13th Anniversary

by and for the RCA engineer

Throughout most of the year this space is utilized by one of the engineering executives to provide an introduction to the [illegible] of the theme for the issue. With this, the Thirteenth Anniversary Issue, I would like to digress from this pattern to extend congratulations to those who make the magazine possible.

My first congratulations go to you—the engineers—[illegible] you are also the authors of the articles. Collectively, you [illegible] skills and fields of interest. Consequently, your re[illegible] and your approaches to problems make fascinating [illegible].

Next in line for kudos are the Technical Publ[illegible] Editorial Representatives. Individuals from th[illegible] out your most interesting projects and [illegible] agree to write an article with a far-distant de[illegible] elephant, they never forget the commitment, [illegible] Without these dedicated individuals, that [illegible] them written, this magazine would not exist.

A variety of other people such as photographers, [illegible] an Advisory Board also make their contribution[illegible] that deserves special recognition at this anniversary [illegible] course, to the Editor, Bill Hadlock, and his sta[illegible] two charming and efficient secretaries, are [illegible] that are filled with deadlines. To this group [illegible] for the RCA engineer," I ask you to join me in [illegible]

Wendell C. Morrison, Staff Vice President
Product Engineering, Research and Engineering, Camden, N.J.

Our Cover

Unity and diversity may seem paradoxical objectives. Yet any measure of RCA's total engineering success would necessarily be based on how well both objectives are met. Traditionally, the papers in the anniversary issue demonstrate engineering diversity in that they come from all areas of RCA and represent a wide range of subjects. To symbolize the unity so vital in achieving RCA's new goal—leadership in the information industry—this thirteenth anniversary cover displays RCA's new look. The convergent, cohesive force implied by the subtle radial lines in this cover give the impression of unity, yet they are elements of separate and precise geometric forms.

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RCA Engineer

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RCA Engineer articles are indexed annually in the April-May Issue and in the "Index to RCA Technical Papers."

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

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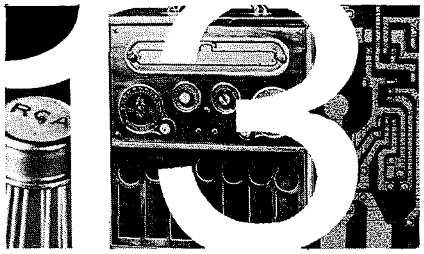


another anniversary—another forward transition

A rewarding look at the accomplishments of our predecessors and a challenging peek into the future is what the authors of this 13th Anniversary Issue provide. The new RCA monogram featured on the front cover provides a striking contrast with the lead article by **F. D. Whitmore** devoted to "RCA Engineering—the first twenty years"; this paper gives the "old timers" an interesting and nostalgic look into the past, yet serves as fresh insight for the newer engineer planning and working in engineering, research, and development for the future. **Dr. G. H. Brown** provides an interesting sequel in his article discussing the modern reformation in the electronics industry: "caused by the proclamation of the transistor and of the computer." Further emphasis is given to the impact of solid-state devices on electronics by **T. A. Smith** who discusses integrated circuit applications in the electronic industry as well as such diverse industries as transportation and medicine. **Dr.'s Nergaard** and **Sobol** set the stage for the future applications of microwave integrated circuits with both a research purview and a business look at the Blue Chip program being carried on at RCA Laboratories in cooperation with several divisions.

Carrying the linear integrated circuits banner, **M. V. Hoover** discusses these multifunction integrated circuits from both a business and design point of view. A specific application of integrated circuits is offered by **F. Ambler** who describes a timing-fuze using p-channel MOS arrays.

Typical of anniversary issues, the 13th draws upon the skills and competence of engineers and scientists from all corners of RCA. Twenty separate divisions of RCA are represented by the twenty-six professional papers published. This cosmopolitan flavor is no accident; the TPA's and Editorial Representatives in each division establish early plans and then follow up tenaciously.

The diverse and wide-ranging skills covered are unique—yet interrelated. Electronic Components, in Lancaster for example, is represented by two fine papers. **J. R. Leaman's** tutorial paper treats the vidicon as a complete optical system—light source to lens to target. **R. E. Johnson's** companion paper covers the use of vidicons in modern television systems.

Commercial Electronic Systems Division engineers, **G. R. Kamerer** and **W. L. Behrend,** discuss, respectively, modern transmitter-receiver communications equipment for the New York City Transit Authority System and television transmitter monitoring — a problem vital to the television broadcast industry. The paper by **R. J. Butler** on "Color Video Switching Systems," shows how corrective devices can compensate for the problems introduced by the use of video tape in color TV programming; to quote the author, "The old demon tape is now quiet as a lamb!"

Computers command their rightful share of this issue, starting with a paper by **D. R. Crosby** and **O. J. Hanas.** Using the design of an RF interstage circuit as an example, these engineers demonstrate how the computer can be used to avoid the tedious and time-consuming calculations involved in making design plots of 50 points each. Computer time-sharing system users should benefit from the practical article by **S. Stimler** and **J. M. Spencer** which discusses the measurement of the RCA Basic Time Sharing System Performance.

Did you find the last issue (devoted to Graphic Systems) of interest? If so, you shouldn't overlook the **Coleman, Day, Gerlich** article which gives a systems look at RCA's Videocomp electronic typesetter—an integrated software and hardware system.

Astro-Electronics engineering and research comes in for its fair share of attention this anniversary; **J. P. Yannello** describes the design of a solar-array test set used to predict accurately the performance of a solar array in space. This ingenious test set can be easily adapted to test most configurations of solar panels. **W. Paroby** discusses the remarkably stable characteristics of polymer-film belts for precise and reliable power transmission in spacecraft tape recorders. **W. A. Harmening** of M&SR describes another defense application in his paper on "Pointing Requirements for Satellite Tracking from Earth." The author develops simplified equations and illustrates tutorially how these equations can be applied to predict the position of a satellite with some accuracy and without resorting to a computer.

Two articles resound with a futuristic ring: **F. T. Harris** and **D. P. Lubin** describe "A Gallium Arsenide (GaAs) Laser-Diode Communicator," and **U. A. Frank** of Medical Electronics Engineering describes the methods of measuring and controlling the neonatal environment of a premature infant. This latter paper may cause the readers to recall the first publication of RCA's participation in medical electronics in the RCA Engineer (April-May 1965).

Another important phase of Product Engineering is expressed in the paper by **G. A. Lucchi** on "Airborne Weather Radar." A part of the West Coast Division, the Aviation Equipment Department designs and builds airborne radar systems for both commercial and military uses.

The reader is directed to four valuable Engineering and Research Notes contained in the back portion of this issue. Such notes provide the reader with interesting techniques, circuits, notes, or equations that might never be included in a more comprehensive paper. We appreciate and encourage readers of the RCA Engineer to submit professional notes of this type. Although these papers are short, they usually convey a new circuit or development.

Last but certainly not least, the Editors take this opportunity to extend sincere thanks to all of the readers for their participation in the last readership survey. About 2250 questionnaires were returned by the readers giving valuable information to the Editors to steer the course of future publications. A capsule of the results of the survey is provided in this issue by **P. C. Farbro,** RCA Personnel Research.

In conclusion this issue contains something old, something new in a (hopefully) beneficial, informative, and timely marriage of many technologies.

Future Issues

The next issue of the RCA ENGINEER emphasizes automatic testing. Some of the topics to be covered are:

Languages for automatic test equipment (ATE)
Electro-optics for ATE
Test and process control for high production
A review of automatic testing within RCA
Automatic IC platter testing
The coordinatograph

Discussions of the following themes are planned for future issues:

Computer use in engineering
Electron tubes: power, conversion, color TV
System assurance: product assurance, reliability, maintainability
Microwave devices
Interdisciplinary aspects of modern engineering

The Engineer and the Corporation

RCA Engineering—the first twenty years

F. D. WHITMORE, Technical Publications Administrator
Defense Communications Systems Division, Camden, N.J.

To reflect upon the early pioneering by RCA engineers provides a better perspective for assessing the present and planning the future. The author traces—in an interesting and informative way—some of the challenges overcome by our predecessors during the emergence of radio engineering, broadcasting and television.

ELECTRICAL ENGINEERING began the day man lifted electricity out of the laboratory and put it to work. The date: January 24, 1838. On that day a practical telegraph emerged from the laboratory for demonstration to the world. The breakthrough united in one circuit Italy's *volt*, Germany's *ohm*, France's *ampere*, England's *farad*, and America's *henry* to solve mankind's elusive problem of rapid communication over great distances regardless of weather. Following in quick succession came the telephone, a cable linking Europe, the electric light, and *wireless*.

IN THE BEGINNING

Wireless unleashed a fury of talent, education, and imagination that combined to produce one of the greatest eras of American history. A new science beckoned—radio engineering. As talents and education merged, inventions poured forth and so did lawsuits that lasted for years. To the international vocabulary of electrical terms, wireless added "wavelength", and radiation became a keyword of the day.

Across the Atlantic, British interests signed up Marconi and formed the British Marconi Wireless Telegraph Company. As Marconi experimented with antennas and increased power, the commercial applications stretched wireless communication over greater and greater distances. Pushing their success overseas, the British formed the Marconi Wireless Telegraph Company of America and installed spark stations along the eastern coast of the United States and from Alaska down to the major cities on the west.

The ability to communicate at the speed of light suffered from one great obstacle—static. It plagued wireless operators everywhere. Equipment designers tried many things to eliminate the "ear-splitting" annoyance except the final answer—short waves. The U.S. Patent office even granted one engineer a patent for an underground antenna. (It really worked on long waves!) Believing long waves best, the experts confined their efforts to the low frequencies, and commercial "sparks" and "arcs" served out their lifetime in that range.

SPARKS AND ROTARIES

Spark transmitter design passed through several stages before settling down to the superior synchronized "rotaries". Excited by vibrators at the end of autotransformers, open spark-coils with tuned circuits appeared in ship installations for over 30 years. With more power ever the goal, wireless engineers abandoned the spark coil and invented rotary-spark transmitters powered by transformers immersed in oil. Unsynchronized at first, they emitted rough notes of low penetrating power. Soon, however, the engineers synchronized the charge-and-discharge timing to produce a 500-cycle note that pierced static better and made distance records more dependable. "Rotaries" appeared aboard ships as well as in land stations. Eventually, though, the noisy shipboard "rotaries" succumbed to the quenched-gap spark that buzzed like a mosquito about to sit down.

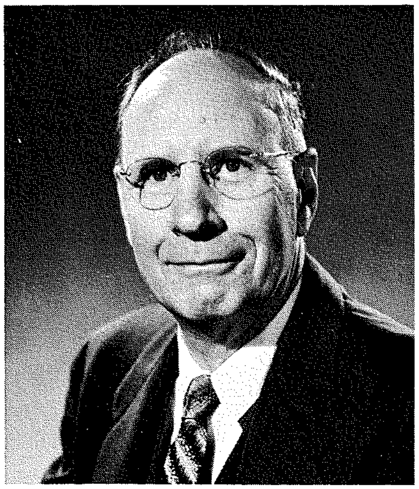
Powerful land stations tolerated the din by housing the "rotaries" in separate buildings nicknamed "thunder houses". Many used 25 kilowatts with big blowers to extinguish the spark between each dot and dash. Tropical Radio in New Orleans combined two 25-kW units and linked the United Fruit Company's vast banana empire together with 50 kilowatts. On clear nights the rhythmic roar escaping that "thunder house" annoyed residents more than a mile away.

On the East coast a pair of 5-kW rotaries sufficed to keep the John Wanamaker stores in New York City and Philadelphia in touch. Youngsters took advantage of the smooth "fists" of those operators to learn the code. Message followed message with never an error or request for repeat. One or two dots acknowledged receipt. Eventually David Sarnoff, the "fist" at the New York City station, rose to head the Radio Corporation of America.

EARLY RECEIVER TECHNIQUES

While one group of engineers, inventors, and experimenters moved transmitter design steadily ahead, another group devoted their efforts to receiver techniques. The coherer, invented by the French physicist Branly for reception of electromagnetic waves, underwent modifications by Marconi who later replaced it with the magnetic detector. Limited to reception of interrupted waves, the coherer gave way to the elctrolytic detector when DeForest modulated an arc

FRANK WHITMORE graduated from Oglethorpe University in 1935 with the AB degree in Liberal Arts. He joined RCA in 1936 as a transmitter tester, and transferred to International Sales in 1938 as a service engineer on the Russian television system contract. In 1941 he became Manager of the Instruction Book department of Special Apparatus. Mr. Whitmore left the Instruction Book department in 1957 to become Manager of Administration Services in DEP, and in 1958 was appointed Technical Publications Administrator for Defense Electronic Products. Mr. Whitmore is now Technical Publications Administrator for DCSD. Author of numerous historical radio articles, Mr. Whitmore's radio experience dates back to the beginning of the broadcast era when he built both crystal and one tube receivers to listen to the early radio programs. In the "thirties" he was a wireless operator in the merchant marine and also an operating engineer in a broadcast station. Mr. Whitmore who currently holds a commercial first class Radio Telephone License, has been active in amateur radio since 1930. His call letters are W2AAA.



Reprint RE-14-1-1/Final manuscript received February 13, 1968.

transmitter and broadcasted a program from the Metropolitan Opera shortly after the turn of the twentieth century. Though capable of either continuous or interrupted wave reception, the electrolytic detector nevertheless experienced only a short life. Discovery about that time of the rectifying ability of certain minerals brought forth the crystal detector with its tantalizing "cat whisker". This cheap, simple detector—the forerunner of solid state engineering—saw service right into the early years of the broadcast era.

In the final years before the start of World War I, experimental tubes improved reception; the hot, temperamental arc transmitters proved the superior penetrating power of continuous waves; Armstrong revolutionized receiver design by inventing the regenerative circuit; and Alexanderson succeeded in combining power with continuous waves through that triumph of mechanical engineering, the high-frequency alternator. This latter achievement set the stage for creation of the Radio Corporation of America. Starting from an original cast of American Marconi engineers, RCA quickly gained momentum as other engineers joined and took over starring roles in the campaign to harness the electron.

Tubes confined to U.S. Signal Corps apparatus during World War I, spread into commercial uses following the Armistice. In 1920, Westinghouse eliminated telegraph charges by handling traffic between their East Pittsburgh and Springfield, Massachusetts, plants with homemade tube transmitters. These master-oscillator/power-amplifier rigs contained tubes without bases. Protruding glass ends at top and bottom of the bulbs snapped into fuse clips wound with asbestos string. General Electric at the time concentrated on a radiotelephone tube design ordered by the U.S. Navy. Engineering in general considered tubes suitable mainly for low-to-medium power, low-frequency, short-distance work. RCA, interested in long-distance communication, moved forward with the Alexanderson alternator.

The Alexanderson high-frequency alternator perfected by the Swedish-American engineer Ernst F. W. Alexanderson and built by GE, occupied a bedplate 10 feet wide by 18 feet long and stood 10 feet high. Three-ton rotors mounted on 8-inch diameter nickel-steel shafts revolved 20,000 r/min to produce up to 26 kilocycles (kHz) at 200 kilowatts. Speed and number of poles determined the exact frequency. Fed into longwire antennas held aloft by a series of towers 450 feet high, the continuous-wave radiations easily reached to distant continents.

RADIO BROADCASTING

Wireless, named "radiotelegraphy" and "radiotelephony" by the U.S. Navy to distinguish between code and voice, intrigued as well as distracted neophyte engineers and college students. Engineering graduates throughout the United States coming East to find work in their field, found radio and tube departments at both Westinghouse and GE. Though armed with EE degrees in power engineering, radio lured them away and they served their apprenticeships in the new field.

The radio activity that student engineers saw at Westinghouse presaged the era of radio broadcasting. But the students didn't see everything. One of Westinghouse's engineers conducted experiments with music and voice over an amateur radio station in his home to the enjoyment of other amateurs and a few experimenters who knew how to build receivers. This activity later developed into the world's pioneer radio broadcast station, KDKA. Licensed to Westinghouse October 27, 1920, KDKA began commercial broadcasting the next month with the Harding-Cox presidential election returns.

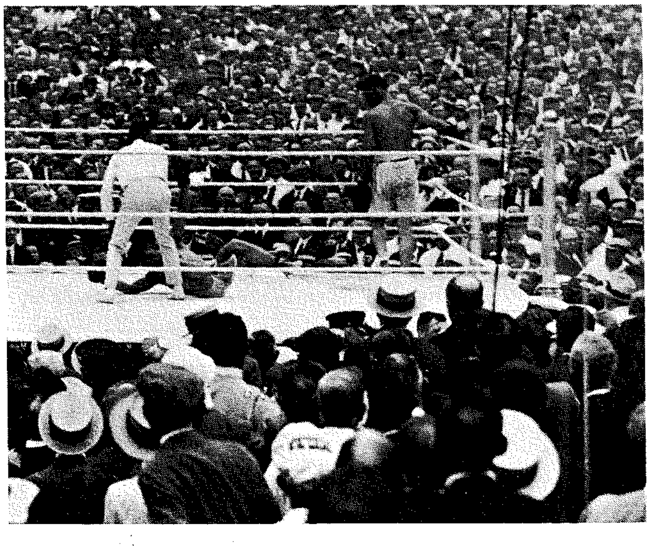
RCA engineers got a taste of radio broadcasting the following summer. The "Battle of the Century" loomed! Jack Dempsey, United States heavyweight champion, would fight Georges Carpentier, the lightning-fast French contender for the heavyweight championship of the world. All sportland wanted to see it. The date: July 2, 1921.

Just three weeks remained until fight time. Between the dignitaries arriving from overseas and the clamoring American public, the 90,000 available tickets for Boyle's Thirty-Acres stadium in Jersey City, New Jersey, disappeared fast. Thousands of disappointed fans remained. Sizing up the situation, certain of RCA's management decided, "if thousands can't get in to see the fight, let's bring the fight out to them" —a gigantic challenge: the broadcasting era didn't start until fall of that year. Needed immediately: 1) permission of Tex Rickard, the fight promoter, 2) a powerful radiophone transmitter to broadcast the fight, 3) enough radio receivers so the receiverless public could listen to the fight!

The eve of the fight found everything ready. The Department of Commerce arranged a clear channel on 1600 meters and assigned call letters WJY for the one-time broadcast. By offering for charity the proceeds received from ticket sales, RCA obtained Tex Rickard's permission. Franklin D. Roosevelt, just recently resigned as Assistant Secretary of the Navy, arranged for RCA to borrow a transmitter just built by General Electric and awaiting shipment to the Navy. And amateur radio operators within a radius of 200 miles converted their receivers to long waves and installed them in theatres, music halls, and auditoriums where sports enthusiasts paid admission to sit and listen to the fight coming direct from ringside. Results exceeded all expectations. Three-hundred thousand fight fans from Maine to Florida heard the broadcast plus ships 1800 miles at sea.

COMMERCIAL LICENSES INCREASE

The Government officially opened the broadcast era with issuance of commercial licenses in September 1921. That fall a handful of broadcast stations went on the air. The Westinghouse plant at Springfield, Massachusetts, received call letters WBZ. There the radiotelegraph personnel improvised. A sliding switch mounted on the panel temporarily converted the two amplifier tubes of the telegraph transmitter to modulators. A lot of wire wound on a bundle of soft iron rods became a Heising modulation choke. Some handwork in the plant's machine shop produced a crude single-button micro-


The end of the Battle of the Century: Dempsey knocked out Carpentier in the fourth—after a second-round fusillade of punches in which Carpentier gave his all, staggered Dempsey but left the Manassas Mauler still standing.

phone. In the early evening they broadcast. Later, the operating personnel yanked the switch converting back to a radiotelegraph set and cleared cw traffic with Pittsburgh the rest of the night.

During 1922 the Department of Commerce issued over 600 commercial broadcast licenses: "K" calls to stations West of the Mississippi, "W" calls in the East. Bitten hard by the "radio bug", the public stopped winding Victrolas and pedaling player pianos and clamored to join the "dial-twisting" gang. RCA's management, enthusiastic for years with the "music box" idea quickly added home-broadcast receiving equipment to the line of amateur radio gear then offered for sale. Under a 60/40 percent manufacturing arrangement, General Electric and Westinghouse built the equipment. Both manufactured receiving tubes as well as receivers.

SHORT WAVES

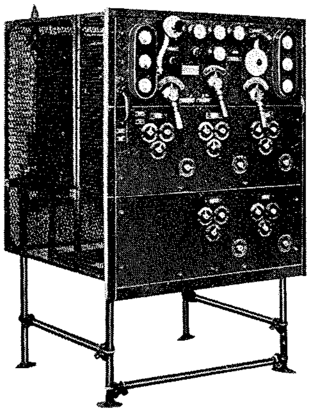
Selling equipment to the amateurs paid off in 1923. Late that year the amateurs awoke the "commercials" to the value of the short waves. A big contest loomed: could amateur shortwave signals hop the Atlantic Ocean on schedule? The American Radio Relay league set up the rules and sent the most experienced short-wave receiver engineer in America to Europe to listen. Huddled beneath a tent by the sea at the rain-soaked site of Ardrossan, Scotland, the American engineer and his Scottish observer tuned the 200-meter band. A switch to a Beverage longwire terminated antenna boosted the amateur signals above the bedlam of European interference. 1BCG of Connecticut got over first and became the first amateur radio station to send a message across the Atlantic. The "commercials" couldn't believe it. A management team from RCA traveled to Connecticut to see the 3-tube transmitter with grasshopper-size antenna that performed such a "miracle" in the shadow of their massive long-wave systems. Following a study by RCA, the appearance of shortwave tube transmitters backed by directional arrays doomed the long-wave era.

RADIO RECEIVERS

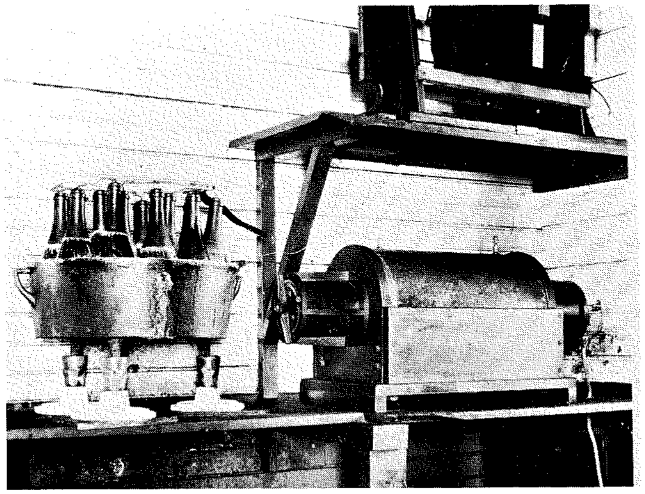
In the early twenties, broadcast receiver merchandising absorbed most of RCA's attention. Competition flourished. On the West Coast—Magnavox; inland—Zenith and Crosley; in the New York-Philadelphia area—Atwater Kent, Paragon, Freed-Eisemann, and numerous others entered the receiver market. RCA met the competition with various Aeriola models manufactured by Westinghouse and similar receivers produced by GE. Shortly after followed coordinated designs bearing the trademark *Radiola*.

The choice of receiver meant little in the beginning. With all broadcast stations operating on 360 meters, cheap, single-circuit engineering designs sufficed. To eliminate interference, stations in the same city shared time during the day or broadcasted on alternate days. At night, when the "locals" signed off, out-of-town stations drifted in. Unfortunately, the out-of-town signals faded badly—the multiwire "T" and inverted "L" flat-tops in use favored high-angle radiation. Much remained for engineers to learn about radiation patterns.

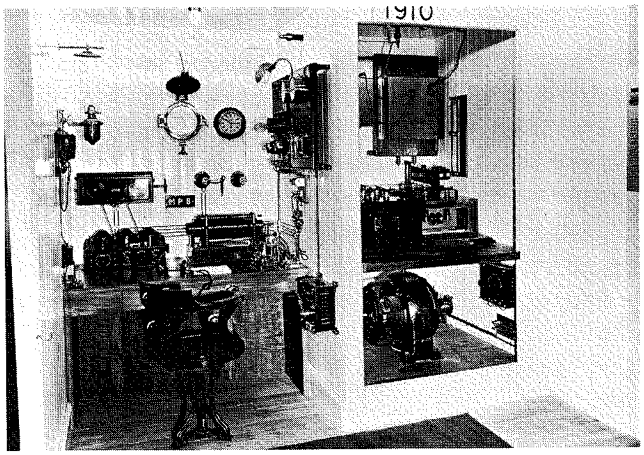
Until formation of the Van Cortlandt Park engineering department by RCA, Westinghouse and General Electric retained their individuality in the receivers sold by RCA. Each company produced a separate line in which only their own tubes worked. Trying to make a profit out of a "split line" put RCA at a competitive disadvantage. RCA balked and pressured General Electric and Westinghouse to form standardizing committees. For the first time standardization



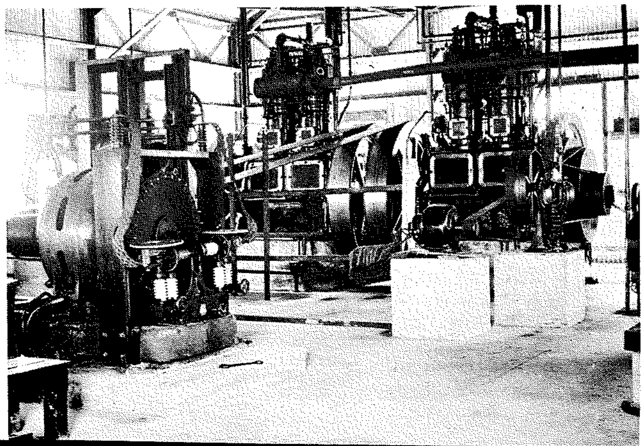
Until 1906, wireless operators sent the distress call "CQD" from these autotransformer, open-spark transmitters. The switch to "SOS" occurred following the 2nd Berlin Conference in 1906.



Wireless operators improvised from the beginning. When the condenser burned out in this Tropical Fruit Company station at Bluefield, Nicaragua in 1906, the personnel made one from champagne bottles set in a pan insulated from the table by whiskey glasses.



High and low power aboard ship. English ship-station MPB contained an open-spark auxiliary on the operator's table and a high power "spark" with boxed in electrodes in the adjoining room.



◀ During the "teens" the Tropical Fruit Company used these 25-kW rotary spark transmitters in Central America to conduct their banana business.

became a part of RCA engineering and the famous *Radiola* line emerged.

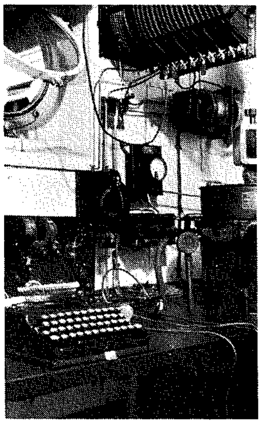
The growth of broadcasting enhanced the trend and showered listeners with many pleasures. Licensing of Class-B stations in 1922 to operate on 400 meters with 500 to 1000 watts provided a second spot on receiver dials for entertainment. The next year the Department of Commerce though lacking the legal power, assigned individual frequencies to the broadcast stations filling the airwaves with programs. RCA engineers working at Van Cortlandt Park invented the magnetic loud speaker that relieved the pressure-sore ears of the public and ended the era of headset splitting so more than one could hear. General Electric engineers improved fidelity by inventing the electrodynamic loud speaker.

Radio stations vying for listener attention broadcasted many "firsts" in their areas: a first church service, a first football game, a first opera program. In October 1926, a highlight occurred: A Philadelphia radio station picked up the Dempsey-Tunney heavyweight championship fight in Philadelphia and fed it to 18 stations from Pittsburgh to New York. The next month RCA formed NBC and listeners gave up distance chasing for the scheduled programs on the network. No longer did rural dwellers set their clocks by the sound of train whistles in the distance; radio synchronized the nation's clocks and spread correct time to every hamlet.

