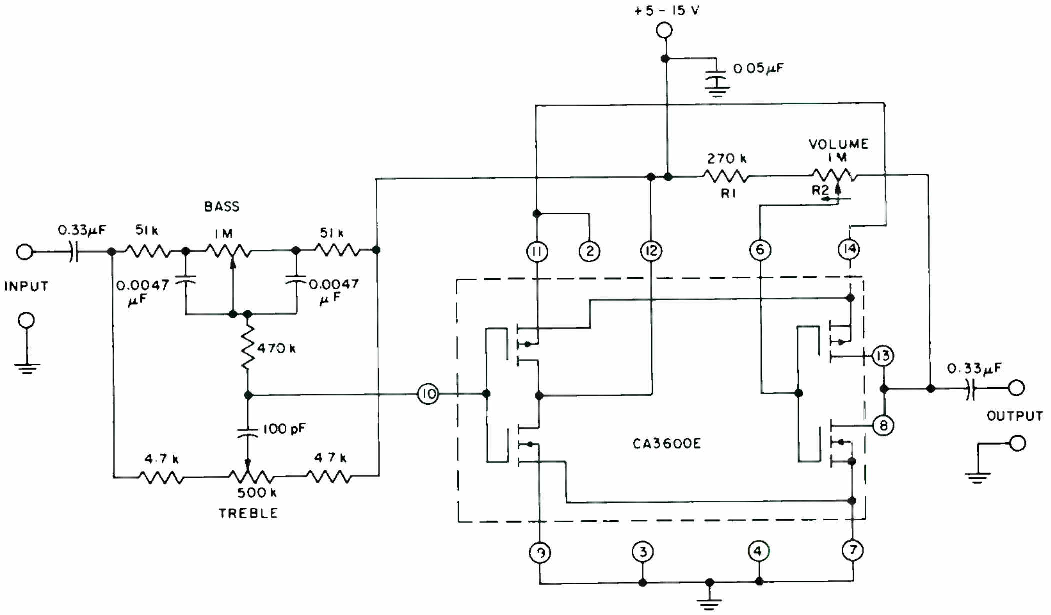
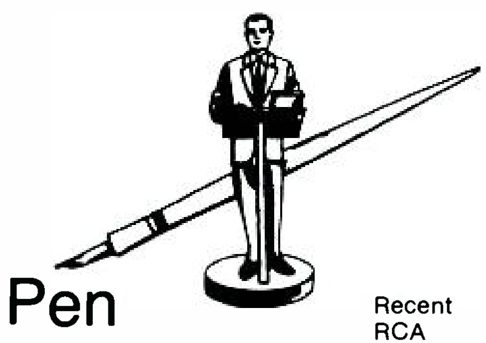


Fig. 1 — COS/MOS linear amplifier with feedback tone and volume controls.



Pen and Podium

Recent RCA technical papers and presentations

Both published papers and verbal presentations are indexed. To obtain a published paper borrow the journal in which it appears from your library or write or call the author for a reprint. For information on unpublished verbal presentations write or call the author. (The author's RCA Division appears parenthetically after his name in the subject-index entry.) For additional assistance in locating RCA technical literature contact **RCA Technical Communications, Bldg. 204-2, Cherry Hill, N.J. (Ext. PC-4256).**

This index is prepared from listings provided bimonthly by RCA Division Technical Publications Administrators and Editorial Representatives—who should be contacted concerning errors or omissions (see inside back cover)

Subject index categories are based upon standard announcement categories used by Technical Information Systems. Bldg. 204-2, Cherry Hill, N.J.

Subject Index

Titles of papers are permuted where necessary to bring significant keyword(s) to the left for easier scanning. Authors' division appears parenthetically after his name.

SERIES 100 BASIC THEORY & METHODOLOGY

120 Life Sciences and Medicine

biology, physiology, psychology medical sciences.

In Cold Blood-II — B.Jacks (AED,Pr) Saturday Review/World 7/16/74

130 Mathematics

basic and applied mathematical methods.

LATTICE GREEN'S function for the face centered cubic lattice — M. Inoue (Labs,Pr) American Instit. of Phys. 1974, *J. Math. Phys.* Vol. 15, No. 6; 6/74

170 Manufacturing and Fabrication

production techniques for materials, devices and equipment.

INTERCONNECTIONS — B.R. Schwartz (MSRD,Mrstn) *Electromechanical Design*; 8/74

PRINTED WIRING processing materials techniques — D.P. Schnorr (GCS,Cam) *Electronic Packaging and Product*, Vol. 14, No. 7; 7/74

180 Management and Business Operations

organization, scheduling, marketing, personnel.

MITE program — Drexel University — P.E. Wright (ATL,Cam) RCA Little Theater, Camden, NJ; 7/19/74

PROJECT MANAGEMENT - future developments — M.W. Buckley (MSRD,Mrstn) AMA Seminar, San Francisco, Calif.; 7/8-9/74 Mtg. Chairman and Instructor

SERIES 200 MATERIALS, DEVICES, & COMPONENTS

205 Materials (Electronic)

preparation and properties of conductors, semi-conductors, dielectrics, magnetic, electro-optical, recording, and electro-magnetic materials.

CMOS/SOS, Transient and steady-state response of — G. Brucker (AED,Pr) IEEE Nuclear Effects Conf., Ft. Collins, Col.; 7/15-19/74

GRANULAR $NiSiO_2$ and $NiAl_2O_3$ **FILMS, Superparamagnetism and relaxation effects in** — J.I. Gittleman, B. Abeles, S. Bozowski (Labs,Pr) *Physical Review B*, Vol. 9, No. 9; 5/74

LIQUID HELIUM below 0.6 K, Small-angle scattering of phonons and sound propagation in — R.K. Wehner (Labs,Pr) *Physical Review A*, Vol. 9, No. 6

PHOTOCONDUCTIVITY of sputtered films of cadmium sulphide resulting from oxygen chemisorption, Changes in the — C.E. Weitzel (Labs,Pr) *Surface Science*, 40 (1973) 555-570

Zn in GaAs, Diffusion coefficients varying with a power of the concentration: convenient solutions and a reexamination of — J. Blanc (Labs,Pr) *J. of Applied Physics*, Vol. 45, No. 5

210 Circuit Devices and Microcircuits

electron tubes and solid-state devices (active and passive); integrated, array and hybrid microcircuits, field-effect devices, resistors and capacitors, modular and printed circuits, circuit interconnection, waveguides and transmission lines.