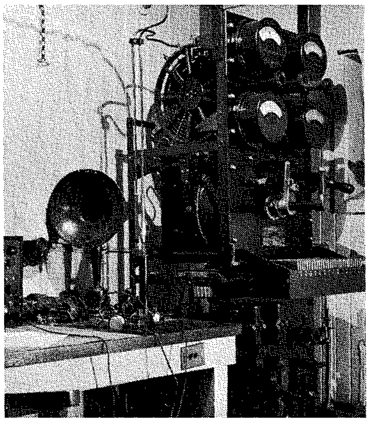
RADIO TUBE DESIGN

Tubes, the heart of all electronic equipment, sometimes followed engineering requirements and other times led the way. Prior to World War I, E. T. Cunningham, Lee DeForest and others manufactured radio tubes for the amateur radio operators. With mortality rates varying anywhere from instantaneous to indefinite, some manufacturers included dual filaments wired separately in a hopeful attempt to prolong life.

In radio tube design, the electrical engineer merged his talents with a battery of physicists, chemists, ceramists and metallurgists. An unimpeded interchange of information passed between the groups. From the early days of, "Here's a tube, find ways to use it," the technique changed by the "thirties" to, "This is what we need, see if you can make it." Different receiving-tube bases with varying pin sizes and quantities disappeared when an electrical engineer stepped across boundaries into mechanical engineering and developed the octal base.



An arc transmitter installation aboard ship. Arcs proved the penetrating power of CW signals over the damped waves of the sparks.



A 2-kW quenched-gap spark transmitter aboard ship. Quenched-gap sparks remained in use aboard ships until the demise of all "sparks" December 31, 1939.

RADIO PROGRAMMING ADVANCES

As network radio spread to the west coast and coast-to-coast programs identified by theme songs became weekly favorites, a new form of entertainment captured the public's enthusiasm —talking motion pictures. "The Jazz Singer" starring Al Jolson introduced the "talkies". The public heard only the songs; the rest of the picture played silent. Dubbed Vitaphone, the sound came from a record that didn't always remain synchronized. Minor misadjustments caused the sound sometimes to follow slightly after lip motion creating a distracting effect. Besides bringing an end to the era of silent pictures, "talkies" also ended the art of the ad-lib piano players who sat in the pit and rendered appropriate mood music as they watched the action and read the supporting captions.

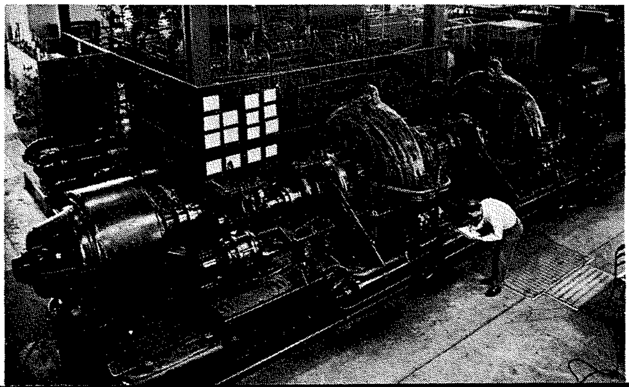
General Electric countered Vitaphone with Photophone. When GE released it from the laboratory in 1928, RCA immediately organized the RCA Photophone Company and entered competition with Western Electric. Photophone used a sound track developed on the side of the film. Sound for each picture frame appeared a certain number of frames behind the image due to the location of the sound head. Snipping a piece of damaged film from a reel couldn't upset synchronization; it only caused a "jump" in sound because of the break in continuity.

Improved sound recording and reproduction solved only two of the three engineering problems associated with the "talkies." The third concerned acoustics. This new field of endeavor for the electronic engineer initiated the little group of RCA engineers at Van Cortlandt Park to the theatre. The challenge: Distribution of sound throughout a conglomeration of auditorium sizes and shapes, and treatment of reflecting surfaces to turn natural reverberation periods into assets.

RADIO CITY

RCA engineers mastered the gamut of theatre variations with the directional baffle. Used singly or in multiple with the custom acoustical treatment of the auditorium, theatre sound throughout became a joy to hear. During the period of changeover from silent pictures to "talkies," RCA's acoustical engineers averaged 150 consultations a year—all free. Backed by such extensive training and experience, the handful of engineers quickly became acknowledged experts in theatre acoustics and culminated this confidence when the architect, during the initial drawing stage, called them in to design the sound system for New York City's Radio City Music Hall.

Started in 1930 and completed in 1932, Radio City Music Hall entertains 80-million people a year. Sixty-two hundred can see a show at one time. The curtain weighs 3 tons and the three-section, adjustable-level stage with turntable in the middle measures 144 feet across by 67 feet deep. The picture screen stands two stories high. In the original speaker system installed behind the screen, three 10-foot long directional baffles cast the sound adequately throughout most of the massive auditorium. To reach the immediate area down front, the engineers mounted a 27-inch speaker directly beneath each of the long horns. A separate sound system with speakers hidden behind theatre decorations re-inforced the stage show. Using velocity microphones designed by RCA engineers, per-



◀ The Alexanderson alternator. Worked in pairs at each installation, these high-power CW transmitters brought about the formation of the Radio Corporation of America.

Broadcast reception started with crystal sets made by both electrical giants. These were followed by the competitive radio receivers of the "twenties" by Atwater Kent, Grebe, Crosley, and Magnavox.

formers dropped the "stage holler" letting the beauty of the natural voice prevail. Even the softness of a crooner's whisper carried to the last row of seats.

SUMMARY OF THE "TWENTIES"

Transmitter design, after progressing from the frequency-shifting modulated oscillators used in the early days of broadcasting and the more stable but still drifting master-oscillator power-amplifier circuits that followed, settled down by the end of the twenties to crystal control with oven-heat regulation. Broadcast engineers discovered the merits of the vertical antenna and the dependability of the ground wave. Fifty-kilowatt transmitters became available. Radio tube engineering gave amateur radio operators the famous 210 triode transmitter tube. Hams discovered that tuned antenna feeders reduced antenna current to milliamperes and increased the radiated power. The first international radiotelegraph conference of 1927 assigned every nation an identifying prefix letter and set up the international amateur bands.

RCA GROWS DESPITE DEPRESSION

In 1929, the year the stock market crashed, RCA bought the Victor Talking Machine Company in Camden, N.J., and took the first step towards integration of the Corporation into a self-contained, self-controlled radio business.

The Victor Company had tried to enter electronics via the Orthophonic Victrola—an electrified Victrola with quite a pronounced hum. However, attempts by the Victor Talking Machine Company to enter the radio business met with little success. They did not even pursue broadcasting following receipt of station license WABU in November 1923. When RCA purchased the Victor Company, it acquired the manufacturing flexibility needed to coordinate sales with production and meet sudden changes by the competition. The purchase ended the three-way split of profits. Besides a factory, RCA gained the remains of a phonograph and record business plus the world renowned Victor "Little Nipper" trademark. Expanding further, RCA added radio tube manufacturing by acquiring General Electric's entire Edison Lamp Works property at Harrison, New Jersey, and the Westinghouse factory at Indianapolis.

While in the wake of the "market crash" an occasional financier still jumped from Wall Street windows, RCA consolidated in the RCA Victor and Radiotron companies all research, engineering, manufacturing, and sales of RCA products, including phonographs and records. To many engineers the move meant an uprooting. As General Electric and Westinghouse divested themselves of the electronic activities assumed by RCA, equipment research and product engineering merged with RCA's Van Cortlandt Park unit and located in Camden, N.J. Receiver-tube engineering transferred to Harrison. Both General Electric and Westinghouse contributed engineers and supervision for transmitters, antennas, audio equipment, studio equipment, television terminal equipment and television and radio receiver design.

HIGH-POWER BROADCASTING

Carrying into the thirties advancements made in the twenties, RCA's concentrated engineering department in Camden, N.J., focused attention on all fields of electronic production and development. Immediately broadcast transmitter engineers got a taste of high power—*five-hundred-thousand watts.* The Federal Radio Commission authorized a rise in power from 50,000 watts for WLW, the Crosley station in Cincinnati, on an experimental basis for a few years.

Early in the decade class-B high-level modulation replaced the less efficient constant-current Heising system and the low-level modulation designs with class-B linear RF amplification. Broadcast antenna engineers applied mathematics to the vertical antenna and mastered the ground wave. Shortly after, engineers wrestled with a power tube enigma: multi-grid transmitter tubes. Government-equipment engineers in Camden struggled to get adequate output from a 500-watt screen-grid tube in A-3 operation. Empirical experiments finally solved the puzzle. From then on engineers knew how to design final transmitter circuits to include modulation of the screen grid as well as the plate.

BETTER RECEIVER SOUND

While the Photophone recording and reproducing engineers continued to improve sound at the movies, home instrument engineers combined the latest achievements to bring excellent sound into the home. Receiver designs worked around a new set of tubes—the 6.3 volt glass line. Radiotron engineers introduced them to replace the 2.5-volt line because they featured better hum control and let the one line suffice for both home receivers and automobile sets. Included for the first time appeared the multi-grid conversion that simplified superheterodyne design and made the compact, transformerless AC/DC radios possible. Shortly after, the 6.3-volt glass tubes gave way to metal tubes.

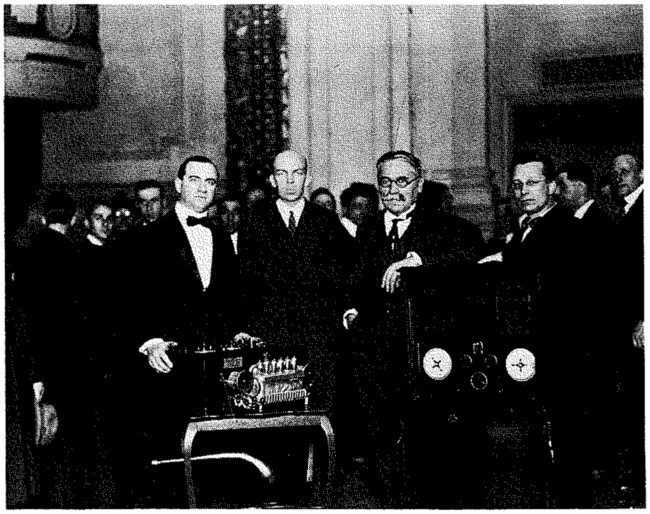
Network affiliation of broadcast stations in all major cities made the same radio programs available everywhere and converted the public from distance-chasing to local listening. Reflecting this trend, engineers simplified station selection by designing receivers with fixed and electric pushbutton tuning. A public craze for short waves in the latter half of the thirties brought the "B and C" short-wave bands to receivers. In some of the more expensive sets the favorite 31-MHz band spread across the whole dial the same as the standard broadcasting scale. Toward the end of the decade, shades of the past arose in reverse. During the twenties RCA sold radios built by Westinghouse and GE. Now, following the return of Westinghouse and General Electric to the radio field, Westinghouse ordered a production run of console radios from RCA.

RECORD AND RECORD PLAYERS

During the thirties, the public became very conscious of good sound. From the rich to the indigent, all shared in the enjoyment. For some of the wealthy, RCA engineers installed quality amplifiers and speaker systems in the private auditoriums of their homes.

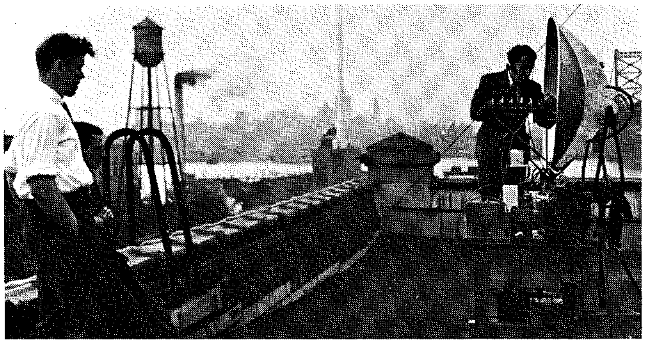
Radio broadcasting, killer in the twenties of the Victor Talking Machine Company's phonograph and record business built both services into big business for RCA in the thirties. With the broadcasting day extending from 6 A.M. until midnight, radio stations turned to records for "fill." For many, record playing became the mainstay of their programs. Listeners, able to hear new tunes practically as fast as they came out, built up libraries of their favorites.

RCA's record players ranged from simple models requiring manual changing of each record to automatic record changers operating alone or in combination with radios. One model, never marketed, played both sides of the record without flipping it over—a separate arm and stylus contacted the under side. Though the state-of-the-art advanced considerably from the first record changer marketed by the Victor Talking Machine Company in 1927, the annoying needle scratch of steel on hard shellac prevailed throughout this decade and most of the next. Not until after World War II did engineers switch to the vinyl record in combination with a lightweight, gem-stylus pickup and obtain the first marked improvement.

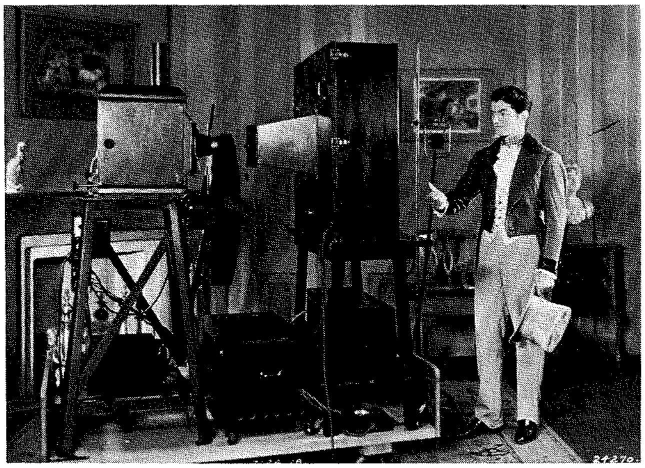


Introducing one of RCA's superheterodynes (standing left to right) are Dr. Alfred N. Goldsmith, Major Armstrong, Pupin, and Morecroft.

Dr. V. K. Zworykin with the Iconoscope camera tube he invented. The Iconoscope tube converted television from the scanning disk to an all-electronic system.



Dr. Irving Wolff testing radar atop building 6 in Camden during the "thirties."



A 1928 studio camera in the scanning-disk days of television.

SPECIAL PRODUCTS

During the latter half of the thirties, RCA delved into many fields of radio before eventually becoming more selective. Engineers designed an automobile radio for Sears Roebuck & Co., that mounted outboard beneath the dash of any car. Another receiver, designed for Buick, featured electric tuning with class-B audio output; it fit into the instrument panel. Unsealed vibrators caused the chief source of trouble in the early automobile sets. Until packaged vibrators became available, assembly line workers adjusted each vibrator individually and engineers struggled to overcome the emitted radio-frequency interference. Aviation-equipment engineers, both government and commercial, flight-tested radio designs in a Ford, tri-motor monoplane owned by the Company.

Another section of engineering designed police radio equipment. The first mobile design obtained power from a generator driven by the automobile fan belt. In an UHF, low-power design that followed, engineers improved voltage regulation by drawing the operating power from the car's storage battery. RCA cultivated amateur radio trade in this decade too. During the early part of the latter half, engineers designed two receivers—one included bandspread on each amateur band then in use—and a 150-watt, multi-band amateur phone/CW transmitter for operation from 160 through 20 meters. Shortly after, about the time beam-power transmitter tubes began to replace transmitter pentodes, RCA dropped the amateur radio line.

While the production engineers applied their skills to consumer products, development engineers explored some of the more mysterious facts of radio with no immediate end use in sight. Non-static broadcasting occupied the attention of a few experimenting with various methods of frequency modulation. Some worked with chemically treated papers and various developers trying to produce an electronic newspaper for the home. Sound engineers experimented with stereo and provided the nine-channel recording system used by Leopold Stokowski when he recorded the music for Walt Disney's film "Fantasia," and also a 120-watt stereo reproducing system reduced to 60 watts for the road shows.

Theatre television engineers ground 30-inch projection lenses at RCA and demonstrated theatre-television projection equipment to dignitaries and stars of the film industry at the New Yorker Theatre on W. 54th Street. Even with all the house lights on, the television pictures stood out clearly visible on the screen. A Belgian engineer who brought his equipment to America and joined RCA, demonstrated the practicality of the electron microscope. Close by, in an unrestricted laboratory, other engineers bounced pulsating signals off neighboring buildings and measured the elapsed time between transmission and the return of the reflected signal. One day, personnel from the Naval Research Laboratory arrived for a demonstration. Immediately following their departure, a sign appeared on the laboratory door reading "SECRET." Behind the restriction, engineers worked on RADAR.

LAND AND MARINE COMMUNICATIONS

RCA's subsidiaries contributed a number of "firsts" in this period too. NBC whose "red" and "blue" networks interlaced the Country, gained naturalism in radio programs by combining studio and auditorium so entertainers could time their material by audience response. Radiomarine engineers concentrated on safety at sea. Spark transmitters, doomed to international extinction by December 31, 1939, dwindled steadily as first the self-rectifying tube conversions—remembered best for emissions of musical, AC modulated, CW tones—then oscillator amplifier CW transmitters extended the dependable range. On the Great Lakes, five-channel radio telephone equipment let ship captains communicate with land stations without carrying a radio operator. For safety in foul weather, diamond shaped direction-finder loops rose from "flying bridges" and guided ships along the coasts or into difficult harbors. And, for ships carrying only one radio operator, automatic alarms tuned to 600 meters maintained watch day and night for SOS distress calls.

During the early experimental days of television, very-high-frequency investigations at RCA Communications laboratories in Rocky Point and Riverhead, Long Island, resulted in a 177-MHz television relay link between the RCA building in Radio City and the transmitter site at the Empire State building. A little later RCA Communications engineers designed a 500-MHz communications link that connected New York City with Philadelphia and featured the innovation of unmanned VHF relay stations at New Brunswick and Mount Holly, N.J. Another symbol of RCA Communications' engineering towered high above the streets of New York City for a number of years—the omni-directional, turnstile television antenna with elements shaped like watermelons. Designed and built at Rocky Point, it mounted on a metal-latticed pedestal atop the dome of the Empire State building and spread NBC's experimental television signals in all directions about the City.

TELEVISION EMERGES

In the closing years of the thirties, RCA's black-and-white all-electronic television beckoned. The public, however, unable to visualize the potential delights in store for them, held back acceptance and missed the pleasures until after the second World War.

Television in America goes back to the early days of radio broadcasting. In those days the spirally-perforated scanning disk prevailed. (Demonstration in 1923 of an electronic pickup tube by a young, Russian-born, Westinghouse engineer (V. K. Zworykin) failed to stimulate Westinghouse interest because of the dim picture, and his management ruled out further research.) The General Electric Company pioneered early television. Late at night after completion of the "radio broadcasting day," GE transmitted narrow-band, experimental television pictures from Schenectady over the Company-owned radio station, WGY. Behind the screen at Proctor's theatre in Schenectady, General Electric engineers duplicated an experiment by RCA in New York City and installed a scanning disk filled with lenses instead of holes and flashed 5x6-foot television pictures on the screen as the current vaudeville actors repeated their acts at a nearby studio. Once, for publicity, GE engineers sent narrow-band TV pictures to Sydney, Australia, and received intelligible pictures right back. At a special presentation early in 1928, General Electric for the first time anywhere demonstrated home-television reception to engineers, scientists, and newspapermen. Later in 1928, Company engineers televised the acceptance speech of Al Smith, governor-elect of New York. In the course of exploring one aspect of television reception, GE engineers measured the movement of secondary images to determine the height and shifting of the Heaviside layer. By not realizing that signals reflected from the Heaviside layer would also reflect from an airplane, RADAR waited another decade for discovery.

Between General Electric's demonstration of home television and the 1939 public introduction by RCA at the New York City World's Fair, eleven years lapsed. During that interval, the pink-tinted pictures enlarged by lenses to 3 inches square and the bell-ringing type push button held in the hand to control synchronization, disappeared in favor of automatic sync and a 12-inch picture reflected from a metal mirror attached to the receiver lid and tilted 45 degrees for viewing.

Television advanced rapidly following formation of the RCA Victor Company in 1930. The scanning disk era ended with RCA's invention of the Iconoscope camera tube. At RCA demonstration of television, strong complaints about the "flicker" in the green-tinted, reflected pictures sounded the death knell for non-interlace scanning and odd-line "interlace" followed. At the time of the RCA demonstration, television still required two complete receivers: one for the AM picture, and one for the AM sound. By 1936, one receiver sufficed for both, white replaced the greenish cast, and scanning reached 343 lines per inch. From 1936 to 1938, RCA-NBC conducted field tests that helped the Federal Communications Commission to set the standards for black-and-white television. And by 1939 when RCA launched television, scanning rested at 441 lines and FM replaced AM sound.

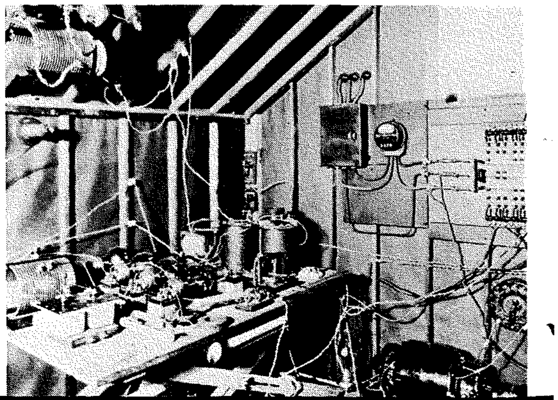
THE WORLD'S FAIR

When the New York City World's Fair opened in April 1939, gay throngs moved about the streets accompanied by sound from the RCA especially designed two-way cubical loud speakers. At the Trylon and Perisphere, symbols of the Fair, the special loudspeaker beneath the Perisphere contained 24 low-frequency units embedded in concrete plus 24 high-frequency units, and radiated sound over a 360 degree angle. Close by stood the RCA exhibit. Inside, a constant stream of visitors passed along a roped-off aisle looking at television pictures reflected from the tilted lids of a battery of TRK-120 receivers lining one wall. Between programs from the Empire State building, the visitors watched television interviews picked up outside by an Iconoscope camera and presented over closed-circuit TV. In another part of the exhibit, RCA introduced the "personalized" radio. Measuring about 10 inches long by 3 inches wide, and 2 inches deep, the hand-held, battery-operated tube receiver featured quality sound from a miniature 2-inch loudspeaker.

During the second year of the Fair, crowds again poured through the RCA exhibit. But the gaiety at the Fair soon passed into consternation and fear. Just as the public became more interested in the miracle of television, war clouds extending over Europe from Russia to the English channel burst into flame. When the Japanese attacked Pearl Harbor, American industry converted to military production and RCA, setting aside television development, girded the electron for battle.

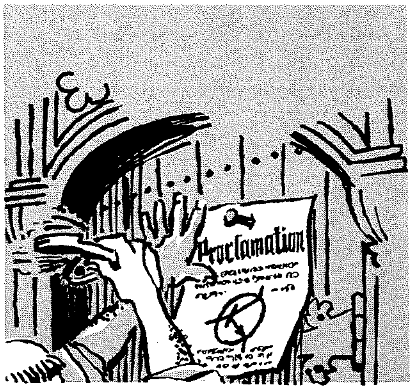
◀ A one-tube battery receiver by Westinghouse.

1BCG, the 1 KW amateur radio transmitter that spanned the Atlantic on 200 meters in 1923 and opened the eyes of the "Commercials" to the value of short waves. ▶



A Modern Electronics Reformation

Dr. George H. Brown
Executive Vice President
Research and Engineering, Princeton, New Jersey



". . . it was the proclamation of the computer and the transistor, nailed figuratively to the doors of electronic research laboratories around the world . . ."

Editor's note: At recent dedication ceremonies of Kelley Hall Research Annex of the University of Rhode Island, Dr. George H. Brown received the honorary degree of Doctor of Engineering and delivered the keynote address at the Annual Student Night of the Rhode Island and Southeastern Massachusetts section of IEEE. Dr. Brown was impressed by the new facilities not only for their elegance and functionalism but also for their sophistication. Dr. Brown traced the development of the electronics industry over the past twenty-five years from "pure science or radio communications or gadgetry" through the unification of diverse disciplines to the present reformation: "Indeed, it was the proclamation of the computer and the transistor, nailed figuratively to the doors of electronics research laboratories around the world, that instigated the reformation currently sweeping the electronics industry."

That portion of Dr. Brown's speech discussing this reformation is reprinted below.

UNLIKE its medieval counterpart of the 14th century, however, the modern electronics reformation is a move towards unity . . . a pulling together of the separate disciplines, devices, systems and applications which make up the science and practice of electronics. Its shibboleths and axioms are *interdisciplinary research, multi-function devices, systems engineering* and so forth. Its emphasis is on combining physics, chemistry, metallurgy, crystallography, electrical engineering and the like to common efforts to produce not gadgets, but whole systems of gadgets . . . using not one phenomenon, but many phenomena . . . with not one purpose, but many purposes in mind.

I have often observed engineers working in our laboratories with scientists—that is, physics graduates, chemistry graduates, math graduates—and at times it was difficult to distinguish the engineers from the scientists, at times their roles were completely interchanged. They simply became intelligent experienced workers who shared technical educations of slightly different disciplines, equally well-grounded in the fundamentals of physical science.

This trend is probably best exemplified in our space program in such undertakings as the Surveyor project wherein solid-state and vacuum tubes phenomena were combined with computer, television, radio and mechanical engineering, to name a few, in order to produce a system that could scan, paw, chemically analyze and even hop about the moon's surface and relay its findings back to earth.

As to the extent of this drive towards unification, it is all-encompassing—made so by virtue of the fact that a common point of view is being used to interpret the functions of all electronic systems, a common language for explaining how these functions are realized, and a common technology for achieving them. The point of view is that all electronic systems are information carriers, the language for describing them is quantum mechanics, and the common technology for achieving them is solid-state processing.

* * *

With the development of a common point of view, a common language and a common technology, it was inevitable that the various electronically based industries—still somewhat separate and distinct—should further merge to produce, at least technologically, a single industry . . . *the electronic industry.*

* * *

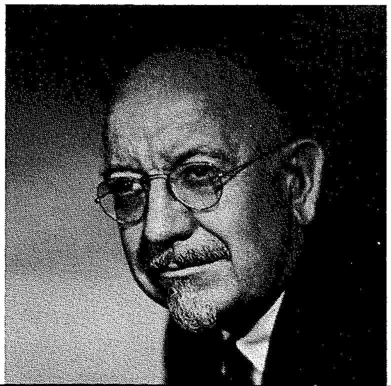
This is not to say that the electronics reformation is merely causing a consolidation to occur among companies and engineering activities which were heretofore distinct. It is also causing these companies to expand with equal force into more and more fields and to diversify their product lines on an escalating scale. This is coming about, I believe, because basic and applied research are finding that the solid state of matter is really an electronic wonderland of unusual energy forms and unsuspected effects that can be harnessed to serve the needs of society in ways never practicable with vacuum technology.

These benefits began to be realized, in fact, from the moment, in 1948, when the transistor was announced. Not only was it a solid-state equivalent of the triode—the first true amplifier of radio waves—but it was incredibly tiny, tough and potentially far more reliable than a vacuum tube.

* * *

The work to perfect and adapt the transistor continued apace through the early 1950's and as the speed with which they could be turned on and off increased, they suggested themselves for use in the emerging computer industry as a solution to the Herculean heat and reliability problems being encountered with tube circuits. Here was a new industry whose requirements were ideally suited to the peculiar advantages of size, cold operation and reliability inherent in the transistor. By 1958, as a result, there were several solid-state computers on the market and solid-state devices and solid-state processing had become fundamental to such equipment.

DR. GEORGE H. BROWN studied at the University of Wisconsin, receiving his BSEE in 1930, his MS in 1931, and his Ph.D. in 1933. In 1962, the University of Wisconsin awarded a Distinguished Service Citation to Dr. Brown for his leadership in industry and engineering. In 1933, Dr. Brown joined the RCA Manufacturing Co. in Camden, N.J., as a research engineer. In 1942 he transferred to the new RCA Laboratories research center at Princeton, N.J. During World War II, Dr. Brown was responsible for important advances in antenna development for military systems, and for the development of radio-frequency heating techniques. He and his associates also developed a method for speeding the production of penicillin. At the end of the war, Dr. Brown received a War Department Certificate of Appreciation "for his outstanding work in the research, design, and development of radio and radar antennas during World War II." From 1948 to 1957, Dr. Brown played a leading part in the direction of RCA's research and development of color and UHF television systems. In 1952, he was appointed Director, Systems Research Laboratory, RCA Laboratories. In 1957, he was appointed Chief Engineer, RCA Commercial Electronic Products Division, Camden, and six months later, Chief Engineer, RCA Industrial Electronic Products. In 1959, he was appointed Vice President, Engineering, Radio Corporation of America, and became Vice President, Research and Engineering, in 1961. He was appointed to his present position in 1965. That same year he was elected to the Board of Directors of RCA. A prolific inventor, Dr. Brown holds 79 U.S. patents; he is included in American Men of Science. Dr. Brown is a Fellow of the IEEE and the American Association for the Advancement of Science, and a member of Sigma Xi, the Franklin Institute, and the National Academy of Engineering. He is a Registered Professional Engineer of the State of New Jersey.



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Blue-Chip Program integrated microwave circuits

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The Blue-Chip Program, conceived and directed by the Laboratories and participated in by a number of other Divisions, has as its goal the development of techniques for fabrication of an integrated solid-state microwave transmit-receive module. The module and associated techniques were designed to meet a variety of impending systems and circuit application requirements within RCA. This paper describes the progress made on the program and gives a brief insight into the future of microwave integrated circuits.

THE REVOLUTION in the electronics industry brought on by the advent of IC's is about to spread into the microwave area. Many of the future airborne, manpacked and space systems will require the small size, high reliability and low cost promised by microwave integrated circuits.

Over the past several years a large segment of the microwave industry has been engaged in R&D programs to extend integration to microwave frequencies. RCA's efforts in this field have been centered in a corporate-wide endeavor—the Blue-Chip Program. This program was directed by the Laboratories and participated in by the Laboratories and various divisions.

The organization of the program is shown in Fig. 1. A broad-scope participation was required to combine the systems, device and technology talents of the Corporation, as well as to assure the timely utilization of new techniques by particular segments of the Corporation.

The function of the Laboratories was to coordinate and direct the overall program, develop basic technology and also to integrate microwave transistor amplifiers and circulators. The function of the Defense Communications Systems Division was to develop integrated mixers and multipliers. Microwave Applied Research in conjunction with the Laboratories developed an integrated tunnel-diode amplifier. The Missile and Surface Radar Division developed a phase shifter and the Aerospace Systems Division a T/R switch. The Astro-Electronics Division contributed an engineer to work with the Labs on the amplifier integration. In addition, some Divisions have had active study programs on airborne and ground-based radar systems using microwave integrated circuits.

The program was started in February 1966 and will conclude during 1968 with the technique applications being continued by the contributing divisions. The goal of the program is to achieve a transmitter power output of 1 to 2 watts at 9 GHz and a receiver noise figure of 6 dB.

INTEGRATED MODULE

A module was conceived to serve as a vehicle for developing the technology, circuits, and systems based on microwave integrated circuits. The module is illustrated in Fig. 2 which shows an X-band front end consisting of a transmitter and a receiver. The S-band input to the transmitter is amplified to several watts and then frequency multiplied to X-band. The receiver contains a tunnel-diode amplifier with a four-port circulator, a balanced mixer, and a 500-MHz IF amplifier. The local oscillator is generated by frequency multiplying an S-band drive signal which may be derived from the source used to drive the transmitter when phase coherence is required. Fig. 2 also shows phase shifters and logic and a T/R switch. These are

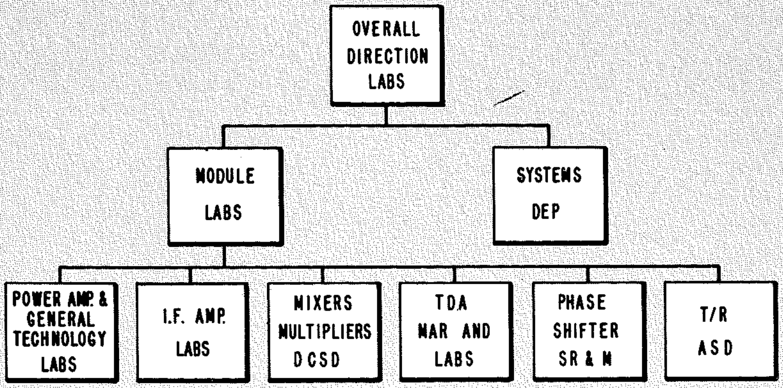

Fig. 1—Blue-chip program, chart of participating activities.

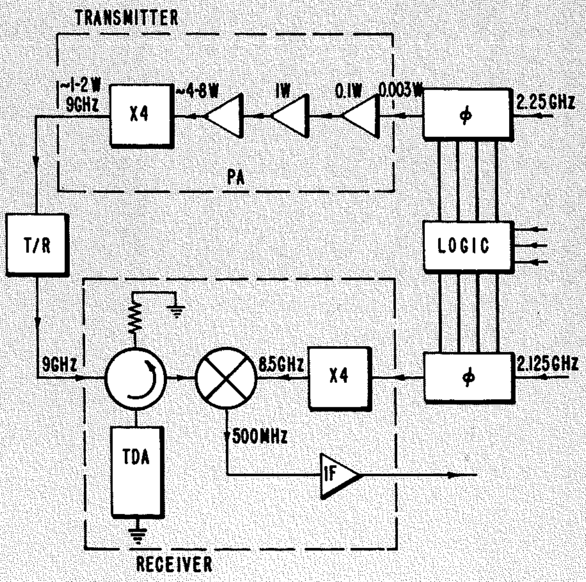

Fig. 2—X-band transmit-receive module.

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* *Now Manager, Microwave Microelectronics, Electronic Components, Somerville.*

used when a large ensemble of modules is assembled on approximately a $\lambda/2$ modulus to form a phased-array radar. One or a few modules may be used for lower power systems.

A module of this type can form the basis of a large number of systems. The power amplifier and IF amplifier are nearly universal components. The order of multiplication can be changed to obtain output frequencies from S- to X-band. It is this nearly-universal character of the modules that may allow, through the use of batch fabrication, the low cost required for cost-effective solid-state systems. Typically, in a radar system, the entire cost of the module must be of the order of $100.

TECHNOLOGY FOR MIC'S

Because the module was intended for a variety of systems with various orders of frequency multiplication, hybrid technology was used for all circuits developed under the Blue-Chip program. As a result, in contrast to the case of monolithic integrated circuits, minor changes are easily achieved. The X-band circuits are fabricated by depositing metallic films on alumina substrates 25 mils thick and then photo-etching the desired pattern. A thin (about 200 Å) chromium layer for adherence to the alumina is vacuum deposited. This is followed by several skin depths (5 to 10μ) of copper or gold. The copper or gold film can be vacuum deposited or plated. The X-band circulator developed on the program used garnet rather than alumina for the substrate.

Transmission lines on ceramic were used for the X-band circuitry. For S-band and lower-frequency circuits, lumped passive elements were deposited on sapphire or alumina substrates to conserve space. It is possible by using precision photolithographic techniques to make minute coils (0.02 to 0.04 inch OD) and capacitors that are truly free of distributed effects at S-band frequencies. Inductors have been fabricated with Q's of 100 and capacitors with Q's of 50. The capacitors were fabricated with chromium-copper electrodes and low-temperature deposited SiO_2. The relatively low capacitor Q is attributed to impurities in the SiO_2.

As noted above, lumped-element circuits are smaller than their microstrip equivalents by as much as a factor of 5 to 10. This great size reduction is important because the production cost of the circuits depends on the number that can be processed simultaneously and with small circuits the number per ceramic wafer is high, of the order of 40. Furthermore, the small size makes hermetic sealing of the circuit easier.

EXAMPLES OF MIC'S

Several receiver modules have been fabricated and tested. A complete receiver using four substrates: a garnet circulator substrate; a ceramic tunnel-diode amplifier substrate; a ceramic microwave substrate with a Schottky-Barrier diode mixer, times four multiplier and bandpass filter; and a sapphire IF amplifier substrate is shown in Fig. 3. The entire receiver is assembled on a 1 inch by 1½ inch copper block. The measured noise figures have been between 6 and 7 dB, which are close to the program goal of 6 dB. The insertion gain of the receiver is 38 dB.

The X-band circulator has nearly 30% bandwidth for greater than 20-dB isolation with less than 0.5-dB insertion loss across the band. The tunnel-diode amplifier is operated with a gain of 12 to 15 dB and has a 6-dB noise figure. The IF amplifier is a four-stage direct-coupled amplifier. The circuit is fabricated in hybrid form on a sapphire substrate using chromium, copper, gold and SiO_2 films. Forty-two amplifiers are simultaneously fabricated on a 1x1 inch sapphire starting wafer. The amplifier, with the proper thin-film element matching-network has exhibited a flat gain of 30 dB over hundreds of megacycles. A noise figure of 2.5 has been achieved at 500 MHz.

The mixer and multiplier are simultaneously defined on a 1x1x0.025 inch alumina substrate. The mixer uses two shunt-mounted Schottky-Barrier diodes in a balanced configuration and has exhibited noise figures of 7 to 8 dB. The multiplier is a 1-2-4 quadrupler with a shunt-mounted varactor. Typical efficiencies at the 5 to 10 milliwatt X-band output level are 15%. A higher power version of the mixer for use in preliminary transmitter tests has exhibited 20% efficiency.

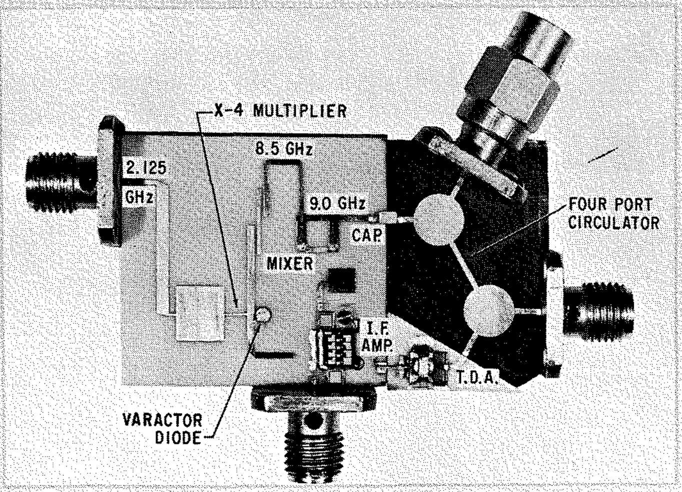

Fig. 3—Blue-chip integrated receiver.

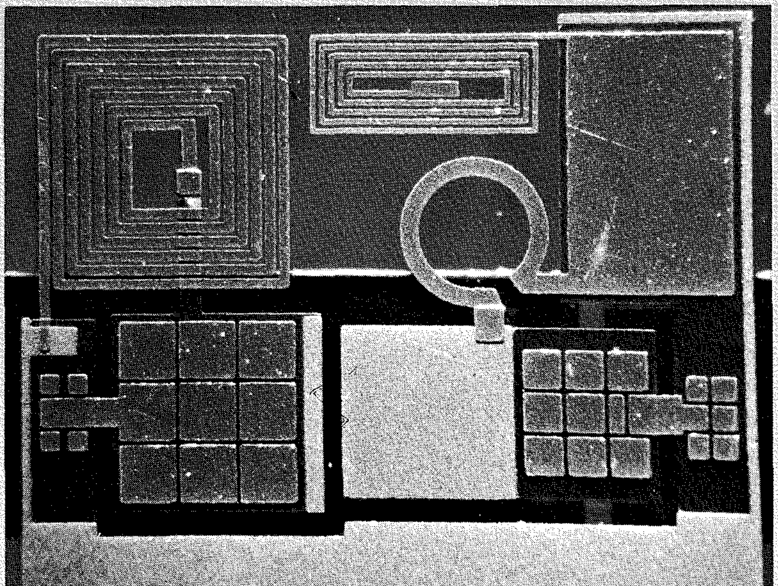

Fig. 4—Blue-chip integrated S-band power amplifier.

Several stages of the transmitter S-band power amplifier have been fabricated and tested. Each stage is a lumped-constant thin-film hybrid integrated circuit measuring 0.12 inch by 0.16 inch. Twenty-five amplifiers are simultaneously fabricated on a 1 inch by ¾ inch sapphire substrate. A typical single-stage amplifier is shown in Fig. 4. As Class-C amplifiers, power outputs of 1 watt with 32% collector efficiency and nearly 5 dB of gain have been achieved. Greater than 10 dB of gain has been measured when two Class-C stages were connected in cascade. Low-level Class-A stages have been built and have produced nearly 13 dB of gain. A Class-A amplifier has been used to drive a Class-C amplifier and a power output of 0.6 watt with 17-dB gain has been achieved. A 1-watt, 30-dB gain amplifier is currently being assembled. The final 4- to 8-watt stage will be added when the transistor currently under development at Electronic Components, Somerville is available.

Several hybrid integrated phase shifters have been built and tested. The S-band analog phase shifters worked well and produced the required 90° phase-shift. Single-bit, digital phase shifters have also been tested. Preliminary experiments have been performed on an X-band T/R switch.

THE FUTURE

Much of the technology required for fabricating microwave integrated circuits has been developed and many good-performance operating circuits have been demonstrated in the Laboratories. The next step is to engineer the modules so that they can be produced in required quantities in a form suitable for systems application. Since the engineering work is best done in the Division that will produce the modules, the Laboratories will phase out of the program during 1968. Much of the work has been transferred to the Microwave-Microelectronics Department of Electronic Components in Somerville. At the same time, a substantial effort to define and "bread-board" modules to meet specific needs is being started in DEP's Defense Microelectronics Group, also in Somerville. With these two organizations in close proximity, close cooperation between EC and DEP will be insured.

The systems divisions have continuing programs on applications of modules to specific systems. These systems will probably appear as operational equipment in the early and mid 70's. All of the systems are characterized by the following:

1) The required power is achieved by combining the power output of many power sources.
2) The required beam width is achieved by virtue of the many power sources.
3) The beam can be steered by phasing the drive to individual elements.
4) Individual modules are highly reliable and random failures of modules in the array do not result in catastrophic failures. Rather, system performance degrades gracefully, i.e., the beam degrades somewhat, the noise level rises a little and the radar range is practically unaffected.
5) Multi-function systems are possible. By proper signal processing and distribution to modules a number of radar and communication functions can be performed by the same system.

With these characteristics, it can be seen that the solid-state phased-array approach to modular systems promises a number of advantages, not the least of which are long life and high reliability.

In the future we will also see advances in the technology. The newer microwave devices, Gunn and Avalanche diodes, will be incorporated into integrated functional blocks. More work will be done on monolithic circuits. Monolithic circuits on semi-insulating GaAs will probably play an important role. Integrating the circuit directly with the device will play an important role in extending the frequency performance of many devices because it will result in a significant reduction in parasitics.

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Dr. Nergaard

Dr. Sobol

The Impact of Integrated Circuits on Electronics

T. A. SMITH, Executive Vice President
Corporate Planning, Camden, N.J.

Just as vacuum tubes, and later solid state devices, changed the electronics industry, so the integrated circuit promises to re-vamp present ideas. We should not only accept the integrated circuit as a compact low-power replacecment for present circuits, we should also re-examine the traditional relationships between components that are carry-overs from tube and transistor technology.

THE ELECTRONICS INDUSTRY has steadily developed through an ever-widening scope of diversified applications. From communications and broadcasting, it has grown into navigation, information processing, industrial control, and a variety of military uses. To a fairly major degree, the adaptability of electronics to new fields has been made possible because of the development of new active components.

VACUUM TUBES

Traditional electronics was based upon the principle of thermionic conduction. Initial general purpose vacuum tubes have been followed by an enormous variety of highly specialized tubes, such as power tubes of all types, energy conversion tubes, display tubes, microwave tubes, and many others. The availability of specialized thermionic tubes has permitted the development of systems, such as television for example, and so, increased specialization of tube functions has played a major role in the creation of new enterprises employing electronics.

At the same time, there has been some development of tubes into multiple function devices, both to accomplish improved results and to reduce costs. Thus including rectifiers and amplifiers within the same glass envelope saves costs; combining a light sensing element with a photomultiplier produces both energy conversion and amplification. Broadly, however, vacuum tubes show only moderate development into multiple function devices.

SOLID STATE DEVICES

New electronics is moving increasingly in the direction of solid state active devices. Here, too, a variety of specialized semiconductor elements is emerging, and these also will lead to many new application opportunities.

Development of semiconductors to operate at higher frequencies, handle more power, function as energy conversion devices, and perform a wide variety of digital functions, has already resulted in improved products with higher performance and, in some cases, with substantially lower costs than the equivalent equipments which used vacuum tubes. One example is that of small portable radio receivers where greatly increased sales have resulted from the use of transistors rather than tubes. Another example is the marked improvement in computer cost/performance with the advent of semiconductors. For the most part, however, semiconductors have been employed to produce the same kind of products as previously existed.

Semiconductors lend themselves to arrangements as multi-function devices in which large numbers of active elements,

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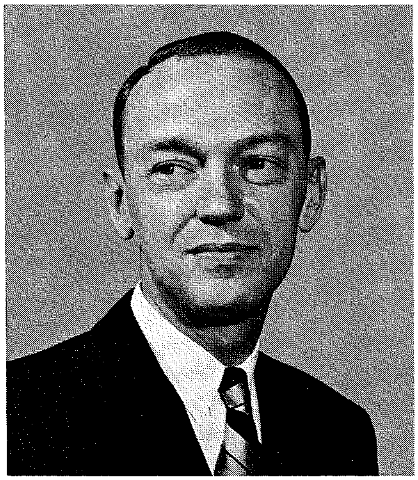
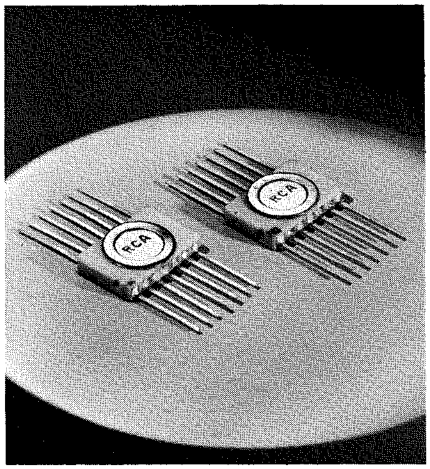
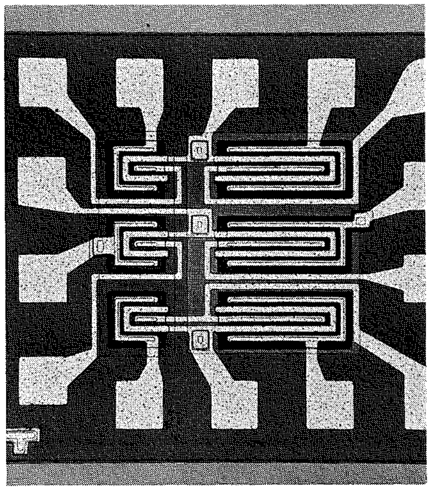
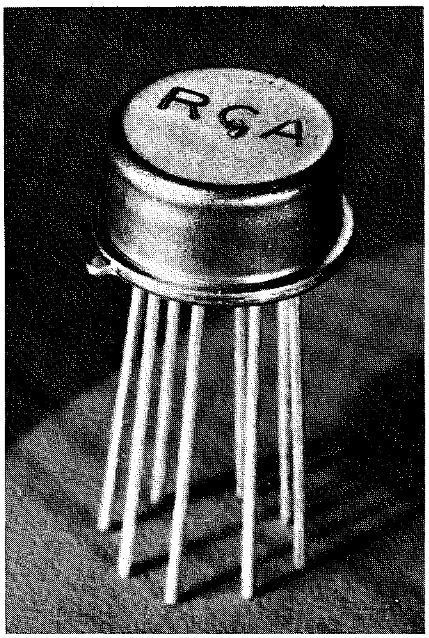








together with interwiring and some passive elements, can be produced as units and used to accomplish complex objectives. Such arrays, or integrated circuits, offer advances in capability orders of magnitude greater than multi-element vacuum tubes.

When new, extremely powerful devices are developed, they are usually applied initially as substitutes for previously existing devices. Thus vacuum tubes were first employed as substitutes for crystal detectors in radio receivers. Not until thermionic tubes were better understood and application engineering was more fully developed, could the versatility of the tube be realized. At this point, a wide variety of new applications and new functions came into being.

It has been observed that the rate of initial application of new developments is often overestimated but that the scope of final application is often underestimated.

INTEGRATED CIRCUITS

While the value of integrated circuits for military applications and for computers has been so great as to result in forced-draft production and application—in a much shorter time than would normally occur—techniques for both production and application are still changing. Until there is a higher degree of stabilization, it is likely that most applications of integrated circuits will be as substitutes for older device functions.

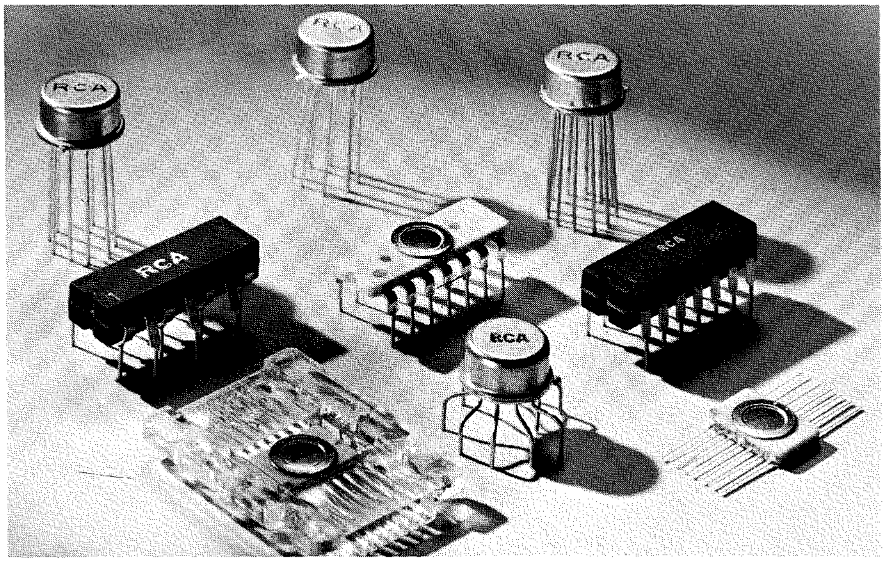
As Harry Kihn has pointed out,[1] the advent of integrated circuits has already caused changes in device and circuit engineering approaches. Yet this is not the end: full exploitation of the potential of integrated circuits will require thought as to their ability to perform entirely new services as well as a thorough re-examination of all other electronic elements relating to integrated circuits which are heritages from the vacuum tube era. It is not too early to consider such matters.

MULTI-FUNCTION IC'S

One may think of the characteristics of integrated circuits which distinguish them from earlier active devices and then attempt to relate the advantages offered to needs which have not been fully satisfied or to functions which were impractical of accomplishment in the past. For example, integrated circuits offer advantages in terms of compactness, light weight, low power, and high reliability. A concomitant factor is that they permit the performance of very complex functions that would have been impractical in the vacuum tube era. They are adaptable to both analog and digital use although, to date, digital applications have prevailed. If desired, they can function as memory elements. They are especially economic when used in the form of repetitive circuits. While presently considered largely for non-terminal circuitry, there would seem to be no reason that they may not find wide use when combined with energy conversion elements, for example, phonograph pickups combined with integrated amplifiers have already been constructed. Perhaps arrays of circuits together with sound converters might be advantageous for sound reproduction. Similarly optical energy converters might be made as a part of integrated circuits.

COST

Obviously, integrated circuits have some disadvantages, too. Presently they are not economical for all purposes and yet past experience has shown that as manufacturing techniques are perfected and volume increases, costs can be reduced substantially. The material cost content of integrated circuits is low, automated production techniques are evolving, and obviously as production techniques provide better yield, increased volume alone tends to push down costs. One industry observer states that in the case of semiconductors, a plot of average price against cumulative units produced forms a straight line on log-log paper.



This photo shows some of the various packages used for integrated circuits: a) ten-lead TO-5; b) nine-lead TO-5; c) twelve-lead TO-5; d) dual in-line plastic (formed leads); e) dual in-line ceramic; f) dual in-line plastic; g) flat-pack in carrier (standard shipping container); h) TO-5 with formed leads, and i) flat pack.

The technique of interwiring large numbers of integrated circuits is relatively new and presently forms a major cost element. Here, too, as experience is gained and as techniques are perfected, costs will come down. With time, it is reasonable to expect that the designer will have available not only a very versatile element but also one that provides low cost per function.

Integrated circuits are limited in other ways. Performance qualities such as linearity, operation at higher frequencies and power handling capabilities are problems, but it is interesting to recall that these factors were also considered as a deterrent to the use of transistors in their early stages of development.

As Harry Kihn also pointed out,[1] design considerations are made more difficult because elements of the circuit are interdependent; they must be considered in relationship to all other circuit elements on the chip.

While time must elapse before the full benefits of integrated circuits can be realized, it is useful to speculate on the opportunities that may be opened up and the requirements that must be satisfied in order to take full advantage of large scale integrated circuits. It would seem that there are two areas to consider.

The first is to think of possible future applications—not merely where integrated circuits can be substituted in present products but where they could greatly change the format of the product—and also to think of entirely new products that do not now exist.

LARGE SCALE INTEGRATION

The use of integrated circuits, particularly large scale integrated (LSI) circuits, should make it possible to produce electronic devices having considerable sophistication. Some of these new products may include elaborate control systems, and it is likely that such products will incorporate both analog and digital elements. Integrated circuits are appealing for use in portable or transportable communications devices where it may be desirable to select, encode or decode and perhaps even process some of the information. They might be used for scrambling voice information on commercial radio transmissions to provide a moderate level of privacy. Perhaps they could enable more efficient use to be made of frequency channels for mobile voice communications, either by compression techniques or by substituting coded signals for commonly used information. They may permit the use of cordless communications devices to a greater degree than in the past. The telephone company has already given hints of portable telephone instruments.

ELECTRONIC AND NON-ELECTRONIC USES

Products employing integrated circuits will offer advantages for the handling of information or for the control of both electronic and non-electronic functions. They may, for example, process some kinds of information locally but then be able to connect to other information systems for additional operations. Small table-model calculators are beginning to employ integrated circuits. Conceivably these calculators may eventually form terminals for connection through communication lines to time sharing systems for computations beyond the ability of local devices. Since information handling is becoming an increasingly important element in our civilization—whether the information be in the form of data, entertainment material, educational, personal or business—it seems likely that integrated circuits will play an increasingly important role because of their extraordinary utility.

Similarly, they could be useful in controlling non-electronic devices of various kinds, particularly where adjustment of the operation is desirable. Control of appliances or electro-mechanical systems might be one such field. They may be used to control isolated, standby-power sources or other stand-alone systems.

SIZE FACTORS

A wide variety of digital measuring instruments have become available and integrated circuits could be useful in reducing the size of these devices and perhaps eventually the cost. In addition, they offer the possibility of analyzing or processing some of the data as well as merely displaying or recording it. Similarly, they could facilitate the introduction of partly processed data into computers. Applications where small size is vital, such as medical devices applied to the person, are already being considered.

Because efficiency of integrated circuits is relatively high, power requirements are at a minimum and so battery power is a convenient method of operation. Thus products that are small and capable of performing sophisticated functions can be portable as well.

APPLICATION CHALLENGES

However, many of the control and terminal devices now available for electronic circuitry are heritages of the vacuum tube era. Some of the control devices, such as variable condensers used as a part of tank circuits to provide selectivity, are ill adapted for use with integrated circuits. While electrically controlled capacitative elements are now useful for higher radio frequencies, it seems likely that circuit logic better adapted to the nature of integrated circuits will evolve.

In analog systems, terminal elements such as displays and energy converters of various kinds must be developed, when the state of the art permits, in order to realize the full advantage of large scale circuit arrays.

One of the problem areas in the television entertainment system is the receiving antenna. In many instances it is difficult to avoid RF reflections that mar picture quality. Arrays of antenna and semiconductor elements are already being used for radar. Perhaps combined arrays or other circuit systems might be used to improve reception.