CMOS circuits, EMP hardened — R.G. Stewart (GCASD,Cam) IEEE Nuclear and space radiation effects conf., Ft. Collins, Col.; 7/15-18/74

COS/MOS devices, Transient and steady-state radiation response of — G. Brucker (AED,Pr) IEEE Nuclear and space radiation effects conf., Ft. Collins, Col.; 7/16/74

MNOS MEMORY DEVICES, Interaction of nuclear environment with — G. Brucker (AED,Pr) IEEE Nuclear Effects Conf., Ft. Collins, Col.; 7/16/74

MNOS MEMORY DEVICES, Interaction of nuclear environment with — G. Brucker (AED,Pr) IEEE Nuclear and Space Radiation Effects Conf.; Ft. Collins, Col.; 7/16/74

215 Circuit and Network Designs

analog and digital functions in electronic equipment; amplifiers, filters, modulators, microwave circuits, A-D cnverters, encoders, oscillators, switches, masers, logic networks, timing and control functions, fluidic circuits.

TRAPATT AMPLIFIERS, Observations on parametric conversion in — A. Schwarzmann (MSRD,Mrstn) 1974 Government Microcircuits Applications Conf., Boulder, Col.; 6/26/74; *Conf. Proc.*

240 Lasers, Electro-Optical and Optical Devices

design and characteristics of lasers, components used with lasers, electro-optical systems, lenses, etc. (excludes: masers).

ACOUSTIC IMAGING with thin annualar apertures — D. Vilkomerson (Labs,Pr) *Acoustical Holography*, Vol. 5

ELECTROLUMINESCENT DIODES, A review of gradual degradation phenomena in — H. Kressel, H.F. Lockwood (Labs,Pr) *J. de Physique*, Vol. 35, No. 4, 4/74

GaP LIGHT-EMITTING DIODES grown on spinel substrates, Properties of — I.Ladany, C.C. Wang (Labs,Pr) *Solid State Electronics* '74, Vol. 17, Pergamon Press

HOLOGRAPHY, An organic recording medium for volume-phase — A. Bloom, R.A. Bartolini, D.L. Ross (Labs,Pr) *Applied Physics Letters*, Vol. 24, No. 12; 6/15/74

IMAGE TUBES, Effects of cathode bumpiness on the spatial resolution of proximity focused — R.U. Martinelli (Labs,Pr) *Applied Optics*, Vol. 12, No. 8; 8/73

LASER DIODE for communications applications, A large optical cavity (LOC) — J. O'Brien, E. Fischer, R. Glicksman (EC,Har) *Conf. Proc. 6th DOD Conf. on laser technology*

OPTICAL WAVEGUIDES and efficient high-speed modulators of $LiNb_xTa_{1-x}O_3$ **Low-loss single-mode** — J.M. Hammer, W. Phillips (Labs,Pr) *Applied Phys. Letters*, Vol. 24, No. 11; 6/74

PHOTOELECTRIC SENSORS for colorimetry — R.W. Engstrom (EC,Har) Electro-optical systems design conf., San Francisco, Calif.; 11/5-6/74

PHOTOMULTIPLIER TUBES in nuclear medicine, The role of — D.E. Persyk, W.D. Lindley (EC,Har) Soc. of nuclear medicine 12th Int'l Annual Mtg., Munich, Germany; 9/11/74

QUANTUM EFFICIENCY of the eye measured with an I-SIT TV camera — R.W. Engstrom (EC,Har) Electro-optical systems design conf., San Francisco, Calif.; 11/5-6/74

QUANTUM EFFICIENCY of the eye measured with a TV camera — R.W. Engstrom (EC,Har) *J. of Applied Optics*

SOLID STATE OPTICAL RECORDING, Progress report on — R.F. Kenville (ATL,Cam) Electro-optical Sys. Design Conf., San Francisco; 11/5-7/74; Proc.

SURFACE RELIEF HOLOGRAMS in evaporated arsenic trisulfide films — S.A. Keneman (Labs,Pr) *Thin Solid Films*, 21 (1974) 281-285

245 Displays

equipment for the display of graphic, alphanmeric, and other data in communications, computer, military, and other systems, CRT devices, solid state displays, holographic displays, etc.

250 Recording Components and Equipment

disk, drum, tape, film, holographic and other assemblies for audio, image, and data systems.

MULTITRACK RECORDING, High density — J.S. Griffin (GCASD,Cam) Princeton Chapter IEEE at Rutgers Univ., New Brunswick, N.J.; 5/74

280 Thermal Components and Equipment

heating and cooling components and equipment, thermal measurement devices, heat sinks.

PYROELECTRIC RADIATION SENSORS, Impedance matching of, using alternating series elements — P.D. Southgate (Labs,Pr) *Proc. of the IEEE* Vol. 62, No. 4; 4/74

SERIES 300 SYSTEMS, EQUIPMENT, & APPLICATIONS

310 Spacecraft and Ground Support

spacecraft and satellite design, launch vehicles, payloads, space missions, space navigation.

ATMOSPHERE EXPLORER power subsystem — A.F. Obenschain, J. Bacher, P. Callen (AED,Pr) Intersociety energy conversion engineering conf., San Francisco, Calif.; 8/13-15/74

ORBIT ADJUST THRUSTING to simultaneously control roll-yaw attitude, Pulse modulation of — R. Cenker (AED,Pr) AIAA Mechanics and control of flight conf. Anaheim, Calif.