One may look to a number of developments of terminal devices that could lead to a variety of new fields in which integrated circuits could be applied. In many instances, the principle of new terminal devices is known, but much further work is required to attain commercial performance and cost.

In the interim, more and more use of integrated circuits in data processors and in military and space equipment can help to stabilize production methods. Use of integrated circuits as elements of commercial designs, as they can be justified, will give designers experience in applying them. The development of new terminal devices promises more effective products in the future, and research on new methods to perform the required logic functions in analog systems is likely to lead to quite different product structure. As costs become lower, entirely new kinds of electronic devices will emerge, made feasible by the special properties of integrated circuits, as a consequence of which the uses of electronics will diffuse into additional new fields.

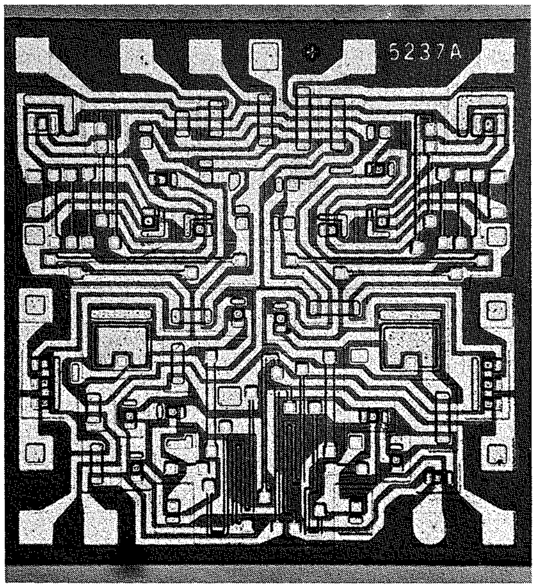
THE FUTURE

Obviously, speculations as to future developments cannot be accurate and both technological progress and economics will set the pattern. Nevertheless there is value in considering what might be worthwhile doing, if technology permits.

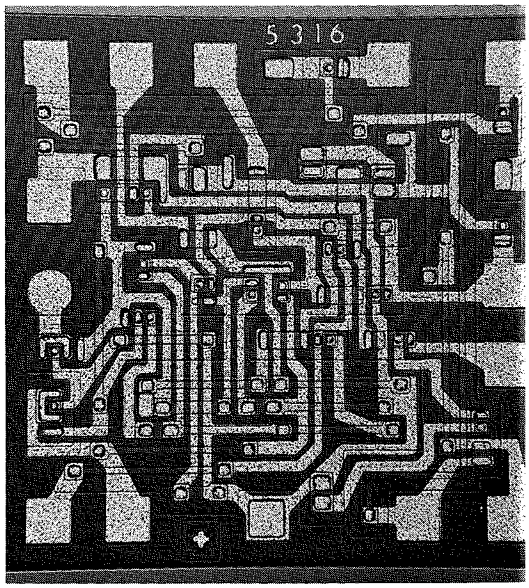
It is difficult to predict which of the various technological approaches will win acceptance and the technological challenge is a major one—to solve the component economic problem—to provide lower cost interconnection systems—to revise older design techniques—to provide more effective equipment logic—and to contrive more suitable control and terminal elements. This is the broad challenge facing the electronics industry today. When such problems are solved, the nature of the industry will have undergone a major change.

REFERENCE

1. Kihn, H., "The Impact of Integrated Circuits on Engineering," *RCA Reprint PE-382, Integrated Circuits.*



Low power DTL circuit.



TV sound IF system.

Monolithic Linear Integrated Circuits—yesterday, today, and tomorrow

M. V. HOOVER, Mgr.
Market Planning
Electronic Components, Somerville, N. J.

In 1959, integrated circuits meant **microscopic** electronics . . . and scientists were interested.

In 1961, integrated circuits meant **more reliable** electronics . . . and the military became excited.

By 1965, a predictable, reproducible, and economical processing technology had made it evident that integrated circuits could also mean **low-cost** electronics . . . and the beginning of another revolution had been wrought by the electronics industry: first tubes, then transistors, and now integrated circuits with every indication that the science of electronics could make its greatest impacts to date on mankind's technologies.

SINCE there has been considerable confusion of terms used in connection with integrated circuits, it is germane to review definitions of terms at the outset. An integrated circuit (IC) may be defined as "a combination of interconnected circuit elements inseparably associated *on* or *within* a continuous substrate." IC's may be classified, in terms of their *functional* end-use, into two major families:

Digital: A family of circuits that operates effectively as "on-off" switches. These circuits are most frequently used in computers to count or compute in accordance with the absence or presence of a signal.

Linear (analog): A family of circuits that operates on an electrical signal to change its shape, increase its strength (amplitude), or modify it for a specific end-function.

A simple example of lamp-bulb control illustrates these definitions. The capability of a *digital* circuit is restricted to "on-off" switching of the light; a *linear* circuit is capable of continuously varying lamp brilliance in the manner of a theatre light-dimmer. In essence, *digital* circuits operate with discontinuous response; *linear* circuits operate with a continuous, proportional response.

Integrated circuits may also be classified in accordance with their *degree* of integration:

Monolithic: IC's in which "active" electronic elements (transistors and/or diodes) are fabricated upon or within a *single* semiconductor substrate (e.g., silicon), usually together with "passive" elements (resistors and/or capacitors), where at least one of the elements is formed *within* the semiconductor substrate. Selective chemical diffusion is employed in fabricating both the "active" and "passive" elements on a single chip. Diffusion is followed by processes through which metallization patterns are formed as a means of interconnecting the various elements.

Hybrid (e.g., mutichip circuits): A complete electronic circuit in which a multiplicity of separately manufactured components is arrayed on a suitable passive substrate (e.g., ceramic) and interconnected by metallization patterns and/or very fine wires. A hybrid may be defined succinctly as any combination of two or more of the following: an active-substrate IC, a passive-substrate IC, discrete components. Currently, individual discrete transistors are used in most hybrid IC's; passive components usually take the form of discrete resistors or capacitors although thin-film and thick-film passive components are also being used. A hybrid IC may also consist of one or more monolithic IC chips housed in a single package with assorted ancillary components. Future hybrid designs will undoubtedly employ pluralities of monolithic IC chips as the prime active electronic constituents.

A definition of the monolithic linear integrated circuit (LIC) may be formed, then, by combining the information for the *linear* family of circuits with the discussion of *monolithic* integration.

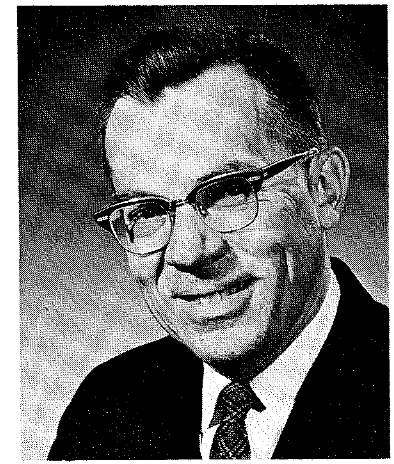
LIC HISTORY

A monolithic LIC was developed during 1958-59 at Texas Instruments (TI). At that time, integrated circuits (both digital and linear) were known as "solid-circuit semiconductor networks." Developments in LIC's were relatively few until 1962 when TI received a contract from the Autonetics Division of North American Aviation for devices to be used in the Air Force's Minuteman program. In December, 1962, TI introduced the first off-the-shelf monolithic LIC's—operational amplifiers with a gain of 62 dB and an upper-frequency capability of about 60 kHz. By 1965, two other firms were introducing LIC's which were forerunners of future major-product lines. In 1965, Fairchild introduced its 700 Series —in particular the 702 and the 709 operational amplifiers. The several manufacturers of the 709-type have sold more of those devices to date than any other LIC product. Also in 1965, RCA introduced the first members of its CA3000 Series—a series particularly intended for communications applications.

THE DIFFERENTIAL AMPLIFIER

The differential amplifier (sometimes called the balanced amplifier) is the primary circuit used in most LIC designs from simple audio amplifiers to multi-function high-frequency "subsystems

M. V. HOOVER received the AB in Physics from Susquehanna University in 1941 and the MA from George Washington University in 1946. During World War II he served as a Radio Engineer at the Naval Research Laboratory, attached to the Transmitter Division. From 1946-48 he was an Instructor in the Physics Department at Susquehanna University. Mr. Hoover joined RCA at Lancaster, Penna., in 1948 to work as an advanced development engineer with a group of engineers engaged in pioneering super-power electronics in power tubes. The work of this group came to fruition in the development of grid-controlled super-power tubes for use in communications, radar and particle accelerator applications. He held a variety of engineering and managerial positions at RCA Lancaster during the period from 1948-66. Mr. Hoover transferred to RCA Somerville in 1966 to engage in the Market Planning of Linear Integrated Circuits. He is currently Manager of Market Planning for linear integrated circuits and MOS transistors. Mr. Hoover is the author of several papers in the literature of Super-Power Electronics, holds 13 patents, and was awarded the Navy Distinguished Medal for "new transmitter circuit developments" during World War II. He is a member of the IEEE and Tau Kappa Alpha.



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LIC's" used in communications applications. Circuit designers have long recognized the versatility and signal-processing advantages of differential amplifiers. With its capability to function from DC to at least 200 MHz, it amplifies, mixes, detects, limits, modulates, compares, and controls a choice of load components, such as tuned-tank circuits or resistors. The differential amplifier (Fig. 1) consists of two symmetrically arranged "half-circuits," each with a transistor (*Q1* or *Q2*) and load resistor (*RL1* or *RL2*). A "balance" exists to the degree that these halves match; mismatched components result in "parameter offsets" which restrict achievement of quintessence in circuit performance. Thus, if the two transistors (*Q1* and *Q2*) match each other in characteristics and are supplied from identical voltage sources (*V1* and *V2*), equal currents will flow through the load resistors (*RL1* and *RL2*) provided they too are of equal value. Optimum circuit simplicity and performance are achieved as increasingly better balance is achieved in these several components.

Although the virtues of the differential amplifier have been recognized for many years, "matched components" have been difficult (consequently expensive) to produce according to the tight specifications required. The same "matched component" problem exists for both tube and discrete transistor differential-amplifier circuits. The perfection of monolithic IC technology has resulted in the simple (and economic) reproduction of transistors with remarkable similar characteristics on the same silicon chip. Likewise, resistors with comparatively good match can be produced simultaneously on the chip by monolithic processes. Furthermore, because the elements (transistors or resistors) are fabricated on a single silicon chip in close proximity, thermal gradients are minimized and "temperature tracking" characteristics are optimized as temperature varies.

In summary, differential amplifiers have been vastly improved and popularized by the use of IC techniques; conversely, the differential (or balanced) amplifier configuration has been directly responsible for the production of performance-optimized LIC's.

Designers of LIC's have learned the technique of cascading the differential amplifier into amplifier chains on a single silicon chip without interstage coupling capacitors or transformers. Fig. 2 is a schematic of a unique LIC intended primarily for use in FM communications systems. IF amplification and AM limiting are accomplished by a chain of three differential-amplifier pairs (*Q1-Q2*, *Q4-Q5*, and *Q7-Q8*). Transistors *Q3* and *Q6* are essentially intercoupling devices between the differential-amplifier stages. The circuit in Fig. 2 typifies the sophistication of LIC designs which can be created with monolithic differential amplifiers, the keystone "building block" in the LIC's of today and many tomorrows!

OPERATIONAL AMPLIFIERS
"jack-of-all-trades" LIC'S

More op-amps have been sold to date than any other type of LIC. The expression "operational amplifier" has come from the analog computer field, where op-amps have long been used to perform such mathematical "operational" functions as addition, subtraction, integration, and differentiation. In the past, op-amps have been designed into instrumentation amplifiers of low-level signals from sensors and gauges. Over a period of time, the applications have spread to include such diverse tasks as servo and process control, analog-to-digital and digital-to-analog conversion, voltage regulation and comparison, logarithmic amplification, active filtration, signal conditioning, function generation, and even precision rectification. Another important attribute of the op-amp is its differential-amplifier's capability to reduce noise picked up in transmission circuits.

An op-amp is a very-high-gain direct-coupled device capable of amplifying both DC and AC signals; it possesses signal-feedback loops to permit determination of the variation in output signal as a function of input signal. The ideal op-amp would have infinite gain, draw zero current from its signal source, produce an output voltage independent of the output current, and be dependent only upon the input signal voltage. Op-amps characteristically have very high input impedances and operate into comparatively low output load resistances.

In an op-amp, frequently most of the output of the amplifying portion is fed back to the input and subtracted from it (negative feedback). The resulting amplifier characteristics are therefore made a function of the passive external feedback elements, and total circuit performance is more nearly dependent on the stability of the passive feedback elements other than on the almost invariably unstable characteristics of active electronic amplifying elements. Because a high-performance "uncompensated" op-amp has a voltage gain of the order of fifty thousand, designers can employ enormous amounts of "compensation" (feedback) in tailoring designs for specific functions. Thus, the amplifier performance characteristics can be optimized and stabilized despite wide variations in operating parameters. The versatility of the op-amp is further demonstrated by the fact that it may be used as a wide-band or instrument amplifier by the application of appropriate "shaping" circuits in the feedback-circuit loop.

One of the newest areas in which op-amps are beginning to find use is active network synthesis, particularly in connection with eliminating the need for inductors which are big, heavy, and expensive; these op-amps obey laws of inductance, but without the need for a big coil of wire and a metal core. This application represents one of the possible important future uses of the op-amp.

Improvements in monolithic LIC's are continuing to be legion: higher input impedances, less low-frequency ("flicker") noise, greater power capability, reduced "offset" (unbalance), and simplification in "compensation" circuit (feedback) techniques. Dual op-amps—two amplifier systems on a monolithic chip—are already available but today's op-amps are without doubt *model-T-Fords* in comparison with the sophisticated op-amps that tomorrow will bring.

MARKETS AND APPLICATIONS FOR LIC'S

In the evolution of IC's, *digital* circuits have served in the pathfinder role even though the *number* of potential applications preponderantly favors linear circuits. Numerous technological and market circumstances have been responsible for this situation, but three factors are particularly noteworthy.

1) The development of simple digital IC's could be accomplished more easily from the technical standpoint.
2) The total environment in computer design and manufacture was most fertile with immediate, urgent needs for the advantages to be offered by IC's: compactness, simplicity of interconnection, economy, enhanced reliability, and faster switching speeds.
3) There was an immediate market for large quantities of comparatively simple circuits.

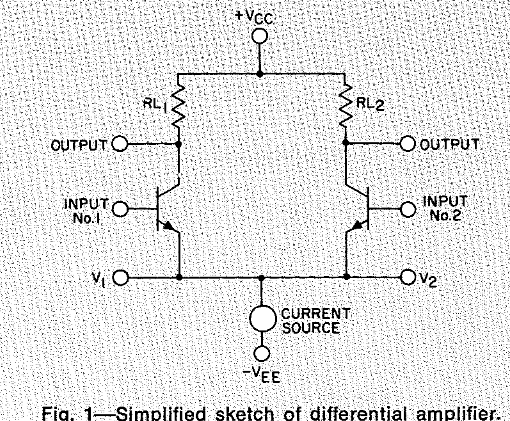


Fig. 1—Simplified sketch of differential amplifier.

Digital IC's now have such a head-start that even the most optimistic prophets of LIC achievement are probably willing to concede sales leadership to the digital circuits until the early 1970's. Nevertheless, the sales gap is closing rapidly; the LIC *sales-growth rate* during 1967 approximately tripled that of digital units. It is estimated that about 8 million LIC's were sold during 1967 and that they accounted for a sales revenue of about $50 million. On the other hand, it is estimated that about 60 million *digital* IC's were sold during 1967 with a sales revenue of about $175 million. Industry forecasts indicate that by 1970 the annual production of LIC's could easily be 50-million units, despite the fact that the automotive industry and the consumer-goods manufacturers will not have become major users. In the early 1970's, these enormous markets are expected to boost the sales of LIC's into the leading position.

Just a few years ago, both manufacturers and potential customers had grave doubts that LIC's would ever become widely used products. Discrete semiconductor and tube circuits seemed to be in virtually impregnable positions from the standpoint of economics and the ability to perform the diverse electronic functions required by users of "linear" devices. Furthermore, the LIC was innately a direct-coupled amplifier and large doses of imagination were necessary to envision this newcomer as a challenger in the high-frequency domains of the communications world. As an additional discouragement, many experts were predicting the steady replacement of analog (linear) methods by direct digital control. In consequence of these and related factors, government-sponsored R&D funding of LIC developments has been comparatively modest. As has so often been true in such formidable situations, a small band of ingenius circuit designers attacked the problems (of LIC design in this case) with dedicated persistence. These battles will continue to be waged, but already major victories have been won as attested to by the sales statistics presented earlier. The progressive gains made by the LIC have brought it to a point where it is either already being used in, or being contemplated for use in, many applications in which discrete components have been found to be impractical. For example, scientists working in medical electronics are excited about the prospective use of LIC's in the processes of diagnosis and treatment. The LIC is so small that it can be implanted in the human body and easily coupled to appropriate sensors.

Today, military and aerospace applications account for an overwhelming 60% of the market for LIC's. Industrial and consumer usage has been nominal, but is increasing rapidly as LIC devices are being put to work in TV sets, radios, industrial controls, automobile voltage-regulators, stereo phonographs, electric organs, light dimmers, and other applications. Barring an all-out war emergency, there is little doubt that the industrial and consumer usage of LIC's will out-distance military and aerospace applications requirements by 1970.

The LIC op-amps account for most LIC sales today. By 1970, however, it appears that this category of application may well be out-distanced by LIC usage in communications circuits, linear periphery circuits for computers, timing and control circuits, and regulators (and associated power circuits) in that order.

MILITARY AND AEROSPACE APPLICATIONS

Military and aerospace users were quick to sense the advantages of LIC's and put them to work; hence today these agencies are the major customers. The military and aerospace users were originally attracted to LIC's by significant advantages in performance, size, weight, logistics, reliability, and suitability for use under widely separated environmental extremes. The applications of LIC's range from simple radios to guided missiles. For example the Redeye missile, fired from the shoulder of a soldier against low-flying aircraft, contains 26 LIC's.

Users of IC's are already beginning to realize that the total-reliability index of a single IC can rival that of individual transistors. Thus, the IC, with its capability to perform a larger subsystem task than a single discrete element, offers vast new opportunities for improved reliability in equipment. Additionally, the IC is effective against those four "bogeys" of field-reliability: heat, humidity, shock, and vibration. In hermetically sealed packages, the IC can operate over the temperature range of −55 to +125°C; it may be stored in temperatures ranging from −65 to +200°C. LIC operational stability for these temperature ranges has been considerably improved over discrete devices by the liberal use of the differential amplifier and a variety of "on-the-chip" temperature-compensation techniques. Because a large portion of the interconnect wiring in an LIC is contained within a hermetically sealed (or encapsulated) enclosure, the LIC offers a greater immunity against the twin enemies of dirt and humidity. Another major strength of the LIC is its ability to sustain exposure to severe shock and vibration. As a consequence of its small *mass* (compared to the mass of discrete components plus their circuits) an LIC is not as likely to be damaged by the high g-forces encountered in shock and vibration.

Maintainability is one of the prime

Fig. 2—Schematic of an LIC for FM Subsystem applications.

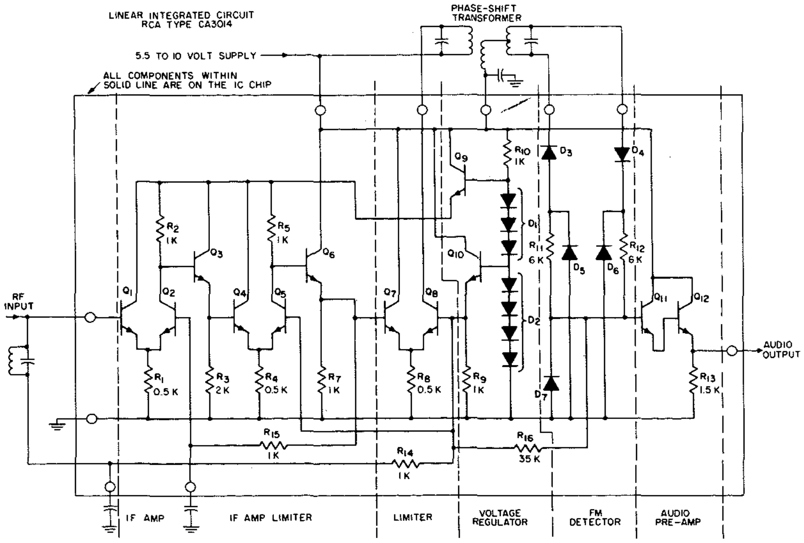
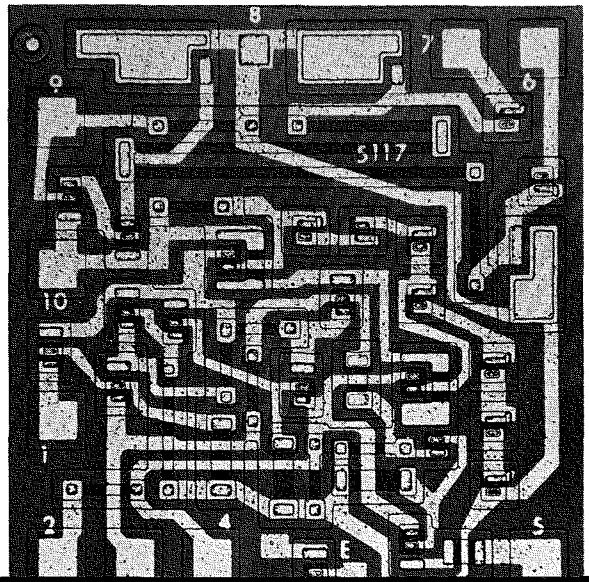


Fig. 3—Photo of linear integrated circuit "chip" (0.060" x 0.064") RCA type CA3014 FM subsystem circuit.



virtues desired in military equipment. LIC's can contribute to maintainability in many ways. First, when an LIC is defective in a piece of equipment, it is more easily identified because it encompasses a larger subsystem function; fewer diagnostic tests are required to determine the faulty sector in the equipment. It is simpler to service equipment in which the subsystem components are comparatively macroscopic in their electronic function. Second, field replacement of a macroscopic subsystem (like an LIC) is physically much simpler and does not require the dexterity normally requisite for the replacement of discrete components (resistors and capacitors) particularly as discrete components become increasingly more microscopic. Finally, there is more than a glimmer of hope that LIC's will eventually be produced so cheaply that the long sought-after "throw-away" module will become a reality. Consequently, repairmen working on IC-powered equipment will require less training and repairs will take less time.

Although, it would be impossible to delineate here the full magnitude and extent of the impact of the IC on new equipment for military and aerospace applications, it is apparent that virtually every "small-signal" function will soon benefit from this new technology. In October 1967, the Army Electronics Command at Fort Monmouth, N.J., stated publicly that IC's are being employed in 28% of the new equipment currently under development in their laboratories. Additionally, IC's have been specified or are being considered for use in another 41% of their possible applications.

PRESENT AND FUTURE TRENDS IN LIC'S

The casual observer of the explosive growth of LIC use can easily get the impression that trends in LIC development are expanding simultaneously in all directions. Actually, all LIC's available today can probably be classified into one of the following categories:

1) *Elementary "building-block"* LIC's: The most common of these is the single differential amplifier shown in Fig. 1 and described above. Its versatility makes it ideal for use in putting the LIC to work immediately in classical circuit designs. This category of LIC also includes those LIC's which are simple multiples of transistors or diodes on a single chip in a single package. The thermal and electrical matching of these devices offers electronic and economic solutions to many chronic problems encountered in trying to achieve electronic "similarity" with discrete transistors or diodes.
2) *Operational amplifiers, general-purpose amplifiers, "universal" circuits:* The "jack-of-all-trades" op-amps have been discussed in detail above. Numerous LIC's are also labelled by their manufacturers as "general-purpose amplifiers." In an effort to convey capability to perform a number of services beyond those of a "general-purpose" circuit, the term "universal circuit" has been used to describe devices (e.g., RCA type CA3020) with circuit adaptability and suitability for use in either "small-signal" or "power" service and/or from DC to VHF.
3) *Special-purpose* LIC's *and "subsystem function"* LIC's: The term "special-purpose; categorizes the LIC designed to perform almost exclusively in a particular function; e.g., the National Semiconductor Type LM-100 Voltage Regulator LIC or the RCA Type CA3034 Automatic-Fine-Tuning LIC.

When the functional scope of the special-purpose LIC becomes complex to the point where it encompasses a plurality of functions, the device can be classified as a "subsystem function" LIC. This type of function is demonstrated by the FM communications system shown in Figs. 2 and 3; Fig. 3 is a photograph of the chip containing the circuit shown in Fig. 2. In an FM communications system, this LIC performs the following major "subsystem" functions: IF amplification, limiting, detection, audio pre-amplification, and voltage regulation.

It is likely that future LIC's will fall into these same general categories although it will be necessary to add an additional one as linear large-scale-integration becomes a reality. The world of digital IC users is currently excited about the advantages anticipated from the introduction of large-scale-integration (LSI) technology. Designers of LIC's are currently demonstrating an ability to provide devices capable of performing complete system functions; in the not too distant future, the electronic functions for a complete radio receiver may be incorporated on a single IC chip. Chips of this type have already been demonstrated in elementary form by several firms and sophistication will follow.

TECHNICAL TODAY . . . AND TOMORROW

Scientists and engineers are busy today trying to plumb the dimensions of the impending IC-fostered "electronics revolution." The future of LIC and its related technology will certainly be more impressive than its early counterpart — the present LIC. The following is a brief glimpse of some "things to come:"

1) *Higher gain and bandwidth:* Today an off-the-shelf LIC (RCA type CA3035) is capable of producing 130 dB of voltage gain at 200 kHz. Philco engineers have been pioneering a wide-bandwidth LIC (approximately 50 dB of gain over a bandwidth of 500 MHz) with a gain-bandwidth product of approximately 150 GHz. Inevitably, the gain-bandwidth dimensions of the LIC capability will be extended considerably.
2) *Microwave* LIC's: The "microstrip" process, in which a flat conductor is deposited atop a dielectric and ground plane, offers great promise in the successful fabrication of microwave LIC's. When coupled with digital-IC-controlled phase-shifters, the microwave LIC is virtually certain of a keystone role in future phased-array radar systems.
3) *Field-effect electronics:* Currently, discrete field-effect transistors are demonstrating the ability to out-perform the now-classical bipolar transistor in many applications. Among other advantages, field-effect devices offer high input impedances and simplified biasing systems; reminiscent of vacuum-tube characteristics. Both of the basic field-effect techniques, JUG-FET (junction-FET) and MOS-FET (metal-oxide-semiconductor-FET) have already been introduced into LIC technology. Because these devices offer unique advantages over the bipolar transistor, field-effect techniques will be employed increasingly for LIC active devices which will be coupled with MOS-type resistors and capacitors on the same chip. Complementary-symmetry MOS (COS/MOS), currently making its debut in digital logic circuit design, will also make noteworthy contributions to new-generation LIC's.
4) Light-sensitive LIC's: Solid-state optical-electronics has already demonstrated a capability to expand the functions available in LIC's by imparting the features of optical interconnections, unilateral signal flow, and provision for isolation between circuit subsystems. The pace of developments in semiconductor light emitters (including diode lasers) continues to be swift. These new techniques are certain to contain the ingredients needed in the design recipes of new generations of light-sensitive LIC's.
5) *New materials and processes:* The LIC's of the 1970's will make use of new materials and processes now on the "technical frontier." A few illustrations must suffice. Gallium arsenide, a promising new material for semiconductors, is also applicable to IC's. Scientists are investigating silicon-on-sapphire technology. Computer-aided design is already a tool of the IC designer and "on-line" computers are already testing IC's. Tomorrow, computers will undoubtedly be used for the conduct of virtually every phase in IC technology: design, automation of manufacturing processes, and testing.