SPACECRAFT COMPUTERS, A survey of — A.J. Aukstikalnis (AED,Pr) *Astronautics and Aeronautics*, 8/74

320 Radar, Sonar, and Tracking

microwave, optical, and other systems for detection, acquisition, tracking, and position indication.

AEGIS AN/SPY-1 radar and the MK 545 ORTS on-line test system, Success through concurrent and integrated design — H.B. Boardman, V. Iacono (MSRD,Mrstn) Twentieth Tri-Service Radar Symp., West Point, N.Y.; 7/16-19/74; Proc. of the 20th Tri-Service Radar Symp.

AEGIS AN/SPY-1 radar as a communications link for the SM-2 missile — S.C. Lange (MSRD,Mrstn) Twentieth Tri-Service Radar Symp., West Point, N.Y.; 7/16-19/74; *Proc. of the 20th Tri-Service Radar Symp.*

AN/SPY-1 performance — M.N. Smith, R.W. Ottinger (MSRD,Mrstn) Twentieth Tri-Service Radar Symp., West Point, N.Y.; 7/16-19/74; *Proc. of the 20th Tri-Service Radar Symp.*

325 Checkout, Maintenance, and User Support

automatic test equipment, (ATE), maintenance and repair methods.

FLEET VEHICLE maintenance, Test equipment for — J.M. Laskey (GCASD, Burl) Automatic Testing '74 Brighton, England; *Proc.*: 11/74

TESTING non-electronic equipment — R.F. Barry, H.U. Burri (GCASD,Burl) Symp. on Rational Fault Analysis, Texas Tech. Univ.; 8/74

340 Communications

industrial, military, commercial systems, telephony, telegraphy and telemetry, (excludes: television, and broadcast radio).

DELTA MODULATION channels with application to video signal processing, A Technique for correcting transmission errors in — M.Z. Ali (GCASD,Cam) IEEE Int'l Conf. on Communications, Minneapolis, Minn.; 6/16-19/74

345 Television and Broadcast

television and radio broadcasting, receivers, transmitters, and systems, television cameras, recorders, studio equipment.

SPACEBORNE TV CAMERAS, The impact of optical design constraints imposed by — M.H. Mesner (AED,Pr) 18th Annual Mtg. of the Soc. of Photo-optical instrumentation engineers San Diego, Calif.; 8/19-22/74

380 Graphic Arts and Documentation

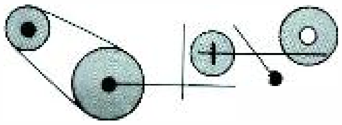
printing, photography, and typesetting; writing, editing, and publishing; information storage, retrieval, and library science.

SCIENTIFIC PERIODICALS in an industrial research library, Selection of — E.F. Hockings (Labs,Pr) *J. of the American Society for Information Science* 3-4/74

FIRE PHOTOGRAPHY, an aid to investigation — C.W. Asbrand (GCASD,Burl) *Law Enforcement Communications*: 6-7/74

Patents Granted

to RCA Engineers



As reported by RCA Domestic Patents Princeton

Consumer Electronics

High Heat Dissipation Solder-Reflow Flip Chip Transistor — B.A. Hegarty, L.H. Trevail (CE,Ind) U.S. Pat. 382469, July 16, 1974

Pulse Delay Circuit — J.H. Wharton (CE,Ind) U.S. Pat 3824411, July 16, 1974

Parity of Tuning Apparatus — W.F. Speer, L.E. Reed (CE,Ind) U.S. Pat. 3824507, July 16, 1974

Method of Soldering Circuit Components to a Substrate — C.F. Coleman (CE Ind) U.S. Pat. 3825994, July 30, 1974

Device for Mounting and Orienting a Workpiece — W.M. Binder (CE,Ind) U.S. Pat. 3826047, July 30, 1974

Delayed Alarm and Drowse for Clock Receivers — G.D. Pyles (CE,Ind) U.S. Pat. 3825836, July 23, 1974

Cartridge Changer with Cartridge Sensing Means — G.D. Pyles (CE,Ind) U.S. Pat. 3825949, July 23, 1974

Electronic Components

Method of Aligning a Two-Capillary Tube Gas Discharge Device — W.E. Riggle (EC,Lanc) U.S. Pat. 3824089, July 16, 1974

Graduated SiGe Alloy Thermocouple — F. Kot (EC,Har) U.S. Pat. 3822152, July 2, 1974; Assigned to U.S. Government.

Solid State Division

High Speed Driving Circuit for Producing Two In-Phase and Two Out-of-Phase Signals — B. Zuk (SSD,Som) U.S. Pat. 3828206, August 6, 1974

Signal Duration Sensing Circuit — V.E. Hills, L. Wu (SSD,Som) U.S. Pat. 3828258, August 6, 1974

Plug Sealing of Hermetic Enclosures — H.L. Blust, N.L. Lindburg (SSD,Som) U.S. Pat. 3826634, July 30, 1974

Multi-Function Logic Gate — D. Hampel (SSD,Som) U.S. Pat. 3825770, July 23, 1974

Temperature-Sensitive Control Circuit — A.A.A. Ahmed (SSD,Som) U.S. Pat. 3825778, July 23, 1974

Raster Correction Circuit Utilizing a Parabolically Varying Load Circuit — W.F.W. Dietz (SSD,Som) U.S. Pat. 3825793, July 23, 1974

RCA Limited

Adjustable Polarization Antenna System — P. Foldes (Ltd,Mont) U.S. Pat. 3827051, July 30, 1974

Missile and Surface Radar Division

Lens Fed Antenna Array System — B.F. Bogner, D.F. Bowman (MSRD,Mrstn) U.S. Pat. 3827055, July 30, 1974