CONCLUSIONS

Perhaps the most significant contributions of LIC's to future electronic systems can be distilled to the following:

1) The availability of LIC packages offering higher reliability, greater sophistication, and relatively lower cost will permit electronic techniques making use of LIC's to be applied to many new services to mankind.
2) LIC technology will provide electronic equipment designers with devices containing an order of magnitude greater complexity and capability than present devices and with increased reliability, all at the same price now paid for devices with far less capability.

A Timing Fuze Employing P-Channel MOS Arrays

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Time delay fuzes become smaller and simpler by incorporating the P-channel MOS arrays described in this paper. A model that uses a chip design capable of driving the detonator and bellows motor silicon controlled rectifiers directly has been demonstrated successfully. The author describes the timing requirements, the system concept and includes several examples of the individual circuits.

DELAY-TIMING FUZES capable of being time-programmed in the field are presently either mechanical or magnetic-core types; both are exceedingly costly to assemble as a "one-shot" type device. The MOS array offers one possible solution to the assembly problem.

A PROPOSED SYSTEM

A timing fuze system employing MOS arrays was designed to provide presetable delays up to a maximum of 200 seconds. This delay-timing fuze system includes three MOS array packages and a number of discrete components; the three arrays are: 1) divide-and-control, 2) interval-timer, and 3) arm-and-fire logic.

All three arrays are the P-channel, thick-oxide type.[1] The divide-and-control array and the interval-timer array form the basic counter for a large number of possible fuze timing applications. These two arrays were specifically designed according to RCA specifications and work on the program was coordinated through Defense Microelectronics (DME), Somerville, N.J.

The arm-and-fire logic array supplies the logic specifically relating to a given fuze design, and the array design employs the universal array developed by DME. Basically, this technique involves a chip with 52 gate-cells, allowing the design engineer freedom of supplying the interconnecting metalization pattern to assemble gates into desired logic functions. The quick turnaround features of the universal array coupled with the two basic counter arrays (divide and control and interval timer) provides a strong tool for swift breadboarding and evaluation of many future timing applications.

For high-volume manufacture, cost per device is of prime consideration; thus, it was recognized that a fuze design constructed of these building blocks must be scrutinized for logic simplification and reduction of the number of MOS packages. For example, with present 40-pin packages, it is conceivable that the fuze design discussed could be developed using one array package.

TIMING REQUIREMENTS

The fuze system chosen for this study has two basic modes of operation: 1) detonation at a preset time after impact, and 2) detonation at a fixed 0.1 second after arm. The timing circuit employs a counter in both modes to measure delay time to *arm.* From *battery strike* (point at which battery power is applied to fuze circuit) to *battery threshold* (point where thermal battery voltage reaches 22 volts) is 0.4 seconds (Fig. 1). Battery threshold is selected by a 22-volt zener and silicon-control-switch circuit that provides a 22-volt step output to reset and start the counter (Fig. 2).

The counter counts the arm delay time, and at *arm,* a bellows activates a power-in-line switch to the detonator; then, providing all in-line safety switches are closed, only the detonator SCR must be fired to provide power to the detonator. In the first mode, the counter must be reset at *impact* with a new delay that determines impact-to-detonate (fire delay) time. When the fuze impacts with any object, the gravitational force created causes the impact switch to momentarily close, initiating impact. In the second mode, detonation occurs 0.1 second after *arm* and it is not necessary to reset the counter a second time.

The timing accuracies relating to the counter are met when the clock frequency is held to ±0.1% over the temperature range from −54°C to +71°C. Circuit delay time is not significant compared with the shortest delay time interval of 0.01 seconds. The timing accuracy from battery strike to battery threshold is a rise time requirement of the thermal battery.

SYSTEM CONCEPT

Metal-oxide-semiconductors, because of their capability of capacitive storage at the exceedingly high-resistance gate input are readily adopted to dynamic type logic.[2] In the two-phase clock system employed, active loads and transmission devices can be "clocked" *on* and *off,* resulting in very simple, high-chip-density circuitry. The active load device approaches a linear resistance when its gate voltage is approximately half the arrays supply voltage. In fuze applications, a single-battery power system is economical; this requires the load gate voltage to be the same as the supply voltage; i.e., −28 volts. This compromise results in a highly nonlinear load resistor and a related threshold drop through the load of approximately 4 volts; Fig. 3 indicates that a logic level more negative than −9 volts is required to turn the inverter *on.* Correspondingly, an input level less negative than −3.5 volts is required to insure that the inverter is *off.* To maintain the logic levels, the proper clock level to turn *on* the load devices for dynamic operation must approach the supply voltage; consequently, the two-phase clock output must employ discrete load resistors to allow this required voltage swing.

CLOCK CIRCUIT

The divide-and-control array provides the active element for the clock circuit as well as the shaping circuit needed to produce a 2-phase square-wave clock system with 50% duty cycle from the sinewave oscillator (Fig. 4). The complexity of the shaper circuit is an indication of the new disciplines involved in use of MOS circuits; such an arrangement using discrete circuits would be considered economically impratical.

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FRANK E. AMBLER received the BSEE from California State Polytechnical College in 1953. Upon graduation, he joined RCA at the West Los Angeles facility. Design responsibilities included deflection generator and power supplies for the AN/GPS-T2 Radar Signal Simulator, Ultrasonic comb filters for pulse-doppler signal acquisition on the AN/DPN47 Bomarc Target Seeker Radar, and Thor Autopilot modifications for special mission applications. In 1959, Mr. Ambler transferred to the newly completed Van Nuys facility (now West Coast Division of DEP) where he has performed a variety of different tasks. The more important of these include: system evaluation and redesign of AN/GPS-T2; Design Integration; ECM evaluations to NAG-la and Federal Standard 222 on Navy Mass Memory System and TV monitors; and magnetic tape equipment for the Saturn 110 computer. At present, Mr. Ambler is a member of the Ordnance Systems group. The past two years have been primarily spent in application of MOS devices to timing fuzes. Mr. Ambler's present assignment is studying multiple beam ranging techniques employing gallium arsenide lasers.

Although a Hartley-type oscillator was employed; other configurations produced similar results. The clock frequency is 204.8 kHz with an accuracy of ±0.1% from −54°C to +71°C. It can be shown that if the frequency is to be held to ±0.1%, the frequency-determining LC product must be held to ±0.2%. Either temperature compensation or a "zero temperature coefficient" approach could have been used. Effort on this program was expended on the latter approach.

A molybdenum-permalloy-powder core was selected because of its tight tolerance on inductance over the temperature range as opposed to the iron-powder types that usually exhibit large Q values in the 200 kHz range. The core selected was Magnetics Incorporated core 50031M with a permeability of 60 and Q (at 1 mH) of approximately 50. This specified inductance-change limit of this unit is ±0.25% over the temperature of −65°C to +135°C. Over the fuze temperature range, this limit may be considerably less since the core curve of inductance versus temperature is an S-shaped curve heading steeply positive at 135°C and steeply negative at −65°C. The feedback tap at ¼ of the total turns, was selected for minimum output waveform distortion.

The capacitors selected are the MPO type with temperature coefficient limits of ±30 ppm/°C. No tank-circuit packaging was involved except that the coil was coated with Q dope. Fig. 5 shows the total deviation to be less than 0.1%. Variation of clock frequency with battery voltage was an order of magnitude below the temperature variations.

FEEDBACK SHIFT REGISTER

The shift register contains eleven stages with feedback from the output stage to the input stage to produce a 2^{11} (2048) division of the clock. The output of each stage is connected as an input to an AND circuit; consequently, the shift register output (the AND output) occurs at 0 time and every *clock period*/2048 = 2048/204.8 kHz = 0.01 seconds thereafter. The shift register stages are initially set to 1 at *initiate* by the 1-0 detector. Before this time, the shift register is operating, but the output is gate inhibited from reaching the first decade counter. The first pulse to the first decade counter occurs at zero delay time.

DECADE COUNTERS

Each decade is made up of four of the binaries shown in Fig. 6. Feedback is employed in the conventional manner to reduce the binaries' total count from 16 to 10. The counters are set by exercising the conventional four binary-coded-decimal (BCD) input lines. These BCD lines are sampled for one clock time immediately following the reset pulse. Selected lines are grounded through the function switch to place the desired count into each decade. The complement of the desired count must be placed into the counter since the counter counts down to produce an output. The input to the first decade located in the divide-and-control array, starts with the first pulse at zero time. This limits the maximum count for the four decades to 99.99 seconds. It has the advantage of the preset input being the 9's complement of the desired count output; e.g., if the desired count is 2, then the 9's complement of 2, which is 7, is set into the counter. This is accomplished by the function switch grounding lines "1", "2" and "4". Although only select counts are normally required in the fuze, the laboratory model constructed for evaluation contained commercial decimal-to-BCD switches with indicator dials which presented the 9's complement of the switch output lines; thus, the dials indicate the actual delay time.

The output from the last decade may be doubled (approximately 200 seconds maximum) by the following binary, which in turn drives a set-reset flip-flop to produce a logic-level change at the completion of the count.

VOLTAGE MONITOR CIRCUIT

The voltage monitor flip-flop is designed with dynamic properties so that its output always comes up in a *one* state when power is applied. This is primarily be-

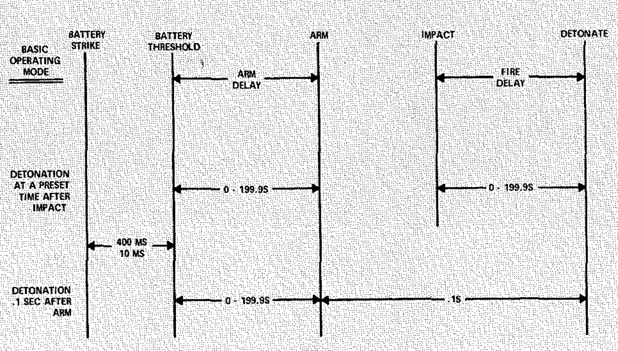

Fig. 1—Fuze timing diagram.

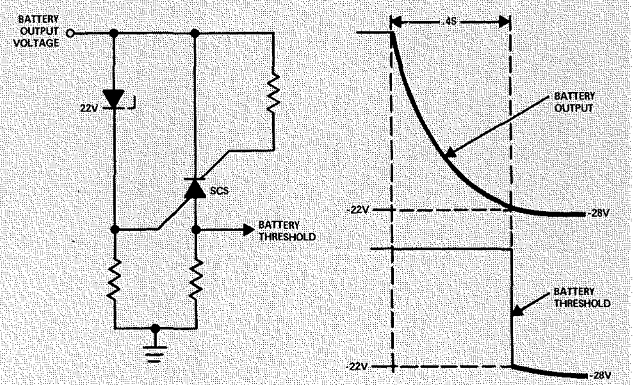

Fig. 2—Battery threshold circuit.

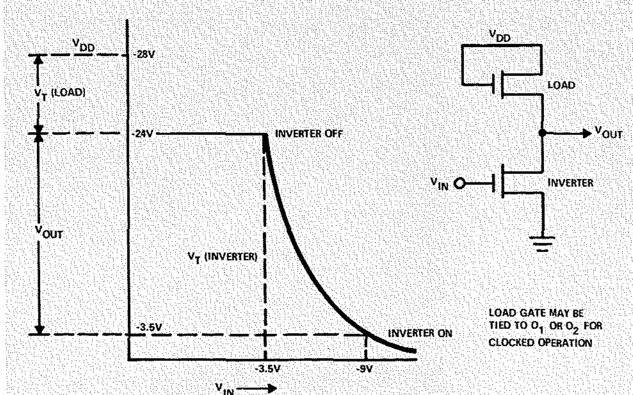

Fig. 3—Transfer characteristics of MOS inverter with saturated load device.

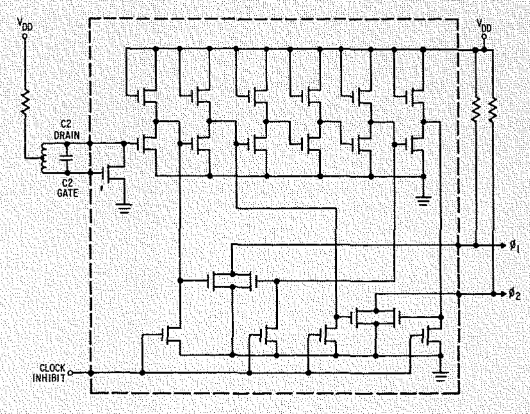

Fig. 4—Two-phase clock circuit.

cause of the gate capacitive and threshold differences between the two sections of the flip-flop. The *Q* output acts as an inhibit signal on the *initate, arm,* and *fire* flip-flops so that they may not be set until the reset signal flips the state of the voltage monitor and changes *Q* to a 0. The set input to the voltage monitor is an output level from the MOS voltage divider. This divider is employed to sample the supply voltage—and if the supply, V_{DD}, drops below −20 volts to set the voltage monitor, thereby changing *Q* to a 1 which inhibits pulses to the counter and inhibits the arm-and-fire flip-flops. It would then be necessary to initiate a complete reset sequence to start the counter again.

ARM RESET

The reset circuit is activated for the *arm delay* when the *battery threshold* is reached and −22 volts is applied through an SCS to the battery-threshold input. A 1-bit shift register is required to synchronize the battery-threshold input to the clock transition. A 1-0 detector produces an output pulse for one clock time that initiates the counter reset pulses and sets a flip-flop. The output pulse from the 1-0 detector initiates a corresponding time output at TEST 2, followed by a sequence of pulses (one clock-time wide) from *reset, PPE,* and *initiate.* This sequence is obtained by tapping off at each bit of the 3-bit shift register to a precharged buffer circuit which drives "off the chip" to the corresponding labeled input on the other arrays.

The TEST-2 input is driven by a pull-down device without load. The TEST-2 input to the divide-and-control array is set input for the voltage monitor flip-flop. The set on this flip-flop comes *on* in a set condition when voltage is applied. Once this flip-flop has been reset, the voltage monitor can be set again by pulling the MOS voltage divider (TEST 2) to ground for one clock pulse. During the *arm reset* just described, the TEST-2 "set" is redundant since the voltage monitor would normally be set when the supply voltage comes on.

FIRE RESET

The *fire reset* is initiated when the *impact* switch goes from −28 volts, momentarily to ground, provided the *bellows* signal has changed from a 1 to a 0 at the end of the *arm delay.* One bit of delay is required to synchronize the input signal to the clock transition. A flip-flop is added in this line so that any bounce in the impact switch will not produce multiple reset outputs. The flip-flop drives a 1-0 detector to give one output for one clock pulse. The flip-flop just described may come up in either position but as described is always set during arm reset at TEST-2 time. The output of the 1-0 detector initiates the identical counter reset procedure as does the 1-0 detector in the arm line.

ARM AND FIRE SIGNAL LOGIC

The array logic must also detect the difference between an arm delay and a fire delay from the counter output. The counter output (count) is a level shift from 0 to 1 at the end of the counter delay time. Prior to reset, this output may be in either state and the possibility of a "false count" during this period must be guarded against. A 1-0 detector is employed so that an output is obtained for only one clock time at the end of the counter delay time. If the RS flip-flop in the interval timer which supplies this count input, comes up in 1 state the 1-0 detector sees a 0-1 transition at reset of the flip-flop and does not respond. The output from the 1-0 detector is routed directly through an inverter and precharge-buffer driver to produce an arm signal output.

The second output from the 1-0 detector is inhibited after passing through an inverter until after the *bellows* and *impact* signals have changed from a 1 to a 0. At *bellows,* the count signal is a 1 since the *arm delay* is completed. Resetting the count back to 0 will not produce a *fire* signal since this is the wrong direction to produce an output from the 1-0 detector. When the counter runs to the end of the *arm delay,* the count output is now free to pass through the circuit producing a *fire* signal output pulse.

In the second mode of operation, a *fire* signal must be obtained 0.1 seconds after the *arm delay* with no resetting of the counter. An OR gate performs the AND function between the *count* and the *air-burst* input. The *count* is taken off a 1-0 detector at a point where the level is steady state rather than a pulse, as is obtained at the output of the detector. *Air burst* signal is taken from between the first and second decade of the counter so it is basically a string of pulses spaced 0.1 seconds apart. One of these pulses occurs at the same time as the count signal; consequently, 1 bit of delay is in the count line to prevent the possibilty of an *air burst* signal producing a *fire* signal at the same instant as the *arm* signal. As previously discussed, the *count* signal may be in the 1 state before reset which would allow a fire signal if an *air burst* pulse was received. This is prevented from happening because the output from the first decade is inhibited in the divide-and-control array until initiate.

CONCLUSIONS

The presented design demonstrates the feasibility of using MOS arrays in delay timing fuzes. Incorporated in the chip design is the active device for a temperature-stable clock oscillator and output circuits capable of directly driving silicon control rectifiers. These features simplify the fuze counter assembly to one multiple SCR package, a few discrete components, and the array chips. Assembly-wise, the MOS arrays are logical candidates for high-volume use when compared to present designs employing magnetic-core counters. The 200-second fuze requires approximately 400 mW battery power, exclusive of the detonator. For exceedingly long delays where battery power becomes a critical design parameter, an extension from the P-MOS devices to the low-power P-N complementary MOS devices appears to be the logical approach for applications in the near future. Needed to complete the MOS application in delay timing fuzes is a reliable method of presetting the count time into the fuze under field conditions that will replace the present mechanical switching methods.

REFERENCES

1. Thomas, Callon, "Large-Scale Integration, MOS Arrays," *Electronics* (Feb. 20, 1967).
2. Przybylski, Miles, Avery, and Rose, *Engineering Course in P-MOS Technology,* American Micro-Systems, Inc., 1966.

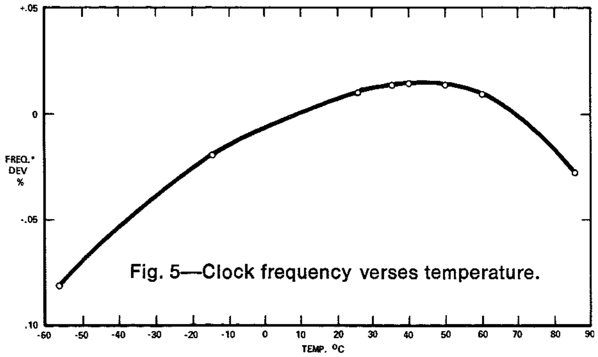

Fig. 5—Clock frequency verses temperature.

*DEVIATION FROM ROOM TEMPERATURE (27°C) PRIOR TO RUN

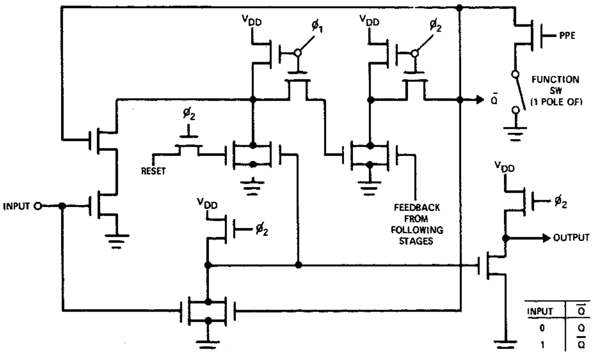

Fig. 6—Counter binary stage.

The Design of a Solar Array Test Set

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The testing of solar-cell arrays cannot be conducted in natural sunlight because of its lack of consistency from day to day. An investigation revealed the inadequacy of the available light sources. Described herein is the design and calibration of a test set that provides the light source, the temperature control of the light source and the solar-cell array, and the instrumentation required to accurately predict the performance of a solar-cell array in space.

THE SOLAR ARRAY TEST SET was designed to meet the requirement for a controlled radiation and temperature environment for evaluating the Lunar Orbiter solar panels for space applications. It was necessary, under these controlled conditions, to measure and record the voltage and current of any solar-panel circuit (or of the complete panel) under various loadings. It was also necessary to employ a standard solar cell to calibrate the uniformity and intensity of radiation at the solar-cell array. To satisfy these requirements, the test set was to perform the following functions:

1) Produce the required radiation and project it onto the solar-cell array;
2) Position positively the solar arrays for reliable repeatibility;
3) Control the temperature of the solar-cell arrays; and
4) Measure the radiant energy applied to the solar-cell array and the temperature and power output of the solar-cell array during test.

The most critical single unit of the test set is the radiant-energy source. A survey of radiant-energy sources available showed that two basic types of energy sources had been previously used: solar-radiation simulators and tungsten lights. To illustrate results of the two approaches, the spectral-energy distribution of the sun in free space (generally accepted as the curve determined by Johnson[1]) and tungsten lamps are compared to solar-cell response as shown in Fig. 1.

SOLAR ILLUMINATORS

Ideally, a solar radiator produces collimated radiation, which matches the spectral energy distribution in free space with a uniform distribution of intensity at a level of 139.6 mW/cm^2 over the cell array area under test. To accomplish the solar simulation, many methods had been tried which combined carbon arcs, Xenon lamps, tungsten lamps, filters, mirrors, and lenses in various combinations. At the time of the survey, the available solar simulators were deficient in one or two major categories: total area that could be irradiated and uniformity of intensity distribution.

TUNGSTEN ILLUMINATORS

The most popular tungsten illuminators used projector and reflector (PAR) type lamps as shown in Fig. 2. Relatively uniform illumination can be obtained from this type of illuminator if sufficient time is taken to aim the lamps to properly overlap the radiant energy. By inserting a ground glass diffuser between the lamps and the solar array, the uniformity of distribution may be further improved. This method was used successfully with seven lamps in a test set for evaluating individual solar cells and small solar arrays.

The Lunar Orbiter solar array, for which the illuminator was being designed, measured 44 x 46 inches. Based upon the experience with the formerly used PAR type lamps, fifty-six 1000-watt lamps would be required to produce the required intensity at a uniformity of ±5% over the solar-array area.

The major drawbacks to the use of the

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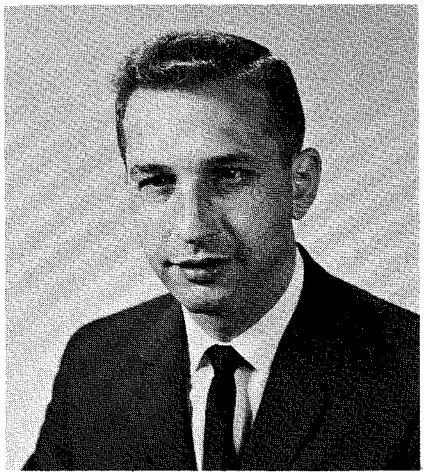

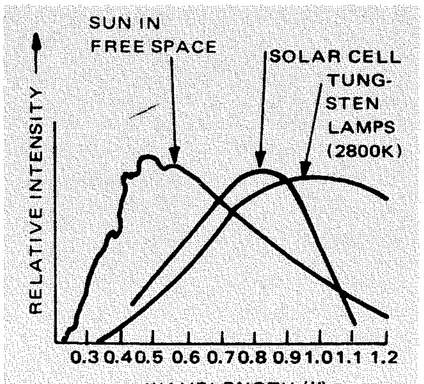

Fig. 1—Solar cell response versus solar and tungsten-lamp spectral energy.

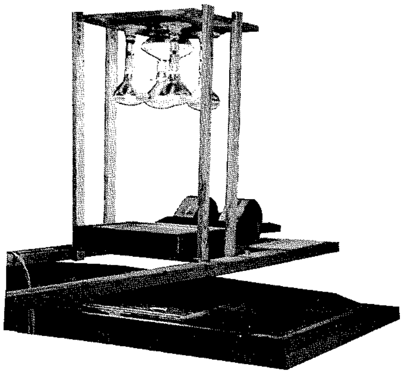

Fig. 2—Illuminator using adjustable PAR lamps.

The design effort for this equipment was originally performed on NASA Contract NASI-3800, under subcontract N64960 to The Boeing Corporation. Reprint RE-14-1-7/Final manuscript received. April 3, 1968.

tungsten type of illuminator are the time required for alignment of the lamps to achieve an acceptable uniformity, changes in light output from each lamp over their lifetime (which necessitates lamp realignment), and the high heat radiated (i.e., radiation greater than 1 micron wavelength to which the solar cells are not sensitive).

IMPROVED TUNGSTEN ILLUMINATOR

The survey showed that the most promising design approach was an illuminator using tungsten lamps. Because of the large number of lamps required for the Lunar Orbiter solar panel and the inherent alignment problem associated with the methods formerly used, a diffusing cavity principle (a light-box) was used. The cavity walls were coated to keep the quantity of lamps to a minimum. The concept of the diffusing cavity requires multiple reflections, therefore the wall must have high, diffuse, and constant reflectance over the spectral region. If this concept is not adhered to, the emitted radiation will be low and unevenly distributed. Radiation above 1 microns is not useful in this application, so a cavity wall coating that absorbs energy above 1 microns was used.

The radiation emerging from an illuminator in which the output from each lamp is multiply reflected off the diffuse walls is independent of lamp position and intensity. Therefore, the problem of lamp alignment was eliminated. However, if only diffuse reflectors were used in the design of the illuminator, the emerging intensity pattern would be as shown in curve *A* of Fig 3. (high values in the center of the pattern with a gradual decrease in level from the center to the edge.) To improve the emerging intensity pattern, specular reflectors were added to the interior surface, contiguous to the illuminator exit. The resulting intensity pattern (curve *B* of Fig. 3) results in a cavity-area to uniform-intensity-area ratio approaching unity.

The final design of the illuminator, as shown in Fig. 3, consisted of a frame, fabricated of aluminum sections welded into a rigid box structure, with an opening of 60 x 60 inches, and mounted on adjustable legs. Aluminum diffuser panels, coated with "white velvet" paint to produce the required diffusion and absorption properties, incorporated tubing for cooling fluid as an integral part of the construction. Cooling fluid (water and ethylene glycol) was supplied from a four-ton chiller unit to the panels at a temperature of 30°C. It was calculated that a temperature rise of 5°C would occur in the illuminator and the fluid would return to the chiller at 35°C through copper tubing. To avoid electrolytic action at the copper tubing and aluminum diffuser panel interface, polyvinyl chloride (PVC) unions were used. The specular reflectors were fabricated from stainless steel and then chrome plated.

The radiant energy source consisted of twelve 1000-watt iodine-quartz lamps. An iodine-quartz lamp is basically a tungsten lamp with iodine gas in the envelope to serve as a cleaning agent and therefore produce a lamp that is capable of maintaining a constant luminous-energy output throughout its rated life of 2000 hours. The socket seals of the lamps had to be maintained below 350°C. To accomplish this, the top portion of the illuminator consisted of an air plenum pressurized by a dual centrifugal-blower (Fig. 4). The cooling air exited from the plenum through orifices located at the base of each lamp. Failure of the plenum blower will open an air-vane switch located at the outlet of the blower and excessive temperature (above 40° C) on the diffuser panel activates a temperature sensor on the panel. The actuation of either switch de-energizes the lamps. The AC voltage to the illuminator lamps were regulated for control of intensity and also to reduce line transients. To minimize the effects of color-temperature variations between lamps, the voltage regulators were set at the same nominal voltage (Fig. 5). A change of ±5 volts from a nominal setting of 115 volts resulted in a change of lamp intensity from +12 to −15 percent and a change in color temperature of ±1.7%. The test-plane radiation, as produced by the illumintor, was uniform within ±5% at an equivalent air-mass-zero intensity of 139.6 mW/cm^2 (as measured with a 2 x 2 cm standard solar cell, over an area of 52 x 52 inches).

SOLAR ARRAY TEST FIXTURE

The solar array test fixture (Fig. 6) provides the means for positioning the solar array under the illuminator with accurate repeatibility. It includes the mechanism for scanning the solar array for temperature measurements and the solar-array test plane for radiation-intensity measurements.

Positive mechanical location of the test fixture in relation to the illuminator is accomplished by a locator bar attached to the legs of the illuminator and by pins on the test figure. The pins mate with *V* notches in the locator bar and automatically align the two units. A pair of latches are then used to lock the units together. Four mounting brackets on the test fixture support and align the solar array with the test fixture.