Balanced Line Driver, Line Receiver System — P.C. Phillips (MSRD,Mrstn) U.S. Pat. 3825682, July 23, 1974

Astro-Electronics Division

Motor Speed Control System — E.A.Goldberg (AED,Pr) U.S. Pat. 3828234, August 6, 1974

Government Communications and Automated Systems Division

Recording Web Tension Control — M.B. Finkelstein (GCASD,Cam) U.S. Pat. 3823896, July 16, 1974

RCA Laboratories

Process for Preparing Superconducting Niobium-Gallium Alloy — L.J. Vieland, A.W. Wicklund (Labs,Pr) U.S. Pat. 3824082, July 16, 1974

Omnidirectional Sound Field Reproducing System — R.M. Christensen, J.J. Gibson, A.L. Limberg (Labs,Pr) U.S. Pat. 3824342, July 16, 1974

Color Signal Producing System Utilizing Spatial Color Encoding and Comb Filtering — J.J. Brandinger, D.H. Pritchard, G.L. Fredendall, A.C. Schroeder (Labs,Pr) U.S. Pat. 3828121, August 6, 1974

Information Playback System Stylus — M.A. Leedom, M.E. Miller (Labs,Pr) U.S. Pat. 3826877, July 30, 1974

Apparatus for Providing an Optical System Using Adaptive Holographic Components — J.J. Amodei (Labs,Pr) U.S. Pat. 3825316, July 23, 1974

Unsaturated Polyester Resin Photoresist Composition — E.B. Davidson (Labs,Pr) U.S. Pat. 3825428, July 23, 1974

Method of Depositing Epitaxial Layers on a Substrate from the Liquid Phase — D.P. Marinelli, T.E. Stockton (Labs,Pr) U.S. Pat. 3825449, July 23, 1974; Assigned to U.S. Government

Transistor Carrier for Microwave Stripline Circuit — E.F. Belohoubek, D.M. Stevenson (Labs,Pr) U.S. Pat. 3825805, July 23, 1974; Assigned to U.S. Government

Author Index

Subject listed opposite each author's name indicates where complete citation to his paper may be found in the subject index. An author may have more than one paper for each subject category.

Dates and Deadlines

As an industry leader, RCA must be well represented in major professional conferences . . . to display its skills and abilities to both commercial and government interests.

How can you and your manager, leader, or chief-engineer do this for RCA?

Plan ahead! Watch these columns every issue for advance notices of upcoming meetings and "calls for papers". Formulate plans at staff meetings—and select pertinent topics to represent you and your group professionally. Every engineer and scientist is urged to scan these columns; call attention of important meetings to your Technical Publications Administrator (TPA) or your manager. Always work closely with your TPA who can help with scheduling and supplement contacts between engineers and professional societies. Inform your TPA whenever you present or publish a paper. These professional accomplishments will be cited in the "Pen and Podium" section of the *RCA Engineer*, as reported by your TPA.

Dates of upcoming meetings —plan ahead

Ed. note: Meetings are listed chronologically. Listed after the meeting title (in bold type) are the sponsor(s), the location, and the person to contact for more information

NOVEMBER 6-8, I974 — **AIAA Life Science and Systems Specialist Conference,** (cosponsored by DOT and NASA), Arlington, Texas. **Prog. info:** American Institute of Aeronautics and Astronautics, 1290 Avenue of the Americas, New York, N Y 10019

NOVEMBER 7-8, 1974 — **Canadian Communications and Power Conference,** IEEE Canadian Region, Montreal Section, Queen Elizabeth Hotel, Montreal, Quebec, Canada **Prog. info:** Gilles Perron, La Societe d'Ingenierie, Cartier Limitee, C.P. 186, Place Bonaventure, Montreal 114, PQ

NOVEMBER 10-15, 1974, **SMPTE fall conference**, Society of Motion Picture & Television Engineers, 862 Scarsdale Ave , Scarsdale, N.Y. 10583. **Prog. info:** SMPTE, c/o Conference Coordinator, 862 Scarsdale Ave., Scarsdale, N.Y 10583

NOVEMBER 11-13, 1974 — **Ultrasonics Symposium,** IEEE SU, Milwaukee, Wisconsin. **Prog. info:** M. Levy, Dept of Physics, Univ of Wisconsin, Milwaukee, Wisconsin 53201

NOVEMBER 12-14, 1974 — **Jt. Measurement Conference,** IEEE IM, et al, Nat'l. Bur. of Standards, Holiday Inn, Gaithersburg, Md. **Prog. info:** A.J Woodington, Dept. 142-00, Gen'l. Dyn., POB 80847, San Diego, Cal 92138

NOVEMBER 12-14, 1974 — **AMS/AIAA Conference on Aerospace and Aeronautical Meteorology,** El Paso, Texas. **Prog. info:** American Institute of Aeronautics and Astronautics, 1290 Avenue of the Americas, New York, N.Y. 10019

NOVEMBER 12-14, 1974 — **AIAA Remotely Piloted Vehicle Technology Meeting (classified),** Tucson, Arizona. **Prog. info:** American Institute of Aeronautics and Astronautics, 1290 Avenue of the Americas, New York, N.Y. 10019

NOVEMBER 17-21, 1974 — **ASME 1974 Winter Annual Meeting,** The American Society of Mechanical Engineers, New York, N.Y., Statler Hilton Hotel, New York City **Prog. info:** Maurice Jones, Manager Information Services, ASME, 345 E. 47th St., New York, N.Y.

NOVEMBER 18-19, 1974 — **International Engineering Seminar,** The American Society of Mechanical Engineers, New York, N.Y., Statler Hilton Hotel, New York City. **Prog. info:** Mark J. Williams, Meetings Coordinator, ASME, 345 E. 47th St., New York, N.Y. 10017

NOVEMBER 18-19, 1974 — **Environmental Sensors and Applications,** IEEE IERE, IEEE UKRI Section IEEE, Inst. of Physics, Royal Society, London, England. **Prog. info:** IERE, 8-9 Bedford Sq . London W.C. 1 B 3RG, England

NOVEMBER 18-20, 1974 — **Semiconductor Laser Conference,** IEEE JQEC, Stauffers, Atlanta, Georgia, **Prog. info:** N. Holonyak, Univ. of Illinois, Urbana, Ill. 61820

NOVEMBER 20-21, 1974 — **Decision and Control-Adaptive Processes,** IEEE CS, IT, SMC, Del Webb's Town House, Phoenix, Arizona. **Prog. info:** E I, Axelband, Hughes Aircraft Co , MS B-12, Bldg. 262, 8433 Fallbrook Ave., Canoga Park, Calif., 91304

NOVEMBER 25-27, 1974 — **Microelectronics Int'l Congress,** IEEE ED, INEA, VDE (NTG), Munich, Germany, **Prog. info:** Internationales Elektronik Zentrum, 8 - Munchen 70, Hauffstr, 2 Germany

DECEMBER 2-4, 1974 — **National Telecommunications Conference,** IEEE AES, Comm, GE, San Diego Section, Sheraton Harbor Island, San Diego, Calif. **Prog. info:** Irvin Jacobs, Linkabit Corp., 10453 Roselle St., Univ Ind Park, San Diego, Calif 92121

DECEMBER 3-4, 1974 — **Compatibility of Energetic Materials with Plastics and Additives,** Materials Division of the American Defense Preparedness Association, Picatinny Arsenal **Prog. info:** Frank D, Swanson, Honeywell, Inc. - Mail Station H2480, 600 Second Street North, Hopkins, MN 55343

DECEMBER 3-5, 1974 — **Power Electronics — Power Semiconductors and Their Applications,** IEEE IEEE, IEEE UKRI Section, Inst. of Physics, IERE, IEEE, London, England **Prog. info:** IEEE, Savoy Place, London W C. 2 R OBL England

DECEMBER 3-6, 1974 — **Magnetism & Magnetic Materials Conference,** IEEE MAG, AIP et al, Jack Tar Hotel, San Francisco, Calif. **Prog. info:** J.M. Lommel, GE R&D Ctr., POB 8, Schenectady, N.Y 12301

DECEMBER 8-11, 1974 — **Int'l Electron Devices Meeting,** IEEE ED, Washington Hilton Hotel, Washington, D.C **Prog. info:** Fred Lindholm, EE Dept., Univ of Florida, Gainesville, Florida 32601

DECEMBER 9-10, 1974 — **Chicago Fall Conf. on Broadcast & Television Receivers,** IEEE BTR, Chicago Section, O'Hare Inn, Rosemont, Illinois. **Prog. info:** W.C. Luplow, Zenith Radio Corp., 6101 W Dickens Ave , Chicago, Ill 60639

DECEMBER 11-13, 1974 — **Nuclear Science & Scintillation & Semiconductor Counter Symposium,** IEEE NAP, NASA, NBS, Shoreham Amer. Hotel, Washington, D.C. **Prog. info:** D.C. Cook, Code 6603C, Naval Res. Lab , Washington, D.C. 20390

DECEMBER 11-13, 1974 — **Nuclear Power Systems Symposium,** IEEE PE, NAP, Shoreham Amer. Hotel, Washington, D.C **Prog. info:** H.A. Thomas, General Atomic Co., POB 81608, San Diego, Calif. 92138

JANUARY 13-15, 1975, **Winter Simulation Conference,** IEEE SMC et al, Waldorf Astoria, New York, N.Y. **Prog. info:** Harold Steinberg, IBM Corp., 909 Third Ave., New York, N.Y. 10022

JANUARY 20-22, 1975 — **Computer Architecture,** IEEE C, et al, Univ. of Houston, Houston, Texas. **Prog. info:** William King, Dept. of Computer Sci., Univ. of Houston, Houston, Texas 77004

JANUARY 20-22, 1975 — **AIAA 13th Aerospace Sciences Meeting,** Pasadena, Calif **Prog. info:** American Institute of Aeronautics and Astronautics, 1290 Avenue of the Americas, New York, N.Y. 10019

JANUARY 21-22, 1975 — **Vehicular Technology Conference,** IEEE VT, Toronto Section, Royal York Hotel, Toronto, Ont., Canada. **Prog. info:** G.A. Ross, Sinclair Radio Labs., 122 Rayette Rd., Concord, Ont., Canada

JANUARY 26-31, 1975 — **IEEE Power Engineering Society Winter Meeting,** IEEE PE, Statler Hilton Hotel, New York, N.Y. **Prog. info:** J.G. Derse, 1030 Country Club Rd., Somerville, N.J. 08876

Calls for papers —be sure deadlines are met.

Ed. Note: Calls are listed chronologically by meeting date Listed after the meeting title (in bold type) are the sponsors(s), the location, and the deadline information for submittals

APRIL 7-8, 1975 — **Rubber & Plastics Ind. Technical Conference,** IEEE IA, Coliseum & Americana Hotel, New York, N Y. **Deadline info:** DL 1-15-75 (abst) **to:** R.L. Bock, B.F. Goodrich Co., 500 S. Main Street, AKkron, Ohio 44311

APRIL 21-23, 1975 — **International Radar Conference,** IEEE Washington Section and Aerospace and Electronics Systems Society (Washington Chapter), Stouffer's National Center Inn, Arlington, Virginia. **Deadline info:** 11-15-74 (papers) **to:** Dr. Merrill I. Skolnik, Chairman, Papers Committee, Code 5305, Naval Research Laboratory, Washington, D.C. 20375

APRIL 21-25, 1975 — **Electrical and Electronic Engineers in Israel,** The Institute of Electrical and Electronics Engineers, Inc., New York, N.Y., Tel-Aviv, Israel. **Deadline info:** 10-15-74 (400 word summary) **to:** The Technical Committee, The Ninth Convention of Electrical and Electronic Engineers in Israel, POB 29234, Tel-Aviv, Israel