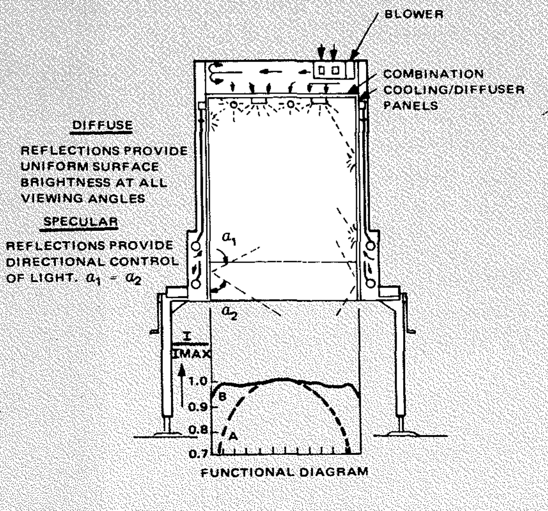

Fig. 3—Illuminator showing general arrangements.

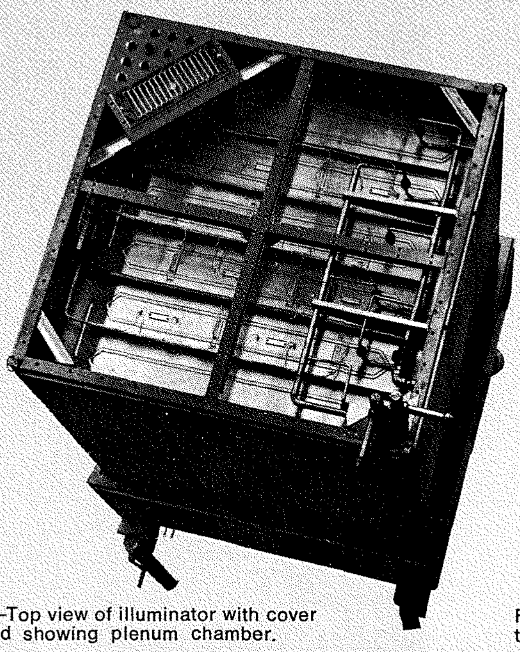

Fig. 4—Top view of illuminator with cover removed showing plenum chamber.

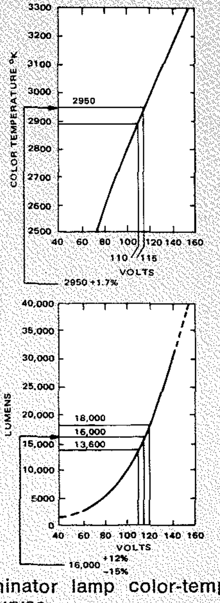

Fig. 5—Illuminator lamp color-temperature output curves.

The solar array is positioned vertically in relation to the illuminator by four adjustable legs on the test fixture, which are driven as a single unit. A mechanical counter, indicating height, allows accurate vertical positioning of the solar array or standard solar cell in the test plane. The optimum test plane was located empirically, 2.85 inches below the bottom of the illuminator. To measure solar-array output accurately, a uniform predetermined temperature condition must exist across the entire array area and the standard-solar-cell temperature must be controlled accurately.

To control the temperature of the array, air (at a controlled temperature) is applied by a three-ton air conditioner through a flexible duct into a plenum chamber. The air leaves the plenum through 239 jets and impinges on the lower side of the solar array. A damper valve, at the entrance of the plenum, allows solar-array temperature control.

Liquid coolant in a closed-loop system controlled the standard-solar-cell temperature. Heat was removed from the fluid in the closed-loop system by a heat exchanger, which transferred it to the fluid used for cooling the illuminator. An adjustable heater in the closed-loop system was used for fine control. The solar-array temperature was controlled to 50 ±4°C and the standard-solar-cell temperature to 50 ±1°C.

The standard solar cell (to establish intensity distribution) and two temperature probes (to establish the temperature distribution) were placed on a movable carriage mounted on ball screws to allow scanning of the array. The carriage was accurately positioned within a horizontal plane and the location was determined by mechanical counters.

The thermocouple probes must be in contact with the array during temperature measurements. Therefore, to prevent damaging the array as a result of inadvertent movement of the probes, a system of mechanical interlocks was provided. The transverse-drive mechanism was so constructed that locking could not take place until the longitudinal drive was first secured against movement. Lowering of the temperature probes took place simultaneously with the locking of the transverse drive. Conversely, the interlock mechanism would not permit unlocking of the longitudinal drive until the transverse drive was first unlocked, simultaneously raising the probes from the array surface.

POWER AND INSTRUMENTATION RACK

A power rack was provided, which housed the voltage regulator for the illuminator lamps and a power distribution panel. The power distribution panel was the centralized point for power control of the illuminator, air conditioner, and chiller units. An instrumentation rack housed the equipment for measuring solar-array output current and voltage, standard-cell output current and voltage, and solar-array and standard-solar-cell temperature. Solar-array and standard-solar-cell outputs were measured by both an X-Y recorder and a digital voltmeter, in conjunction with an electronic load. The X-Y recorder provides a permanent record of the current-voltage (*I-V*) curve. The digital voltmeter displayed visual (and more accurate) measurement of the open-circuit voltage, short-circuit current, and the voltage and current under selected loads. Solar-array and standard-solar-cell temperatures were displayed on a direct-reading temperature indicator.

EXTENSION OF DESIGN

The solar array test set was originally designed for use on the Lunar Orbiter Program. Since then, a solar array test fixture was designed to accommodate a Tiros operational satellite (tos) "hat." (The hat is the outer structure of the satellite containing the solar cell arrays.) With the addition of a seven-ton air conditioner to control the temperature of the hat, tos solar arrays have been tested with the solar array test set.

Following the tos addition, a sliding frame was added to the Lunar Orbiter test fixture to accommodate another solar array panel, which measures 10 x 65 inches. The sliding frame allowed discrete portions of the 65-inch panel to be centered under the illuminator. Tests are presently in progress on these solar panels.

A test fixture is presently being designed to handle a Tiros M solar panel. The Tiros M panel measures 36 x 65 inches and is curved. A sliding frame, as for the 10 x 65-inch panel, is being mounted on a Lunar Orbiter fixture and, in conjunction with a redesign of the temperature probes (which now have to contact the curved surface of the Tiros M panel), the solar array test set will be used to test the Tiros M solar panels.

A test fixture is also being designed to accommodate a solar-array hat for a classified program. The fixture will consist of a commercial hydraulic table modified to RCA requirements. The table will have the capability of height adjustment, tilt, and rotation. Experience has shown that the radiation intensity and intensity distribution from the illuminator is relatively stable; therefore, the movable carriage that scans for intensity and temperature distribution will be eliminated for the classified program. Instead, a standard solar cell will be mounted in a corner of the illuminator, intensity scan will be made manually, and the average intensity will be referenced to the standard-solar-cell output. In the same manner, a temperature scan of the hat will be made manually and the average temperature will be referenced to the open-circuit voltage of the hat, since this voltage is extremely dependent on temperature.

The solar array test set described in this paper can be used to test most configurations of solar panels with only a modification of the existing test fixture or the design of a new fixture.

REFERENCE

1. Johnson, F., "The Solar Constant," *J. of Meteorology* (Dec. 1954).

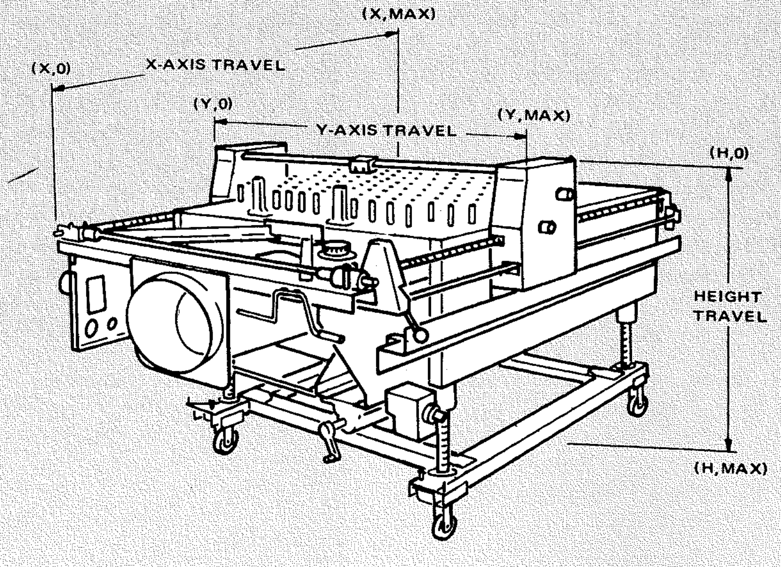

Fig. 6—Solar-cell test fixture, showing axes of movement.

A Bus Communication System for NY City Transit Authority

This paper describes the application of RCA communications equipment to satisfy the special requirements of New York City transit authority's vast system. Complete bus transmitter-receiver communications equipment, companion antennas, and low-power and high-power base station equipments are discussed.

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The New York City Transit radio communications system involves the use of 4200 bus radios, 46 snow-fighter radios, 58 patrol and supervisory vehicle radios, and 250 hand-held portable radios. Each bus has specially designed public address amplifiers. There are 19 base stations for bus control and 2 base stations for control of supervisory vehicles. A master control center will consist of 24 control consoles. In addition to being one of the largest mobile radio systems in the world, this system constitutes one of the largest ever to be planned and executed as a single unit. The major goal in the design of this system, or in fact any system, involves satisfying the customer specifications. However, this system is somewhat unique since the radios are installed in buses rather than trucks or autos, and the system consists of a very large number of special mobile and base stations placed in operation during a relatively short period of time.

MODERN BUS REQUIREMENTS

A modern bus does not have a dashboard such as those found in trucks or autos. The windshield of the vehicle covers a large area giving the operator maximum visibility directly in front of the bus as close to the front bumper as possible. Therefore, it is not desirable to place radio controls above the indicator panel of the bus. In addition, the buses in a large metropolitan area are prone to considerable vandalism and the radios must be protected from damage.

The customer required control of the radio communications system from a central site and demanded that base stations be dispersed in case of a catastrophic failure or destruction of the central site. Because of this, the base stations must be capable of being locally controlled from a nearby garage dispatcher.

These application factors and customer specifications lead to a number of new communication equipment designs.

BUS COMMUNICATIONS EQUIPMENT

Each bus radio system consists of a transmitter/receiver unit, handset, handset-holder assembly, control-head-speaker assembly, public-address amplifier assembly, gooseneck microphone, and associated cabling (Fig. 1).

Transmitter-Receiver

The transmitter/receiver unit is mounted in a protective enclosure behind the operator's seat (Fig. 2). A protective cover fits over the unit to protect it from accidental damage or vandalism. Other than the special connector for adaptation to the AAR baseplate, basically, the transmitter/receiver is a standard RCA Super Fleetfone equipment. The radio uses all transistor circuits; no vacuum tubes or relays are used in the transmitter or receiver, including the antenna switching circuit. The only mechanical switching devices are the hermetically sealed reed devices used in the subaudible tone-squelch circuits.

The receiver is a double-superheterodyne type using a 6.7-MHz high-frequency IF and a 455-kHz low-frequency IF. The major selectivity of the receiver is contained in a multiple-section, fixed-tuned and sealed 455-kHz filter. A major percentage of the receiver gain occurs after the 455 kHz filter.

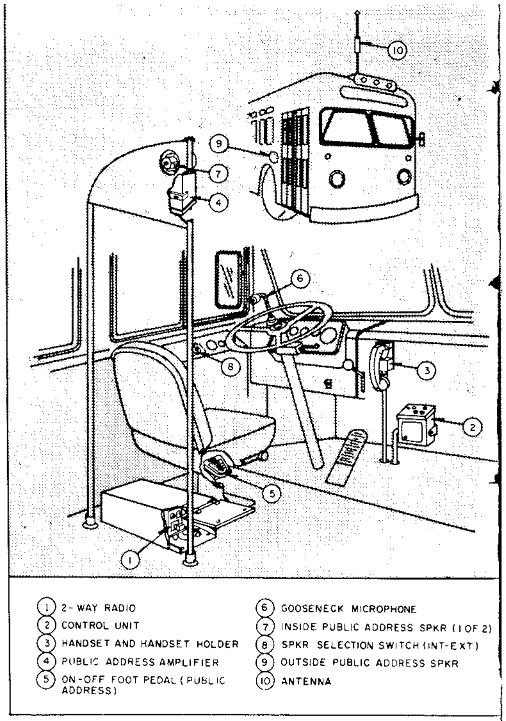

Fig. 1—Sketch of a bus interior showing the transmitter-receiver system.

The transmitter is divided into four major parts (five in the 150-MHz band):

1) The exciter, which includes the modulation limiter stage;
2) The oscillator;
3) The phase modulator;
4) The multiplier strip; and
5) The power amplifier stages and the filter-antenna switching module.

The 150-MHz equipment also includes an intermediate power amplifier between the multiplier and power amplifier. RCA overlay-type transistors are used in all the power stages. Transmitter DC voltages are supplied from a transistor inverter operated at approximately 1000 Hz producing 28 volts DC from the nominal 12-volt DC supply. The 28-volt output is regulated and current limited for two reasons:

1) To protect the output stages;
2) To meet FCC requirements on licensed input power.

Handset

The handset holder assembly (Fig. 3) includes switching which transfers the received audio signals from the speaker in the control-head assembly to the handset earpiece. Additional switching in this assembly is used to disable the receiver tone-squelch circuits. These features enable the operator to carry on a conversation without the bus passengers hearing the details.

Control Head

The control head mounted below the handset holder (Fig. 3) is designed for mounting on a flat surface since a suitable dash overhang is not available on a

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bus. This unit has a squelch circuit, audio controls and a normal-monitor switch plus a transmit indicator lamp. The normal-monitor switch is used to diable the tone squelch in case of failure. A speaker and speaker amplifier are also included in this assembly to minimize the number of pieces to be installed. All active and control elements of this unit are mounted on a single removable chassis (Fig. 4). This chassis uses a blue ribbon connector which has a mating connector in the housing. This feature allows easy replacement of the control head in case of failure. A set of terminal boards on the bottom of the housing accept the system cables. Only the wiring and interconnections are a permanent part of the bus.

Public Address

Included in the bus equipment is a public-address amplifier used to communicate with passengers. The specification that only two speakers be used on the public address system in each bus posed some problems. This meant that a high level must be used in each speaker to cover the whole bus. The use of high levels in a closed system (the microphone in close proximity to the speaker) immediately posed an acoustic feedback problem. Another problem, no less serious, was that of possible discomfort to those passengers standing near the speakers. Also, high ambient noise generated by the motor in the rear of the bus dictated that one speaker be mounted in the rear.

A combination of solutions were used to overcome these problems. Directional speakers were chosen so that a speaker at each end of the bus would push sound toward the middle. This allows the front speaker to be pointed away from the microphone to reduce acoustic feedback. The front speaker is above and away from the passenger's head. Since both are directional speakers, with narrow dispersion patterns, a person sitting or standing directly below the speakers, will not suffer any discomfort. An additional speaker is mounted in the skin of the bus near the front door used to address passengers on the curb. A selective switch on the bus operator's console selects the internal or external public-address systems at the operator's option.

The audio response of the system was chosen to be above the low-frequency ambient noise of the bus resulting in a high intelligibility system suitable for voice announcing. A noise-cancelling microphone was selected to reduce the pickup of bus ambient noise and also to reduce the acoustic feedback; this microphone will be mounted within easy

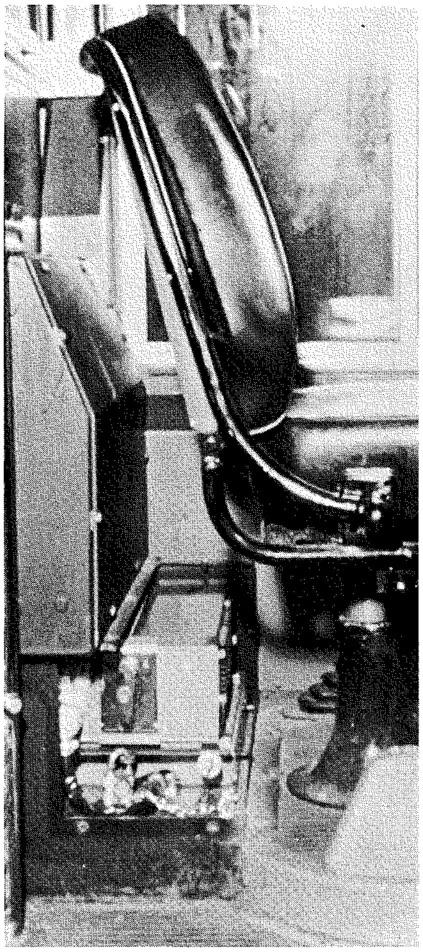
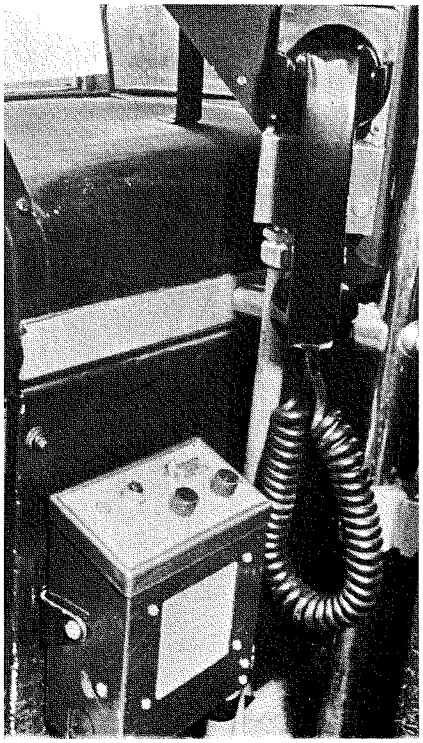


Fig. 2—The mobile T/R unit with protective cover removed.

Fig. 3—Control unit and handset holder mounted in vehicle.



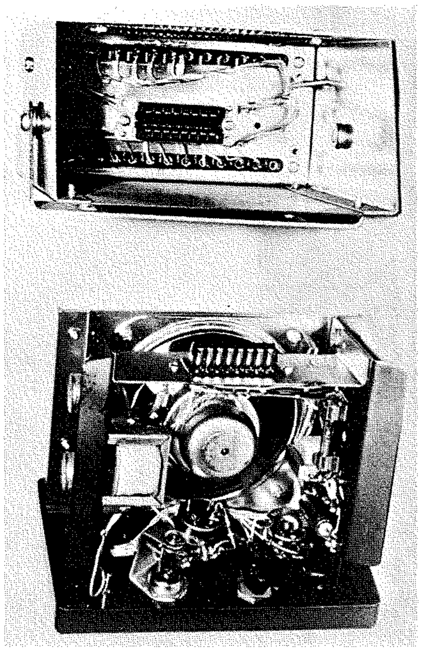
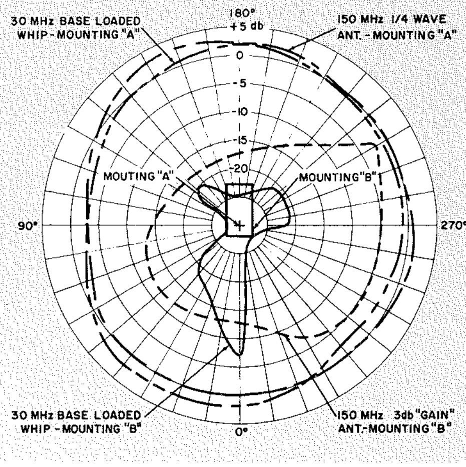


Fig. 4—Control (plug-in) unit and housing showing mating connector.

Fig. 5—Microphone is positioned for minimum feedback and accessibility.

Fig. 6—Low- and high-band bus plots.



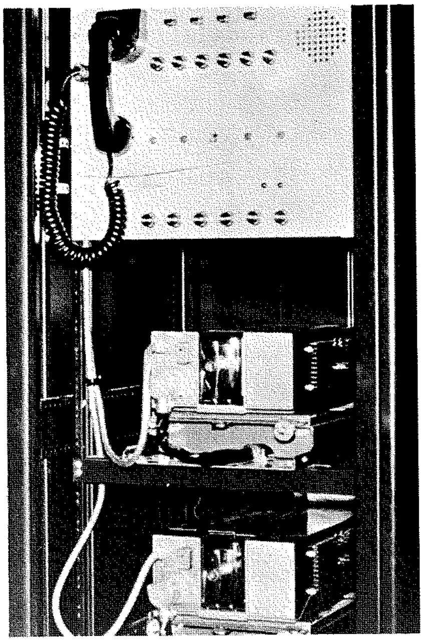


Fig. 7—Base station rack equipment.

reach of the driver (Fig. 5). The audio amplifier packaging is similar to the control head. Plug-in construction allows easy replacement of the whole amplifier. Again, the only part of the system permanently affixed to the bus are the interconnect wiring and housings.

Bus Antennas

This system will use frequencies in both the low (30 to 50 MHz) and the high (150 to 170 MHz) VHF band. There is a minimum of clearance along the bus routes and the use of a normal length 30-MHz antenna on the side of the bus in several locations produced a very distorted radiation pattern with null points of 20 dB or more (Fig. 6). A field strength comparison of a specially designed low-profile antenna and a much longer antenna showed the low-profile antenna to have only 2 dB loss, when both antennas were mounted in the center of a bus roof. However, the radiation pattern of the low-profile antenna was circular within 2 dB. Since the bus can be facing any direction, the 2 dB overall loss was felt to be a small price for consistent coverage in all directions. The low-profile antenna is only eighteen inches long. A quarter-wave monopole antenna, about eighteen inches long, will be used for the 150-MHz band. Both the 150-MHz and 50-MHz antennas mount on the same base. This feature allows the bus to be converted to either band with a minimum of effort.

30-WATT BASE STATION EQUIPMENT

Nineteen of the base stations in this system will use the low-powered (30 watt) T/R units identical to the mobile (bus) units (Fig. 7). This allows interchangeability between the mobile unit and base stations. Each station uses two T/R units—one for normal use, the other for reserve use. The selection and control of each unit can be made separately by telephone lines, through an extended local control unit or locally within the rack. Control of the stations is done from a specially designed line-termination panel and local-control panel. These panels contain the switching and audio amplifiers necessary to control the stations. The power for these stations is supplied from a set of central-office type batteries with a floating charging system operating from the AC lines. The capacity of the charger and battery were selected to provide twenty-four hours of operation in case of power failure. The use of mobile units as T/R units in the base station facilitates the operation as a battery-powered station.

An extended local-control unit provides local garage dispatcher control of the base station; this unit has facilities for full control of the base station in case of an emergency. Since the unit may be located some distance from the base station, an internal amplifier is used to boost the mike audio. A meter monitors the station supply battery voltage.

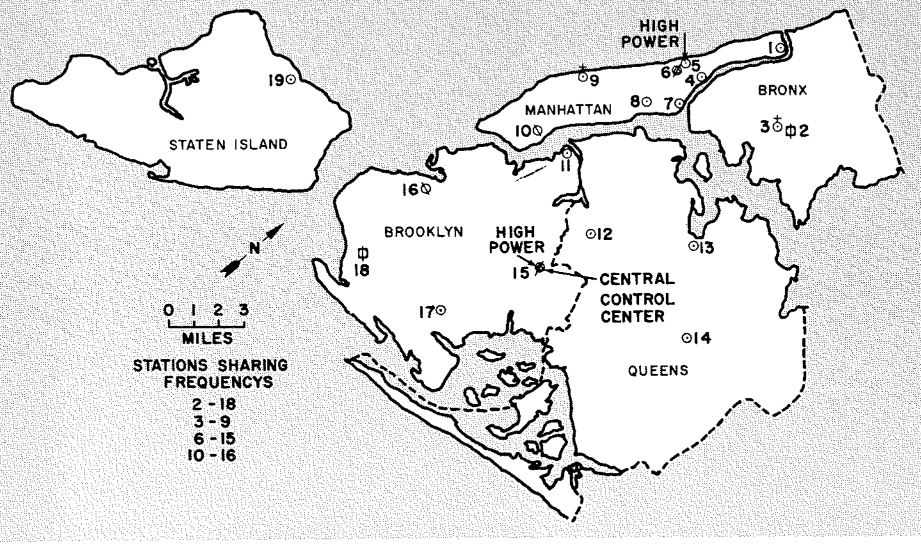
350-WATT BASE STATION EQUIPMENT

The two additional base stations will be highpower (350 watts) RCA super basefone equipment featuring full duplication for safety and reliability. In case of power failure, an emergency power generator will supply AC operating current. The low-power stations will be used for local area bus traffic and will be installed in nineteen bus garages located throughout the five boroughs of New York. The high-powered stations will be used for maintenance, supervision and patrol functions and will be installed at two locations in the city (Fig. 8).

MASTER CONTROL

The entire system will be controlled from a master central-control center in East New York. This control center will consist of twenty-four consoles and two assignment panels. Each console (Fig. 9) will be surrounded by a booth giving the operator semi-privacy. A map of the operating area will be suspended above the console within easy view of the operator. The console will be capable of controlling up to six base stations. During the busy hours, each console will probably control only one base station; during the slack periods the number of operators will be decreased and the number of stations per console increased. Normally the number of console operators will be somewhat proportional to the number of operating vehicles. Assignment panels are used to key the desired base stations to the desired console; these panels indicate assignment status at a glance. The selection of normal or reserve status on the base stations is also made at the assignment panel. The selection and assignment is indicated by pilot lamps on the assignment panel and on the appropriate console control panels. This feature allows complete supervision of the central control room assignment status. The consoles and assignment panels contain a minimum of active elements. As far as possible, all active elements—amplifiers, power supplies, relays—are contained in separate console racks and only the switching and indication is done at the console. This feature allows most of the

Fig. 8—Location of high-powered stations.



maintenance to be done in the rack area with a minimum of interruption to the dispatching operation.

In addition to the radio controls, the consoles have Electrowriters for written communication to the garages and *call director* for telephone communication facilities. The console racks will be equipped with multiple-track low-speed tape recorders to record every radio transmission and reception.

SYSTEM OPERATION

The dispatcher presses a call-alert button on the console. This causes transmission of a 1000 Hz tone. The transmitter carrier also has the proper subaudible-tone-squelch tone deviation. All buses assigned to the base station then hear the 1000-Hz alert tone. The dispatcher then verbally calls the exact bus by number to communicate. When the bus responds, the dispatcher disables the base station tone-squelch encoder for the remainder of the contact. When the bus operator lifts the handset to respond, the receive-tone squelch system is disabled, negating the need for a subaudible tone on the base-station transmission. However, all other buses assigned to this base require a subaudible tone to open the speaker; and, therefore the remainder of the conversation will not be heard on the other bus speakers. This not only prevents the bus passengers from hearing the text of the message, but also reduces the disturbance to others not concerned with the message. The base station subaudible tone frequencies and bus subaudible tone frequencies are different, thereby preventing the bus operators from hailing each other except by prior arrangement through the dispatcher or by an unlikely coincidence.

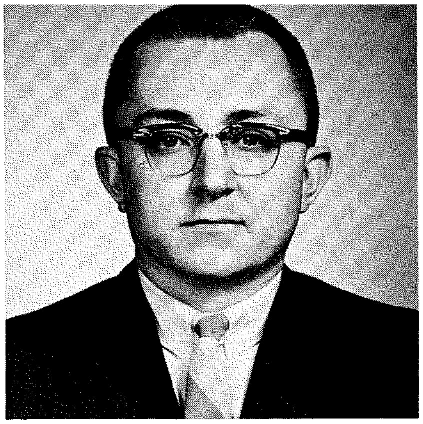
PORTABLE UNITS

Approximately 250 hand-held portables are required in this system for use by street dispatchers during rush hours and emergencies. The hand-held units communicate directly with the buses or supervisory vehicles over very short line-of-sight distances. These units allow street dispatchers to direct a bus even though the operator may not be able to see the dispatcher at a crowded bus stop.

COVERAGE SURVEY

A preliminary radio-coverage survey of the bus operating areas was made using temporary antenna installations. This information was used to determine the type antenna and tower height required for coverage of the area. In addition, the preliminary survey information pinpoints the poorest signal areas. This knowledge determines where the highest concentration of measurements should be made. The final survey was then taken with a high percentage of measurements made in the known weak signal areas.