MAY 4-7, 1975 — **Offshore Technology Conference,** TAB Oceanography Coor. Comm. et al, Astrohall, Houston, Texas, **Deadline info:** DL I0-74 (abst) **to:** OTC, 6200 N. Central Expressway, Dallas, Texas 75206

MAY 6-8, 1975 — **Photovoltaic Specialists Conference,** The Institute of Electrical and Electronics Engineers, Inc., New York, N.Y., Phoenix, Arizona. **Deadline info:** 11-1-74 (abst) **to:** Mr. R.L. Statler, Technical Program Chairman, Naval Research Laboratory, Code 6603F, Washington, D.C. 20375

MAY 7-9, 1974 — **Region Six Conference & Exhibit "Communications Technology",** IEEE Region 6, Utah Section, Salt Lake City, Utah, **Deadline info:** DL 2-7-75 (ms) **to:** R.O. Evans, Sperry Univac, 322 N. 22nd St , Salt Lake City, Utah 84116

MAY 12-14, 1975 — **International Microwave Symposium,** IEEE MIT, Rickey's Hyatt House, Palo Alto, Calif. **Deadline info:** DL 1-2-75 (ms) **to:** E.W. Matthews, 1264 Via Huerta, Los Altos, Calif. 94022

MAY 12-14, 1975 — **Electrical and Electronic Measurement and Test Instrument Conference,** The Institute of Electrical & Electronics Engineers, Inc., New York, N.Y., Skyline Hotel, Ottawa, Canada. **Deadline info:** 12-31-74 (abst) **to:** Richard F. Clark, Conference Chairman, National Research Council, Division of Physics, Montreal Road, Bldg. M-36, Ottawa, Ontario, KIA OS1, Canada

JUNE 9-11, 1975 — **Applications of Ferroelectrics,** The Institute of Electrical and Electronics Engineers, Inc., New York, N.Y., Albuquerque Hilton Inn, Albuquerque, N.M. **Deadline info:** 1-15-75 (abst) **to:** Prof. L.E. Cross, Materials Research Lab. - Room 251A, The Pennsylvania State University, University Park, Penna. 16802

JULY 20-25, 1975 — **IEEE Power Engineering Society Summer Meeting,** IEEE PE, San Francisco Hilton Hotel, San Francisco, Calif. **Deadline info:** DL 2-1-75 (ms) **to:** C.H. Sedam, Pacific Gas & Elec. Co., Gen'l Construction, Rm. 1445, 77 Beale St., San Francisco, Calif. 94106

OCTOBER 5-9, 1975 — **Electrical/Electronics Insulation Conference,** IEEE EI, NEA, Boston, Mass. **Deadline info:** DL 10-1-74 (abst) **to:** F.A. Blankenbaker, Dielectric Material & Sys., 3 M Co., 3M Ctr., St. Paul, Minn. 55101

OCTOBER 20-22, 1975 — **Frontiers in Education International Conference,** The Institute of Electrical and Electronics Engineers, Inc., New York, N.Y., Atlanta, Georgia. **Deadline info:** 12-15-74 (abst) **to:** Dr. Lawrence P. Grayson, National Institute of Education, Washington, D.C. 20208

1976 — **Second International Conference on the Mechanical Behavior of Materials** (ICM-2), The Institute of Electrical and Electronics Engineers, Inc., New York, N.Y.

Engineering News and Highlights

Aires named Chief Engineer, EASD

Frederick H. Krantz, Division Vice President and General Manager, Electromagnetic and Aviation Systems Division, Van Nuys, Calif., announced the appointment of **Ramon Aires** as Chief Engineer. In this capacity, Mr. Aires is responsible for the EASD engineering activities: Aviation Equipment, Rapid Score, Terminals, and Government Systems.

Mr. Aires received the BEE from Cornell in 1950 and the MSEE from the University of Pennsylvania in 1959. Recently, he established an activity for Product Technology and Design Assurance to emphasize the improvement in reliability, producibility and cost effectiveness in EASD products. From June 1972 through 1973, he was Program Manager for several major proposals. From 1965 to 1972, Mr. Aires was Chief Engineer of the Government and Terminal Engineering activities at EASD. From 1963 to 1965, he was responsible for RCA's Defense Microelectronics activity where he played an active role in corporate planning of microelectronic programs. He personally contributed to RCA's accomplishments in high-speed monolithic digital and analog circuits to meet critical military performance requirements. From 1959 to 1963, Mr. Aires was Staff Engineer reporting to the Chief Defense Engineer, responsible for management of the DEP's IR&D program. From 1954 to 1959 he was a Leader and Manager for airborne fire control systems — and later a Manager for TIROS Electrical Design. His direct contributions in the latter include development of state-of-the-art circuitry utilizing solid-state devices. Before joining RCA, Mr. Aires worked for the Philco Corporation where he engaged in developing precise deflection and high-voltage circuitry for a single-gun color tube. Several patents were issued for these developments. Mr. Aires is a member of Eta Kappa Nu, a Senior Member of the IEEE, and past Chairman and member of the Executive Committee of the San Fernando Valley Section; he has been a Director of the San Fernando Valley Engineers' Council and is a Fellow of the Institute for the Advancement of Engineering. He was Co-Chairman of the Technical Program Committee, for WESCON 1974.

Promotions

RCA Alaska Communications, Inc.

D. Keim from Ldr.,/Draftsman to Mgr., Technical Svcs. (G.V. Bartley, Anchorage, AK)
J.T. Nixon from Sr. Engr. to Mgr., Microwave /Multiplex Engrg. (V.B. Robinett, Anchorage, AK)

RCA Global Communications, Inc.

D. G. Epstein from Group Ldr. to Mgr., Computer Telex Engrg. (J.R. McDonald, New York)
A. J. Falco from Group Ldr. To Mgr., Switched Data System Engrg. (J.R. McDonald, New York)
N. Kotsolios from Ldr. to Mgr., CLC Engrg. (S. Schadoff, New York)

RCA Service Company

M.W. Linton from Associate Ships Instrumentation Engr. to Ldr., Instrumentation Systems (J. Simpson, MTP, FL)
J.L. Otto from Systems Service Engr. to Ldr., Systems Service Engrs. (T.J. Barry, Springfield, VA)

Missile and Surface Radar Division

O.G. Allen from Ldr., Quality Control to Mgr., Product Assur. (G.J. Branin, Moorestown)
G. DeLong from Sr. Mbr. Engrg. Staff to Ldr. Des & Dev. (M. Korsen, Moorestown)
C. Dobbins from Laboratory Tech. to Mbr., Engrg. Staff (F. Balliet, Moorestown)
C. Hughes from Sr. Mbr. Engrg. Staff to Princ. Mbr. Engrg. Staff (M. Korsen, Moorestown)
V. C. Iacono from Sr. Mbr. Engrg. Staff to Ldr., Des & Dev. (M. Korsen, Moorestown)
J. Jackson from Engr. to Sr. Mbr. Engrg. Staff (M. Korsen, Moorestown)
E. G. Lurcott from Sr. Mbr. Engrg. St. to Ldr., Des. & Dev. (M. Korsen, Moorestown)
M.H. Plofker from Princ. Mbr. Engrg. St. to Ldr., Des. & Dev. (M. Korsen, Moorestown)
A. Plumer from Sr. Mbr. Engrg. Staff to Sr. Sales Rep. (M. Lehrer, Moorestown)
M. Ratliff from Sr. Mbr. Engrg. Staff to Ldr. Des. & Dev. (M. Korsen, Moorestown)
D. Staiman from Sr. Mbr. Engrg. Staff to Ldr. Des. & Dev. (H. Coller, Moorestown)
S.A. Stern from Princ. Mbr. Engrg. St. to Ldr., Des. & Dev. (M. Korsen, Moorestown
F.J. Stewart, Jr. from Sr. Mbr. Engrg. Staff to Ldr., Des. & Dev. (M. Korsen, Moorestown)

Solid State Division

W. Austin from Mbr., Tech Staff to Ldr., Tech. Staff (M.V. Hoover, Somerville)
L. Jacobus from Ldr., Tech. Staff to Mgr., Wafer and Assembly Tech. (H. Khajezadeh, Somerville)
R. Kleppinger from Sr. Member, Tech. Staff to Ldr., Tech. Staff (D.S. Jacobson, Somerville)
W. Lewis from Ldr., Tech. Staff to Mgr., Model Shop (H. Khajezadeh, Somerville)
K. Orlowsky from Mbr., Tech. Staff to Ldr., Tech. Staff (H. Khajezadeh, Somerville)
E. Reiss from Ldr., Tech. Staff to Mgr., High Rel. Engrg. (J.P. McCarthy, Somerville)
A. Sheng from Ldr., Tech. Staff to Mgr., Circuit Design and Development (H. Khajezadeh, Somerville)

Electronic Components

R.F. Shelton from Sr. Liaison Engr. to Ldr., Liaison Engrgs. (E. L. Batz, Bloomington)
N. Meena from Mgr., Process & Production Engrg. Marion to Mgr., Product Engrg. Circleville, Ohio

Staff announcements

Astro-Electronics Division

C.S. Constantino, Division Vice President and General Manager, has announced the appointment of **Wilbur B. Botzong,** as Manager, AED West Coast Operations.

Consumer Electronics

C. Wayne Hamilton, Plant Manager, Indianapolis Components Plant, has announced the appointment of **Leonard M. Krugman** as Manager, Plant Quality Control.

Roy H. Pollack, Vice President and General Manager, has announced the organization of Consumer Electronics as follows: **James M. Alic,** Division Vice President, Manufacturing Operations; **William E. Boss,** Division Vice President, Marketing; **Gordon W. Bricker,** Director "SelectaVision" Products; **Keith U. Clary,** Division Vice President, Industrial Relations; **W. Thomas Collins,** Director, Consumer Affairs; **David E. Daly,** Division Vice President, Product Planning and Industrial Design; **Loren R. Kirkwood,** Division Vice President, Television Engineering and Strategic Planning; **Francis V. McCann,** Director, News and Information; **Donald S. McCoy,** Division Vice President, Development Engineering. **Roy H. Pollack,** Acting, International.

International Licensing

Allan D. Gordon, Staff Vice President has announced the appointment of **Robert E. Holtz** as Director, Technical Programs; **Clifford W. Slaybaugh,** was elected Managing Director by the Board of Directors of Laboratories RCA Limited (Zurich).

Global Communications, Inc.

H. Rice, Acting Manager, Satcom Systems Technical Support, has announced the appointment of **Murray Fruchter** as Manager, Satcom Circuit Technical Support.

Saul Schadoff, Director, Commercial Leased Channels, Engineering and Implementation, has announced the appointment of **Notis Kotsolios** as Manager, Commercial Leased Channels Engineering.

Government and Commercial Systems

Irving K. Kessler, Executive Vice President has announced the new responsibilities of the following activities that formerly comprised the Manufacturing Services Organization:

1. The Government Product Assurance activity will be transferred to Government Engineering; **Edwin S. Shecter** continues as Manager, Government Product Assurance and will report to **Harry J. Woll,** Division Vice President, Government Engineering; **Alfred S. Wall** continues as Manager, Reliability and Maintainability and will continue to report to Mr. Shecter.
2. The Facilities and Plant Engineering activity will be transferred to Finance; **Kenneth W. Aukett** and **Frank I. Hans** will continue in their present positions and will report to **John H. Pflieger,** Manager, Facilities Planning and Budgets.
3. The Industrial Engineering activity will be transferred to the Camden Plant. **H. Stanley Barr, Max L. Dooneief** and **Fred Pfifferling** will report to **Arthur J. Barrett,** Plant Manager, Camden Plant.