The final survey measurement points on a typical garage are shown in Fig. 10; each *X* indicates a measuring point. The preliminary survey on this garage showed the weakest signal to occur in lower Manhattan and, therefore, the largest percentage of measurements were made below 45th street with an even larger percentage taken below 15th street. Fig. 11 shows the cumulative distribution of signal amplitudes for the same station shown in Fig. 12. Since the measurement technique was heavily weighted toward weaker signal areas, this chart is a conservative indication of the signal coverage. The final surveys were made using the assigned frequencies, final antennas, and tower heights as delivered and installed. A bus with a transmitter-receiver unit and the proper antenna installed was used as a mobile transmitting unit. The signal strength was then measured on a calibrated receiver at the base-station site. A thru-line wattmeter was connected to the bus to maintain and correct any transmitter output power changes during measurement.



GEORGE R. KAMERER graduated from the University of Pittsburgh with the BS in Electrical Engineering in 1958. He joined Melpar, Falls Church, Virginia upon graduation where he worked on the design and production of the Air Force F101 flight simulators. He joined RCA in 1960 and was employed in the Mobile Equipment Design Group. In 1964, he joined the Systems Engineering Group where he has been employed in the design and implementation of system projects.

Due to the scarcity of frequencies, several of the garage base stations share an RC channel with another garage. In this case, different subaudible-squelch-tone frequency pairs prevent interference during the calling mode. Geographic separation and choice of antenna patterns provide signal-strength ratios sufficient to provide receiver capture in the desired operating areas of either base station sharing a frequency. This precludes either station from interfering with the other during the operating mode.

Fig. 9—Typical control console.

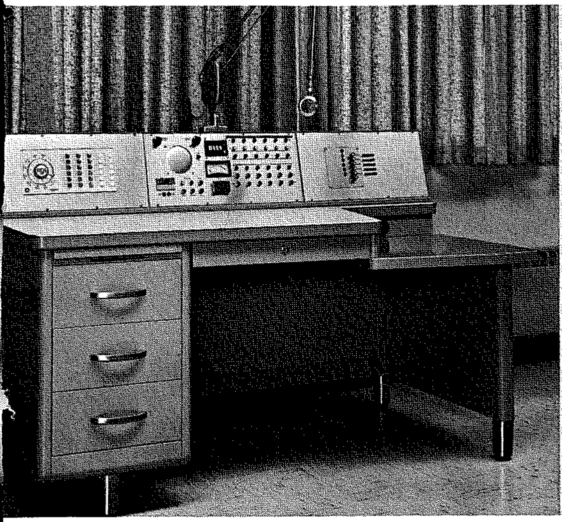


Fig. 10—Measurement distribution.

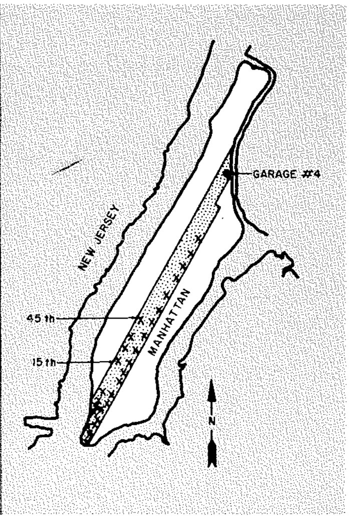
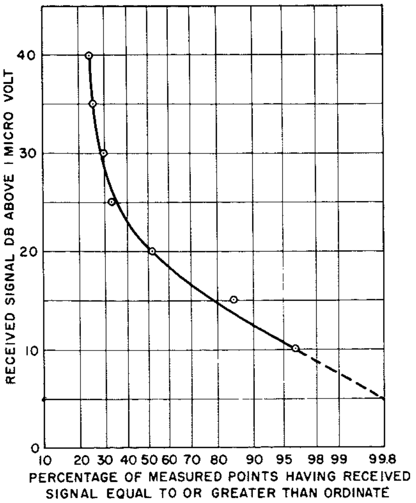


Fig. 11—Percentage of measured points having received signal equal to or greater than ordinate.



TV Transmitter Monitoring Problems

At present, the TV broadcast industry does not have a standard RF monitor. This paper discusses the use of a standard receiver in a vestigial-sideband system to determine the transmitted signal characteristics, and considers also the difficulties involved in measuring the characteristics of a standard receiver. Problems of determining the phase pre-equalization of the system and the resulting phase characteristic of the station demodulator are described. Results of measurements made on two receivers illustrate the need to solve the phase equalization and standard monitoring problem.

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IDEALLY, the television transmitter provides a transparent window between the transmitter's 0 to 4.2-MHz input and the TV receiver. Its purpose is to translate the frequency spectrum and increase the power of the intelligence. However, in a vestigial-sideband system, transmitter and receiver are interlocked and system amplitude response should be determined by the receiver (receiver attenuation); some phase pre-distortion provided at the transmitter accommodates what was considered as the normal receiver at the time color TV standards were set. The system amplitude response and the delay specification for the transmitter are shown in Figs. 1 and 2.

LIMITATIONS DUE TO IMPLEMENTATION TECHNIQUES

Ideal System

The versatile color TV system has the capacity to reproduce a color picture with 4.2-MHz luminance detail, three-color detail to 0.5 MHz, and two-color detail from 0.5 MHz to 1.3 MHz. The system was planned wisely to ensure an unrestricted future color equipment development. The system has vestigial-sideband characteristic adopted when monochrome standards were set; this characteristic imposes a limitation on the TV receiver.

Assume that the transmitted signal is a linear phase RF signal and the receiver has a linear phase RF/IF characteristic. When these conditions exist, a linear-slope or skew-symmetrical receiver vestigial-amplitude characteristic, with practically no sideband response lower than 0.75 MHz, reproduces the correct video amplitude and phase. If the transmitted signal is phase equalized by video equalizers at the transmitter video input, the system can then be phase equalized ideally for only one vestigial slope at the demodulator.

Receiver Limitations

One receiver characteristic causing quadrature distortion is that the demodulator is an envelope detector. This aspect of TV receivers makes it mandatory that the transmitter be monitored by at least an envelope detector.

At low-signal levels, the asymmetry of the receiver's response about the picture carrier is a function of the antenna terminal voltage. As the amplitude of the received signal increases, a level is reached where the response remains essentially the same, independent of signal level. Even for large signal-level response conditions, there is the additional problem that responses of different type receivers are not the same. This will be discussed when low-frequency phase equalization is considered. Receiver-response amplitude shaping solely by minimum phase circuits produces some phase distortion within the pass band. Presently, a phase pre-equalization is inserted at the transmitter for the higher video-frequency phase distortion of what is considered the normal receiver (Fig. 2); but, there is no low-frequency pre-equalization. Some receiver manufacturers peak the video amplitude response at approximately 1.5 MHz in the second detector and video amplifier to correct partially for the phase distortion of the IF amplifier. According to A. vanWeel's paper,[1] low-frequency group-delay distortion reduces to approximately 60 nanoseconds by this technique. Other receivers have IF responses that are closer to Gaussian with the picture-carrier response below the 50% response point; this technique may be used in combination with video peaking. Perhaps future receivers may have IF circuits with phase correction.[2]

Transmitter Limitations

Complexities involved in the transmitter are the high-voltage and power levels that are generated as modulated signals; consequently, large components and tube techniques for modulating the signal, and methods for increasing the power are all involved.

The transmitter must meet certain specifications put forth by the FCC and EIA. Within specifications, the system will produce good pictures, but monitoring and possible phase equalization problems must be solved by the industry to improve system performance. As pointed out, monitoring is interlocked closely with the receiver characteristics. An industry study is required wherein there may be benefits in arriving at new specifications and modifying others.

TRANSMITTER MONITORING PROBLEMS

The industry has not specified an RF demodulator; EIA standard RS-240 stipulates an *ideal vestigial demodulator* for certain transmitter performance measurements, but the ideal vestigial demodulator is not defined. A small start has been made by the EIA TR-4.1 engineering subcommittee on television broadcast transmitters to determine what industry

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Fig. 1—System amplitude response.

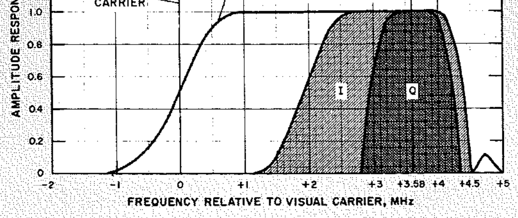


Fig. 2—Required transmitter envelope delay.

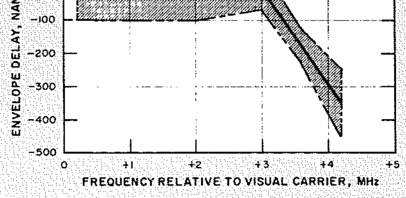
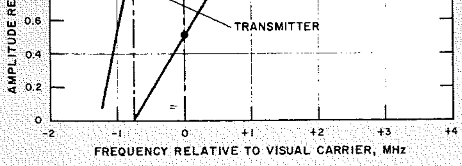
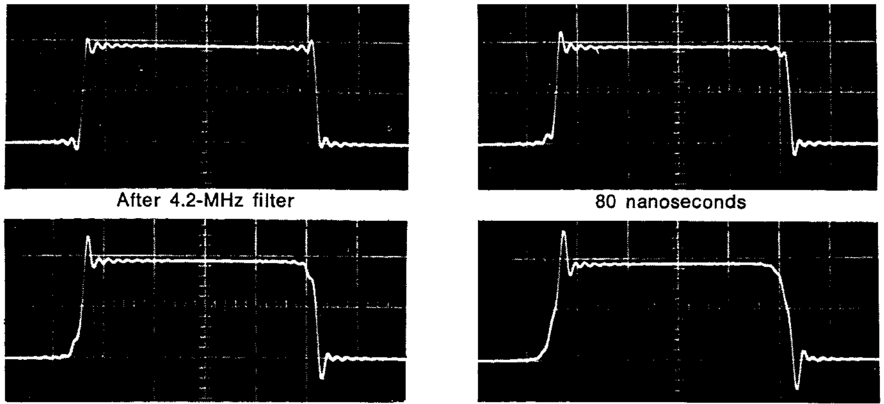


Fig. 3—Idealized lower sideband response of a transmitter and receiver.




After 4.2-MHz filter

80 nanoseconds

140 nanoseconds

280 nanoseconds

Fig. 4—A 100-kHz square-wave, band limited to 4.2 MHz (phase equalized filter). Low-frequency equalization is similar to delay characteristics of Fig. 9.

standards are required for the characteristics desired in a standard vestigial demodulator. The dependency of the television system performance on the demodulator characteristic was pointed out in 1949 by Kell and Fredendall;[3] they suggested the need for a standard monitor to ensure uniform transmissions by the many stations.

The low video frequencies and the high video frequencies, which are considered relative to the mid-band frequencies, will be discussed in this article.

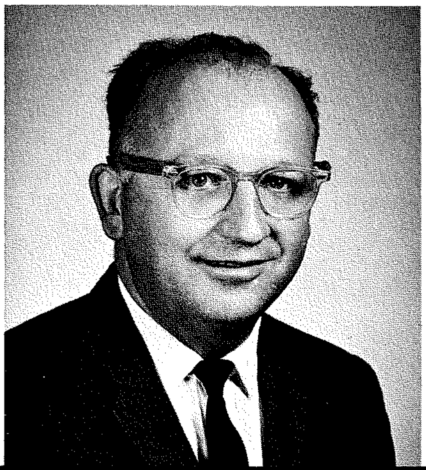
Low-Frequency Response

Present television vestigial sideband systems are premised on the concept that the amplitude-versus-frequency characteristic be determined by receiver attenuation (Fig. 3).

Ideally, a transmitter with a linear RF phase characteristic and a receiver with a linear phase characteristic through the IF amplifier would have only one requirement for optimum system performance: the receiver amplitude characteristic must be a linear-slope or skew-symmetrical about the picture carrier between —0.75 MHz and +0.75 MHz.

However, the transmitters do not have linear RF phase and the receivers do not have linear phase through the IF amplifier; the transmitters are phase equalized by video circuits at the transmitter input. Under these circumstances, the phase can be equalized for only one vestigial-amplitude characteristic. Evidently the intent of present TV technical standards (Fig. 2) is to equalize the transmitter for a demodulator with linear phase; an expression for the video-demodulated phase angle is given in the appendix.

WILLIAM L. BEHREND received the BSEE in 1964 and the MSEE in 1947 both from the University of Wisconsin. From 1947 to 1964, he was at RCA Laboratories where he was associated with the Systems Research Laboratory. At the laboratories he worked on TV broadcast antennae, an omni-range navigation antenna, experimental UHF-TV transmitters, color TV camera, experimental color TV test equipment, system studies of the advantages of precise frequency control of TV visual carriers, color TV tape recording and color TV image reproducers. He was also associated with the work of the National Television Systems Committee and the Television Allocations Study Organization. At the laboratories he received three RCA Achievement Awards. In 1964 he transferred to the Broadcast and Communications Products Division, Meadow Lands, where he has done experimental work on the multiplexing of land mobile signals on the carrier of an FM broadcast station and TV studies. He was associated with the work of the FCC Advisory Committee for Land Mobile Radio Service. Mr. Behrend is a Senior Member of the IEEE, a member of the American Association for the Advancement of Science, and Sigma Xi.



A receiver, with a vestigial IF slope (Fig. 1) determined by minimum phase circuits and a flat amplitude-versus-frequency characteristic in the second detector and video amplifier, will have the low frequencies delayed with respect to mid-band frequencies by approximately 0.15 to 0.2 micro-seconds.[1,4] Kell and Fredendall[3] showed improvement in receiver video response when the transmitted signal had a phase pre-equalization to correct for the low-frequency phase distortion of the receiver. However, present standards do not specify a low-frequency pre-equalization at the transmitter.

If average receiver performance would be improved by low-frequency phase pre-equalization at the transmitter, the only disadvantage would be some reduction in the percentage modulation since the equalization causes some "spiking" on edges. If a partial pre-equalization for receiver low-frequency phase distortion (such as 100 nanoseconds) is added as a compromise at the transmitter, the transmitter video pre-equalization would be 200 to 300 nanoseconds; this includes the correction required for the vestigial-sideband filtering that follows the transmitter and the transmitter output circuits. Fig. 4 shows a 100-kHz square wave at the output of a phase-equalized 4.2-MHz low-pass filter; and the signal with 80-, 140-, and 280-nanoseconds pre-equalization of the low frequencies with respect to mid-band frequencies; the delay characteristics are similar to those of Fig. 9.

It is seen that 280-nanoseconds pre-equalization produces a spike equal to 35% of the black-to-white transition. If a transmitter handles modulation levels up to 10% in the white direction (black-to-white is 75% to 10% modulation or 65% of total signal); then, to accommodate the low-frequency phase equalization ideally the white-to-black transition or the modulation portion that determines signal-to-noise ratio at the receiver would have to be reduced from 65% to 48% of the total signal (white level reduced from 10% to 27%). However, industry could consider also the following methods of operation:

1) Reduce white level to 20% and attempt to modulate the transmitter 100%;
2) Maintain white level at 10%, clip video at a level equivalent to 0% modulation.

If industry should adopt low-frequency pre-distortion at the transmitter to accommodate a standard receiver, then of course, the transmitter RF monitor phase characteristic should be that of the standard receiver. The apparent intent of present standards is that the RF monitor should be phase equalized for low-video frequencies.

VIDEO LOW-FREQUENCY PERFORMANCE OF A TRANSMITTER DEMODULATOR AND TWO TELEVISION RECEIVERS

Although the testing of demodulators and receivers is complicated by the lack of an ideal vestigial transmitter, demodulator selectivity (vestigial slope) is measured by other methods; if when the demodulator is used on an actual system the vestigial amplitude response is determined by the demodulator, a great many valid tests can be made on a double-sideband test generator for a vestigial-sideband system.

There are difficulties in making selectivity measurements because the second detector might affect the response; this happens when a change occurs in the loading effect on the last IF stage along with a change in the modulation frequency. At times a great many measurements may be required to determine the selectivity characteristic.

One method of measurement is to search the spectrum with an RF carrier amplitude-modulated by a small percentage with a 1-kHz tone; the demodulated 1-kHz tone is monitored at the

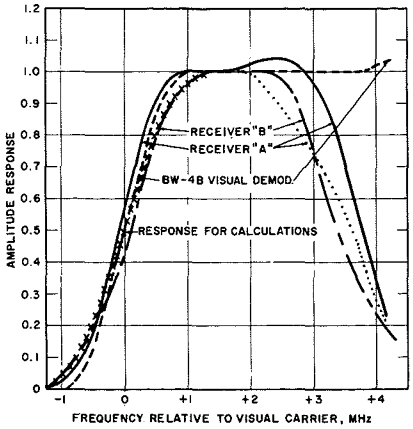


Fig. 5—Amplitude versus frequency response of receivers and vestigial demodulators.

video amplifier output by a selective 1-kHz voltmeter. The advantage of this method of measurement is its independence of the video response of second-detector output circuits and the video amplifier. It has the disadvantage of not including loading effects of the second detector as a function of modulating frequency when such effects are present.

A second method includes the loading effect of the second detector, but has the disadvantage that it depends on the video response of the second detector output circuits and the video amplifier. If the second detector can be monitored successfully without changing its performance, then the video amplifier can be removed from the measurement; but, there is usually some doubt. The measurement technique is to add a low-level sinewave to the picture carrier; the resultant signal is similar to a single-sideband signal. The frequency of the added signal is varied about the carrier, and a tuneable selective voltmeter measures the amplitude of the frequency difference signal.

As an additional check on the response, a video-in (test transmitter)-to-video-out sweep measurement and/or a video multiburst measurement can be made. A video multiburst signal is a composite TV signal having the picture information of one horizontal scan replaced by frequency bursts at frequencies within the video pass band.

Fig. 5 gives the selectivity of an RCA BW-4B RF Demodulator, a color receiver "A", and a monochrome receiver "B." The BW-4B was measured by the 1-kHz technique and confirmed by multiburst measurements. Receiver "A" was measured by both methods; the second method includes any effect the scope probe had on second detector response. It is seen that the two measurements on receiver "A" agree for the important vestigial slope part of the response. Receiver "B" is a 1-kHz measurement. Only this one measurement was made because much more effort would have been required to separate video response from RF-IF response. The circuits driven by the second detector influence its operation — the receiver is essentially an integral package.

By using a double-sideband test generator video-in-to-video-out group delay was measured at the second detector output, at the green cathode-drive of receiver "A", at the cathode drive of receiver "B", and at the video output of the BW-4B (Fig. 6).

Data for receiver "A" are given for three receiver tunings; i.e., picture IF equal to 45.750 MHz (standard IF frequency, picture-carrier response 64%), 45.840 MHz (sound carrier tuned "into trap", picture carrier response 58%), and 45.940 MHz (picture carrier response 50%). Receiver "B" was tuned for a picture IF of 45.750 MHz, the same tuning as for the selectivity measurement. The RCA BW-4B is fixed tuned.

Receivers "A" and "B" were measured by use of Rohde and Schwarz equipment; the equipment provides a delay measurement over an increment of 40 kHz. The RCA BW-4B was measured at a different time by use of the RCA BW-8A group-delay measurement equipment. This equipment measures the delay, starting at 1.5 MHz, relative to the delay at 200 kHz. A measurement is made over a 400-kHz increment, causing the 4.2-MHz measurement to be doubtful because of the large amplitude roll-off from 4.2 MHz to 4.5 MHz when the sound trap is used. The RCA BW-4B has a sound trap that can be switched in or out. It also has a video phase equalizer that provided good group-delay equalization for the unit tested without the sound trap, and fairly good equalization to the inverse of the specified receiver delay (Fig. 2) with the sound trap.

The Rohde and Schwarz equipment can be used for RF-IF group delay measurements, but again there is the doubt about the second detector loading on the last IF stage because the RF search carrier is amplitude modulated with a constant frequency (20 kHz). It does have the advantage that the phase characteristic of the output circuits of the diode and the video amplifiers do not affect the measurement.

For receiver "A", one would expect the RF-IF group delay measurement to be correct, at least about the carrier, based on the selectivity measured by the two methods given previously. The RF-IF group delay was measured and the group-delay curve integrated to obtain the phase characteristic. Using the derived phase characteristic and the measured selectivity characteristic, for

Fig. 6a—Group delay at diode output of receiver "A". Calculated delay double-sideband, linear-phase transmission, and single-sideband transmission that was phase equalized with a linear phase demodulator.

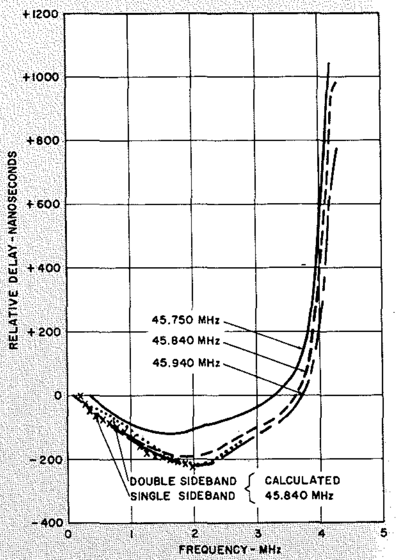


Fig. 6b—Group delay at green cathode (video peaker switch in *middle* and *up* positions).

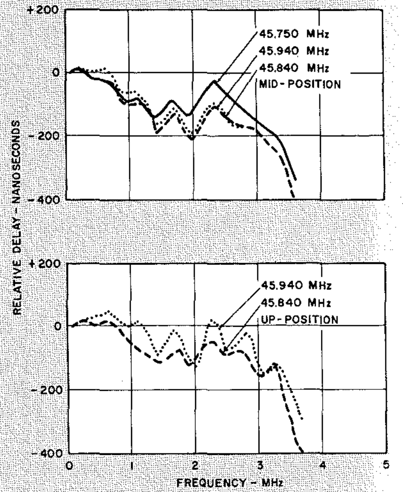
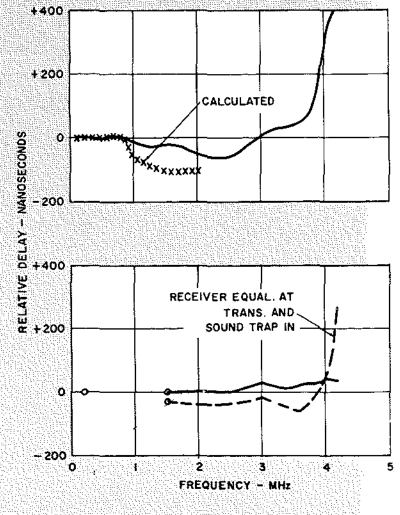


Fig. 6c—Group delay at cathode of receiver "B" (top). Calculated delay for single-sideband transmission that was phase equalized with a linear phase demodulator. Group delay at video output of RCA BW-4B—with and without sound trap (bottom).



an IF picture carrier of 45.840 MHz, the video group delay was calculated. The calculated results (Fig. 6) agree reasonably well with the measured video group delay.

Observations of test waveforms were made as pre-equalization was inserted at the video input of the test transmitter (Fig. 7). Receiver "A" was equipped with switchable video-peaking circuits; except where indicated, the switch was in the high-peaking position as this produced the most symmetrical transitions for most tunings. The various low-frequency, group-delay equalizations at the transmitter input for the waveforms of Fig. 7 are given in Fig. 9.

Fig. 8 is a T-pulse ($\sin^2$ pulse, 125-nanoseconds pulse width at half-amplitude) at the output of the BW-4B with the sound trap and with the receiver phase equalizer at the input to the double-sideband transmitter.

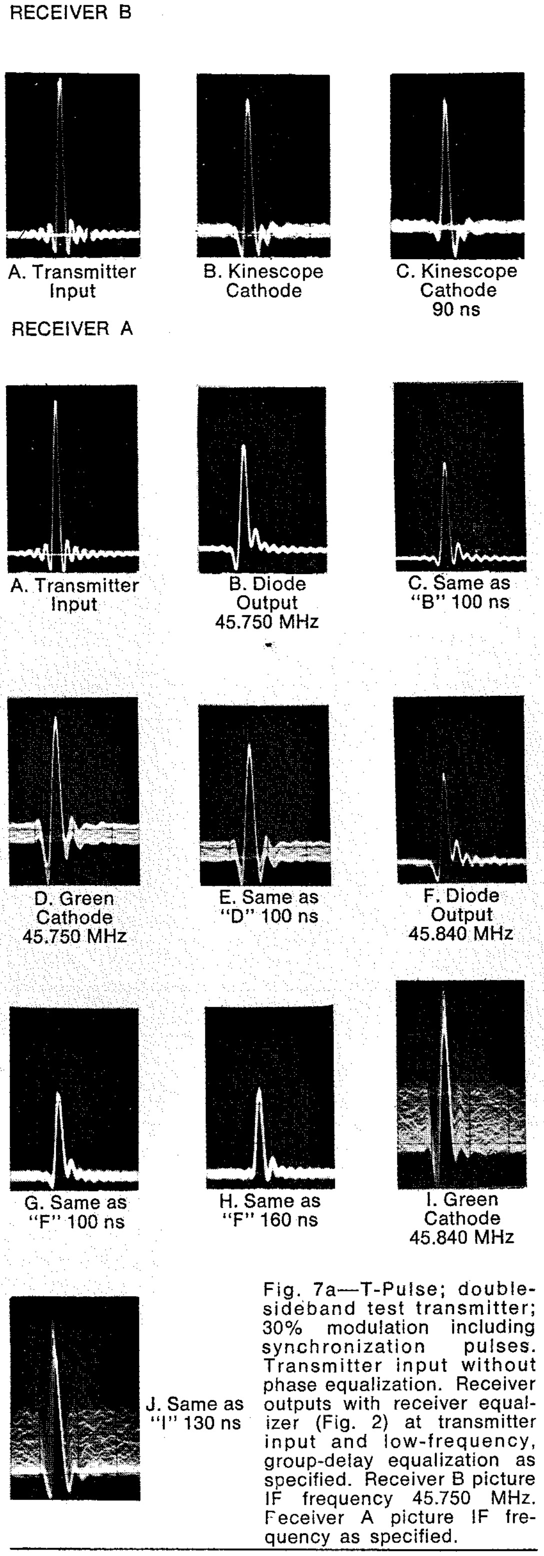
The performance of the receivers would be slightly different on an actual vestigial-sideband system with the transmitter equalized to match a linear demodulator. The vestigial slope (Nyquist slope) of a linear demodulator is to a certain extent arbitrary at this time. A slope that has been used in practical demodulators is given in Fig. 5. The vestigial slopes specified by various demodulator manufacturers are different from one another by a small amount.

The transmitter signal was video-phase equalized for a paper system consisting of:

1) A demodulator with the amplitude of Fig. 5 and a linear phase characteristic;
2) A transmitter with a typical amplitude response and the phase characteristic of two coupled pairs that match the transmitter amplitude response; and
3) The measured characteristics of a Filterplexer (the RF filter between transmitter and antenna).

The group delay at the output of the second detector of receiver "A" was calculated for the above system using the selectivity characteristic of Fig. 5 and the phase characteristic mentioned previously for an IF picture carrier of 45.840 MHz. The calculated video group delays are given in Fig. 6.