Government Communications and Automated Systems Division

James M. Osborne, Division Vice President and General Manager has announced **David A. Miller** as Manager, Sales, Advanced Systems and Techniques.

Stanley S. Kolodkin, Division Vice President, Burlington Operations, announced **Ruth J. McNaughton** as Manager, Management Information Systems and Engineering Programming Services; **Joseph L. Gotthelf** as Manager, Radar Systems Marketing.

Electromagnetic and Aviation Systems Division

Frederick H. Krantz, Division Vice President and General Manager, has announced the appointment of **Charles L. Gordon** as Manager, Custom Terminals; **W. Robert McKinley** as Manager, Rapid Score; **Bobby J. Fletcher** as Manager, Government Systems; and **Ramon H. Aires** as Chief Engineer.

Missile and Surface Radar Division

George J. Branin, Manager, Product Assurance has announced the organization of Product Assurance as follows: **Orange G. Allen,** Manager, Product Quality Assurance; **Menzo A. Christman,** Manager, Material Quality Assurance; **Gordon J. Rarich,** Administrator, Product Assurance; **Paul H. Sprowls,** Manager, Field and Wararnty Product Assurance; **Howard W. Wintling,** Manager, Product Assurance Services; **Howard W. Wintling,** Acting Administrator, Product Assurance.

Solid State Division

Dale M. Baugher, Director, Thyristor & Rectifier Operations announced that the Applications Engineering activity in the Thyristor & Rectifier Operations organization is transferred to the staff of the Director, Thyristor & Rectifier Operations. **Thomas C. McNulty** will continue as Manager, Applications Engineering — Thyristors & Rectifiers.

Dale M. Baugher, Director, Thyristor & Rectifier Operations announced the organization of Thyristor & Rectifier Operations as follows:

James M. Assour, Manager, Engineering — Thyristor & Rectifiers;
Richard E. Davey, Manager, Manufacturing — Packaging & Rectifiers;
Charles E. Farley, Administrator, Operations Planning — Thyristors;
Leonard H. Gibbons, Manager Market Planning — Thyristors & Rectifiers; and
David A. Riggs, Manager, Manufacturing — Thyristors & Rectifiers.

Norman C. Turner, Director, C/MOS IC Product Operations announced the appointment of **George A. Riley** as Manager, IC Market Planning.

Ben A. Jacoby, Division Vice President, Solid State Marketing announced the appointment of **Paul R. Thomas** as Manager, Product Distribution.

Carl R. Turner, Division Vice President, Solid State Power Devices announced the appointment of **George W. Ianson** as Manager, Operations Planning & Administration.

James C. Miller, Director, Power Transistor Operations announced **Donald Watson** as Manager, Market Planning — Power Transistors.

Henry C. Waltke, Manager, Operations Support announced the organization of the Operations Support activity as follows: **John A. Adolfson,** Manager, Industrial Engineering; **Robert P. Blazaskie,** Administrator, Cost Reduction; **Thomas E. Nash,** Manager, Plant Engineering; **John E. Sauchak,** Manager, Facilities & Equipment Standards.

Edward M. Troy, Division Vice President, Solid State Services & Off-Shore Manufacturing announced the Solid State Services & Off-Shore Manufacturing organization as follows: **Melvin Bondy,** Manager, Manufacturing Support; **Richard J. Hall,** General Manager, RCA Senderian Berhad (Malaysia); **Leonard Mineur,** Manager, Industrial Engineering & Manufacturing Systems; **Raymond C. Reutter,** Manager, Solid State, RCA Taiwan, Ltd., **Edward M. Troy,** Acting Manager, Solid State Operations Planning and Administration; **Gilbert Wolfe,** Administrator, International Planning; **Parker T. Valentine,** Manager, Solid State Services; and **John D. Watkins,** Manager, Solid State Materials.

William F. Allen, Jr., Manager, High Speed Bipolar IC Products announced the High Speed Bipolar IC Products organization as follows: **William F. Allen, Jr.,** Acting Manager, Engineering; **William F. Allen, Jr.,** Acting Leader, Testing; **Norman H. Ditrick,** Leader, Process Development; **Samuel Husni,** Project Leader, DI Substrate; **Peter Idell,** Leader, Process Engineering; **Michael I. Payne,** Leader, Circuit & IC Design; **William F. Allen, Jr.,** Acting Manager, Market Planning; **Marvin E. Mendelson,** Administrator, Product Control, Distribution & Planning; **Fred J. Reiss,** Leader, Quality Assurance; **George L. Schnable,** Manager, Technology; **Harold A. Uhl,** Manager, Manufacturing; and **Joseph N. Florio,** Superintendent, Manufacturing.

Executive Vice President

William C. Hittinger, Executive Vice President has announced the election of **Robert A. Schieber** as Vice President and General Manager, RCA Limited (Canada).

RCA Service Company

Lawrence G. Borgeson, Division Vice President, Consumer Services announced the appointment of **James J. Badaracco** as Director of Consumer Sales and Merchandising.

Errata

In the last issue (Vol. 20, No. 2), there was an error in Mr. Jellinek's article on "Operational requirements for a ship transponder system." The last two paragraphs on p. 76 should read as follows:

Providing the required range measurement accuracy is straightforward. With a bandwidth about the same as that of the radar, and a reply signal power greater than that of the radar, random errors will be minimized by proper specification of transponder turnaround time.

Providing the required bearing measurement is also straightforward. Radar blips appear on the scope as an arc representing the position of a number of hits on the target as the antenna beam sweeps by. . . .

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[illegible]

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[illegible] Patent Plans and Services, Princeton, N.J.

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