The same calculations were made for receiver "B". Comparison of the calculated group delays of receiver "B", with the measured double-sideband delays, are in doubt for several reasons. The calculations are the delays at the output of the second detector. It is not known for certain if there were loading effects of the second detector that were not included in the selectivity measurements. Also, the group delay measurements were made at the kinescope cathode; the video circuits may have had


RECEIVER B

A. Transmitter Input

B. Kinescope Cathode

C. Kinescope Cathode 90 ns

RECEIVER A

A. Transmitter Input

B. Diode Output 45.750 MHz

C. Same as "B" 100 ns

D. Green Cathode 45.750 MHz

E. Same as "D" 100 ns

F. Diode Output 45.840 MHz

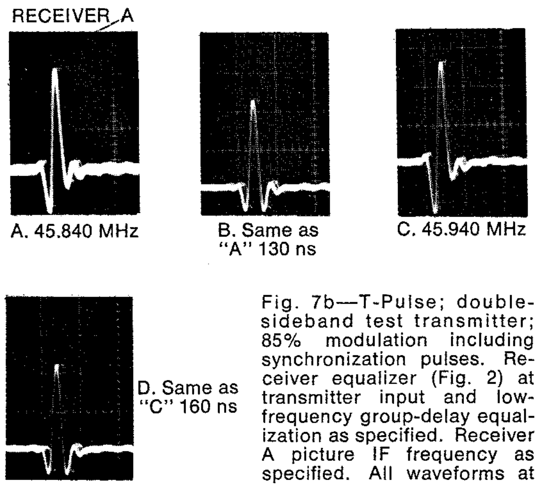
G. Same as "F" 100 ns

H. Same as "F" 160 ns

I. Green Cathode 45.840 MHz

J. Same as "I" 130 ns

Fig. 7a—T-Pulse; double-sideband test transmitter; 30% modulation including synchronization pulses. Transmitter input without phase equalization. Receiver outputs with receiver equalizer (Fig. 2) at transmitter input and low-frequency, group-delay equalization as specified. Receiver B picture IF frequency 45.750 MHz. Receiver A picture IF frequency as specified.


RECEIVER A

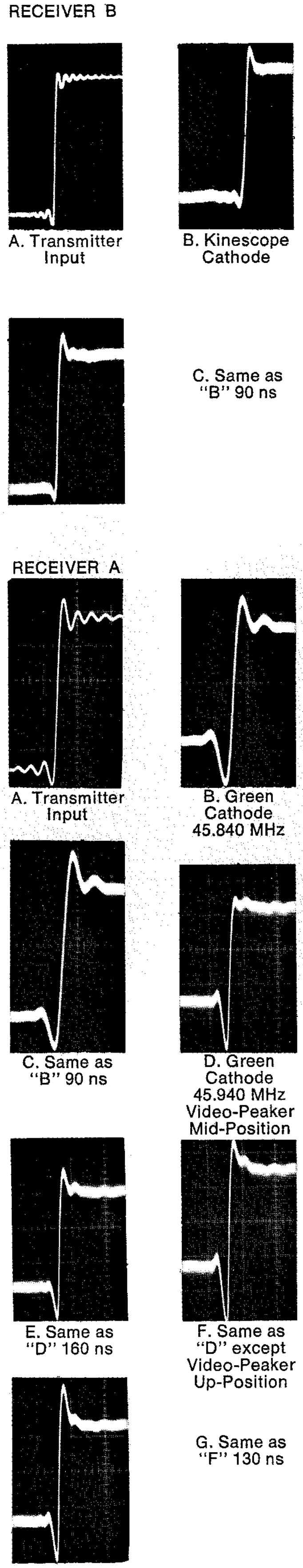
A. 45.840 MHz

B. Same as "A" 130 ns

C. 45.940 MHz

D. Same as "C" 160 ns

Fig. 7b—T-Pulse; double-sideband test transmitter; 85% modulation including synchronization pulses. Receiver equalizer (Fig. 2) at transmitter input and low-frequency group-delay equalization as specified. Receiver A picture IF frequency as specified. All waveforms at kinescope green cathode.


RECEIVER B

A. Transmitter Input

B. Kinescope Cathode

C. Same as "B" 90 ns

RECEIVER A

A. Transmitter Input

B. Green Cathode 45.840 MHz

C. Same as "B" 90 ns

D. Green Cathode 45.940 MHz Video-Peaker Mid-Position

E. Same as "D" 160 ns

F. Same as "D" except Video-Peaker Up-Position

G. Same as "F" 130 ns

Fig. 7c—Edge of 25 kHz square wave; double-sideband test generator; 30% modulation, no synchronizing pulses on signal. Transmitter input without phase equalization. Receiver equalizer (Fig. 2) at transmitter input and low-frequency group-delay equalization as specified. Receiver B picture IF frequency 45.750 MHz. Receiver A picture IF frequency as specified.

Fig. 8—Performance of BW-4 vestigial demodulator to sine-squared T pulse (test transmitter is double sideband and includes high frequency envelope delay predistortion — "receive equalizer" and 4.2 MHz lowpass filter).

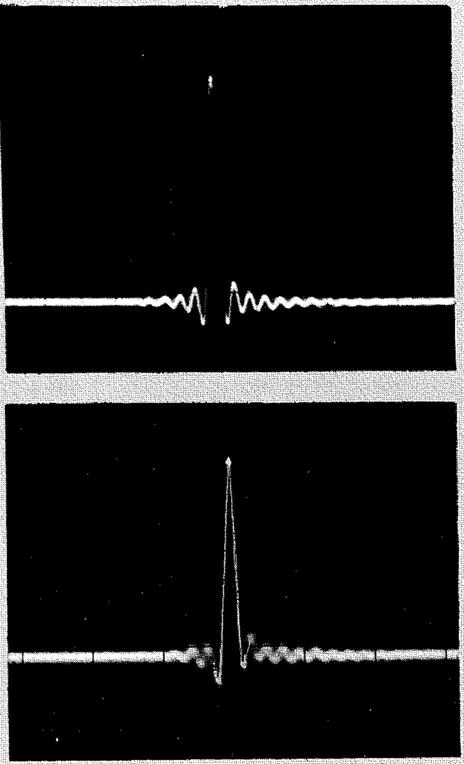
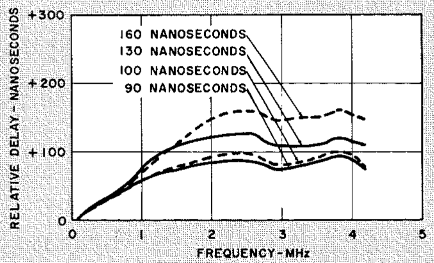


Fig. 9—Low-frequency, group-delay equalizations at the transmitter input for the waveforms shown on Fig. 7.



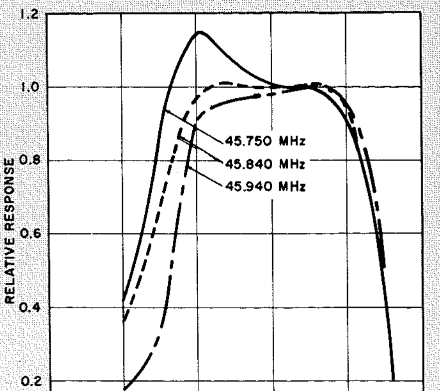


Fig. 10—Measured amplitude responses for various IF picture-carrier frequencies.

mid-band peaking providing some phase correction. The calculated delays are given in Fig. 6. The calculated results indicate that a 100-nanosecond, low-frequency pre-distortion would benefit the receiver "B" signal. However, the effect of the video circuits is not known.

Whether or not low-frequency phase pre-equalization is to be done at the transmitter will require industry solution. *Based on very limited results, it appears that a pre-equalization of approximately 100 nanoseconds would be beneficial.* This magnitude of equalization agrees with the delay recommended by the CCIR[5] for stations that wish to transmit a low-frequency pre-equalization to compensate for receiver distortions. Assuming the present equalization of the group delay at the color-subcarrier frequency to be optimum relative to the 0- to 200-kHz luminance frequencies, the 100-nanosecond pre-equalization would require a change in delay of — 100 nanoseconds at the color subcarrier to ensure a proper relationship of luminance and color difference signals at the color kinescope. This is discussed under video high-frequency response.

HIGH-FREQUENCY RESPONSE

As the TV system is single sideband, the phase of the higher frequencies of the demodulated video signal is the same as the RF phase difference between the upper sideband and the picture carrier. The RF phase can be equalized by video equalizers at the transmitter input.

All TV systems differ in the methods of RF filtering between the transmitter and the antenna. Some systems filter out only the lower sideband and, except for the higher frequency roll-off caused by the transmitters, provide essentially flat amplitude response at the upper sidebands; the only high-frequency phase equalization required is that to correct the transmitter phase. Other RF filtering systems produce a sharp notch at the sound carrier, 4.5 MHz above the picture carrier. Phase equalization is then required for the transmitter and the notch.

In addition to equalizing the transmitting system, a pre-equalization (Fig. 2) is included to correct phase distortion of what is considered a normal color receiver.

The color standards adopted in 1953 included the receiver phase pre-equalization and was based on color receivers available at that time, which had RF-IF frequency response characteristics that were approximately flat to 4.2 MHz above the picture carrier.

Some confusion now exists in the industry because many of the receivers have the *haystack* IF response which has a more linear phase due to the more gradual amplitude response roll-off: response approaches a gaussian. The confusion has reached the point where one manufacturer of RF transmitter demodulators features a composite video output having what is called the *receiver characteristic.* At the published figure of response, roll-off occurs at a video frequency below the color subcarrier with the subcarrier response down a substantial amount. Ideally, the color system requires an overall flat-amplitude response and linear phase for the chrominance signal from transmitter input to the input of the video-color demodulators. If the overall system to the color-demodulator inputs does not have these characteristics, the two independent color signals in the chrominance signal will not remain orthogonal. The outputs of the demodulators will contain color crosstalk and the wanted signals will not have the correct amplitude and phase.

If the chrominance signal, after going through the *haystack* IF and demodulator, passes through flat-amplitude response circuits, there would be large amounts of color crosstalk at the outputs of the color demodulators; this condition exists even when all circuits in combination with transmitter phase predistortion have a linear-phase characteristic. The requirement that overall amplitude versus frequency response of the receiver RF-IF amplifiers, second detector, and chrominance circuits to the color demodulator be flat was pointed out in 1954[6] and again in 1966[7]. For IF circuits that roll-off, the chroma circuits are peaked to provide an overall flat response at the input to the color demodulators. Thus, the overall phase characteristic to the input of the color demodulators is far different than that of the IF amplifier alone.

Overall amplitude and group-delay measurements were made at the input to the color demodulators of receiver "A". The measurements for an IF picture-carrier frequency of 45.750 MHz were made on the receiver as received. For a receiver tuning that would place the sound carrier in the trap (pix IF of 45.840 MHz), the tuning of chroma circuits was adjusted very slightly to change the amplitude response about the color subcarrier about one dB from an unbalanced to a balanced response. The measured amplitude responses are given in Fig. 10 for IF picture-carrier frequencies of 45.750 MHz (standard picture IF frequency), of 45.840 MHz (sound carrier tuned "into trap", picture-carrier response 58%), and 45.940 MHz (picture-carrier response 50%).

Group-delay measurements for the

same picture carrier IF frequencies are given in Fig. 11. Delay measurements relative to the color subcarrier were made with and without the standard receiver-delay equalization (Fig. 2) at the test transmitter input.

Within the frequency band occupied by the chrominance signal, there will be no color crosstalk and the amplitude of the wanted signals will be correct at the output of the color demodulators, if:

1) The overall transfer characteristic at the input of the color demodulators has constant amplitude and a linear phase characteristic, or
2) A phase characteristic that is skew-symmetrical about the color subcarrier.

However, there would be some phase distortion of the wanted signal if the phase characteristic were skew-symmetrical. It is seen (Fig. 11) that the receiver phase equalization at the transmitter produces a phase characteristic closer to a skew-symmetrical characteristic and reduces the color crosstalk, but for this receiver, the phase equalization is not correct. The modification in phase equalization for this case could involve two different conditions and a large amount of work to determine which method is best. Considering only the chrominance circuits, performance would be optimized by a group-delay pre-equalization beginning to equalize at color-subcarrier frequency (3.6 MHz), and insert a larger equalization at frequencies above 3.6 MHz. This would provide the most linear phase characteristic for the chrominance circuits. However, present receivers may require the present standard group-delay pre-equalization (170 nanoseconds at 3.6 MHz) with respect to the luminance information from 0 to 200 kHz. In this case, it might be better to provide an equalization that produces a skew-symmetrical phase characteristic about the color subcarrier. This equalization would be the same as the present one up to 3.6 MHz; above 3.6 MHz, the equalization would be greater. There would not be color crosstalk, but there would be some phase distortion of the wanted signals at the output of the color demodulators.

It may not be possible to completely equalize the system to 4.18 MHz because of the large delay corrections required. One of the advantages of a skew-symmetrical phase is that less correction is required at the higher video frequencies relative to 3.6 MHz. The 45.940-MHz IF tuning requires the least amount of equalization.

The most important effect of the receiver phase equalizer is on the chrominance part of the color signal as the higher frequency luminance signals are rolled off in the color receivers; the "roll-off" is also present in monochrome receivers.

CONCLUSIONS

For optimum performance of a TV system, some of the characteristics of the radiated signal are determined by the RF vestigial demodulator. The industry should specify a standard demodulator to ensure uniform transmissions from all stations. To specify the monitor, the industry must decide what is the best vestigial slope to provide optimum performance for the maximum number of present and future receivers. If group delay pre-equalization is to be different than present standards, the characteristic should be included in a standard demodulator.

REFERENCES

1. A. vanWeel, "Phase-linear Television Receivers," *Philips Research Reports*, vol. 10, pp. 281-298.
2. F. G. Johannesen, "Television IF Amplifier with Phase-Correcting Interstage Network," *IEEE Transactions on Broadcast and Television Receivers*, vol. BTR-11 (Jul 1965) pp. 112-120.
3. R. D. Kell and G. L. Fredendall, "Standardization of the Transient Response of Television Transmitters," *RCA Review* (Mar 1949).
4. F. G. Johannesen, "The Performance Requirements of a Television Monitor Receiver (Nyqyist Demodulator) and Methods of Measurement," *The Radio and Electronic Engineer*, vol. 30, No. 3 (Sep 1965).
5. Recommendation 266, "Phase Correction of Television Transmitters Necessitated by the Use of Vestigial-Sideband Transmission." International Radio Consultative Committee, Documents of the XIth Plenary Assembly, Oslo (1966).
6. J. Avins, "The Design of IF Amplifiers for Color Television Receivers," *IRE Transactions on Broadcast and Television Receivers*, PGBTR-7 (Jul 1954) pp. 14-25.
7. L. Blaser and D. Bray, "Color TV Processing using Integrated Circuits," *IEEE Transactions on Broadcast and Television Receivers* (Nov. 1966).

APPENDIX

1. Expressions for the amplitude and phase of the IF envelope at the input to the second detector.

$$C_{ENV.} = A_c + \{A_L{}^2 + A_u{}^2 + 2A_uA_L \cos [(\emptyset_u - \emptyset_c) - (\emptyset_c - \emptyset_l)]\}^{1/2} \times \cos (W_m t + \Theta)$$

where,

$$\Theta = \tan^{-1} \frac{A_u \sin (\emptyset_u - \emptyset_c) + A_L \sin (\emptyset_c - \emptyset_l)}{A_u \cos (\emptyset_u - \emptyset_c) + A_L \cos (\emptyset_c - \emptyset_l)}$$

A_c is the amplitude of picture carrier at detector input after passing through complete system;

A_L is the amplitude of lower sideband at detector input;

A_u is the amplitude of upper sideband at detector input;

$\emptyset_c$ is the phase shift of carrier at detector input;

$\emptyset_u$ is the phase shift of upper sideband at detector input;

$\emptyset_l$ is the phase shift of lower sideband at detector input; and

$\cos W_m t$ is the original modulating signal at the transmitter. The percentage of modulation is included in A_L and A_u.

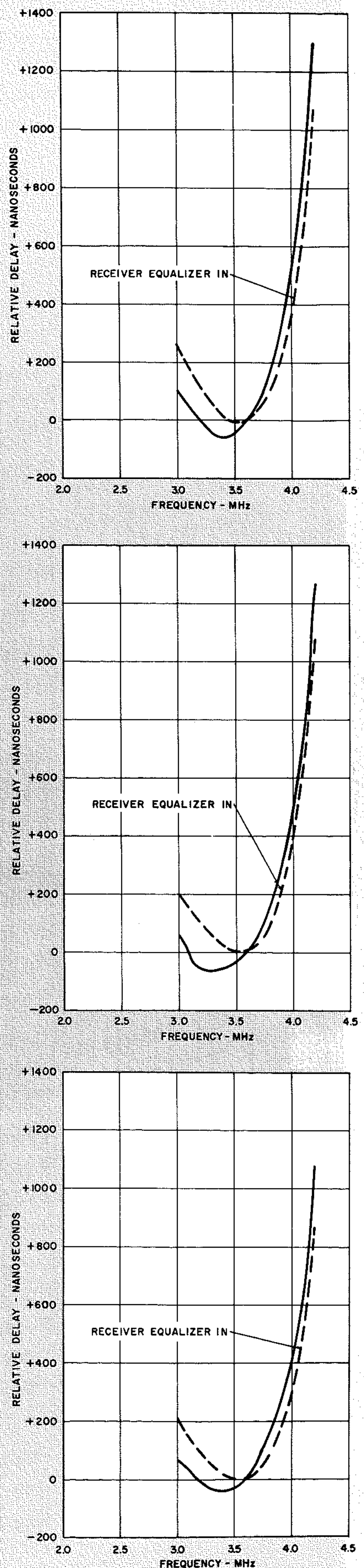


Fig. 11—Group-delay measurements for the frequencies of Fig. 10.

Using a Computer in RF Interstage Circuit Design

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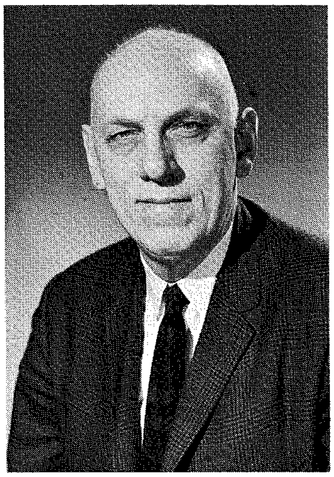
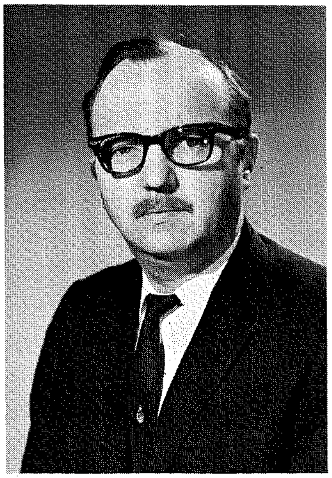
This paper describes how a computer is used to directly print plots relating to the performance of RF amplifiers. The plots are made by a computer-operated page-printer, normally employed to print data in tabular form. The plots use circular coordinates, the outlines of which are also formed by the page-printer. This approach has the great advantage of displaying some central properties of the amplifier through the shape, size, and location of the plot within the circular area. Experience has shown that it is not practical to get the equivalent information by a study of tabulated data. A manual plot is tedious and time consuming, particularly as several plots of 50 points each may be required. The computer also calculates and plots a curve of boundary mismatch, indicating the areas of tolerable and intolerable impedance match.



DAVID ROGERS CROSBY received the BSEE from Rensselaer Polytechnic Institute in 1934 and the MS from Harvard University in 1935. From 1935 to 1941 he was employed as an engineer by the International Telephone and Telegraph Company. Since joining RCA in Camden, New Jersey, in 1941, he has been engaged in development work on high powered transmitters, RF transmission lines, antennas, microwave devices, modulation theory, circuit analysis and computer-aided design. His part time teaching has been extensive, including 14 courses at RCA and at Rutgers University in field theory and in mathematics. Five patents have been issued to him, and eight of his papers have been published in professional journals. Among his memberships are the IEEE and the Mathematical Association of America; also he is a Registered Professional Engineer.



OREST J. HANAS received the BSEE from the University of Maryland in 1960, and the MSEE from the Drexel Institute of Technology in 1964. From 1960 to 1961 he was employed as an engineer by the Philco Corporation, Philadelphia, Pennsylvania. In 1961 he joined RCA in Camden, New Jersey, where he has been engaged in design and development work of spectrally pure high power, high efficiency varactor multipliers and multiplier chains in the 100-MHz to 40-GHz region. More recently he has done development work in the VHF and UHF regions on wideband phase-locked loops, multiplexing methods, spurious frequency analysis, wide range low and high power VCO's and low and medium power wideband amplifiers. He has been part time instructor (1964-1965) at Villanova University in the electromagnetic field theory. He is co-holder of two patents and co-author of one published article, and several internal RCA Technical Reports. He is a member of the IEEE (PGMTT and PGCT).

COMPUTER AIDED design verification begins when a circuit configuration, the element values, and the transistors have been selected and a first version constructed. The contributions of the computer usage fall into five classes:

1) Produces an improved set of transistor parameters,
2) Produces an improved estimate of stray reactances,
3) Verifies mode of operation,
4) Produces voltage and current information for each component, and
5) Permits worst-case analysis.

TRANSISTOR PARAMETERS

In many cases, the high-level drive impedance of a transistor is inadequately presented on the rating sheets. An optimum design is most efficiently achieved when this impedance is known. Computer data for the circuit can be compared with the experimental voltage at nodes near the transistor to lead to an estimate of transistor impedance.

STRAY REACTANCES

The effective value of a capacitor at 100 MHz and above is typically 20% larger than the low frequency capacity due to the inductance of the capacitor leads. This inductance is difficult to measure or calculate, but knowledge of it is useful in determining the best nominal value of the capacitor and the allowable tolerances on the capacitor. A comparison of data from a computer search with known circuit performance will indicate the approximate stray inductance.

VERIFICATION OF MODE OF OPERATION

An RF amplifier may have a mode of operation that is different from that indicated from the schematic. There may be spurious cavity resonances, spurious oscillations, unrecognized transmission line effects. Such spurious modes, if not recognized, may not be adequately stabilized in the production phases, resulting in undesirable non-uniformity of performance in the finished product. A computer verification, based on the schematic with possible additions of small stray inductances and capacities, gives considerable assurance that there is no important spurious mode.

VOLTAGES AND CURRENTS

Measuring RF voltages across components and currents through components is often difficult and slow, particularly when neither terminal of the component is at ground potential. A computer analysis is a substantial aid here. Once the configuration, including the significant strays, is known and the element values

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are known, one computation at each frequency is sufficient. Any experimentally known power across a resistive component, or known magnitude of node voltage with respect to ground, is sufficient base to scale the entire computer results so that all the absolute levels of voltages and currents are known.

WORST CASE ANALYSIS

Here the computer can make its major contribution. In many cases it is not feasible to make a worst case mathematical analysis without a computer. An experimental worst case analysis is hampered by the extreme difficulty of obtaining an assortment of semiconductor devices that have characteristics of the required tolerance limits.

OTHER EFFECTS

In an RF interstage circuit, such as the one under discussion, the variable elements such as the tuning capacitors do much to reduce the need for tight tolerances on the initial values of the fixed capacitors and fixed inductances. However, the effect of capacity drifts with temperature, for example, can be studied on the computer as an isolated phenomenon, which is not possible experimentally.

THE RF AMPLIFIER

The circuit under consideration is a 10-watt, broadband, single-ended transistor amplifier operating from 200 to 400 MHz. Transistors in this power and frequency range typically exhibit low input impedances. The real part of the input series impedance is smaller than the imaginary part and therefore broadbanding of amplifiers using such transistors require special circuits.

Typically, the high-power high-frequency transistors have decreasing gain with increasing frequency which must be compensated if flat octave bandwidth response is achieved.

The amplifier circuit under consideration consisted of a multi-section L-C impedance transforming and compensating section and a simple tapped auto-transformer. Fig. 1 shows the schematic used for the computer verification; Fig. 2 is the measured gain curve.

CALCULATIONS

The first exploratory calculations resulted in three "web" plots; one of these plots is partially reproduced in Fig. 3, showing 24 computer-plotted points on a Smith Chart. [*A Smith Chart is a circular plotting area with a coordinate system which has proven useful for recording traces of complex impedance versus frequency, and providing simplifications and insight when transmission line elements are involved. The plotting routine used is an extension of that of J. W. Bandler.*[1] *All possible combinations of six inductance values and of four resistance values are plotted in Fig. 3. The plotted points are joined by straight lines, resulting in a set of traces of constant inductance, and a set of traces of constant resistance, producing the web pattern.*] A study of the three web plots led to the conclusion that the most likely value of the driven transistor input resistance (B16 of Fig. 1) is 2.4 ohms, and the most likely input inductance (B15 of Fig. 1) is 4 nanohenries.

A principal argument for reaching these conclusions is that the amplifier is known to have reasonable gain in the 300- to 350-MHz region, so the input impedance to the matching network which loads the driving transistor must be close to optimum. This optimum load impedance region for typical driving transistors is known to be inductive, and to be near the center of the Smith Chart, but below the horizontal diameter of the chart.

Since the shape and orientation of the

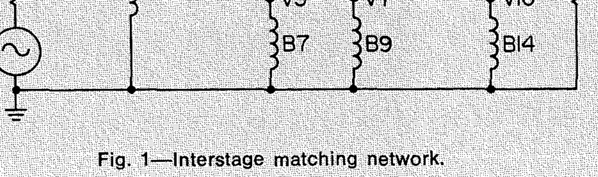

Fig. 1—Interstage matching network.

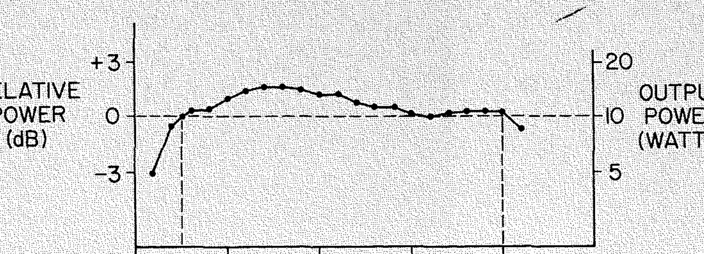

Fig. 2—Measured gain curve.

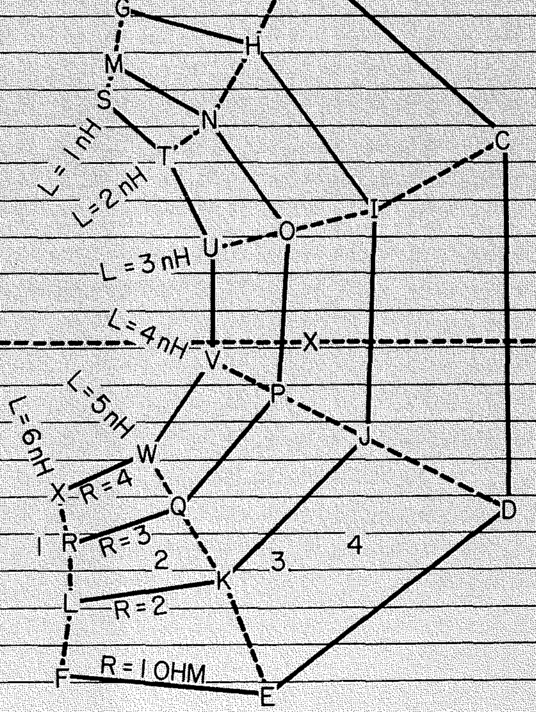

Fig. 3—Section of Smith chart plotted by page-printer (plotted points are load impedances for driver stage); this scan is to determine input impedance of transistor.

web varies markedly with frequency, these rough guidelines are adequate to indicate the transistor input inductance and the base resistance. A more careful determination could be made by using experimental data, such as node voltages, and then varying the parameters in the computations until the best fit between computed and measured node voltages is obtained.

A check on the reasonable value of stray reactances is shown in Fig. 4, where the input impedance of the network is plotted versus frequency. Two traces are plotted: one with strays of three nanohenries and one with strays of five nanohenries. The computed wide excursions of the trace for the five nanohenry condition is evidence that the strays are less than five nanohenries in view of the experimental performance. Four equal stray inductances were used (B5, B7, B12, B14 of Fig. 1).

The input impedance trace for the case of four nanohenry strays is shown in Fig. 5. Also shown is a target trace consisting of four points, joined by a double line. This is the calculated optimum input impedance to the network, based on an output circuit of the transistor having five picofarads in parallel with a resistor.

The dotted smaller circle is the locus of the 3-dB mismatch points, referred to the 300-MHz point on the target trace. Thus points outside this circle have greater than a 3-dB mismatch loss at 300 MHz. The mismatch contour is theoretically a circle, and the departure from a circle is caused only by the granularity of the plotting and the irregular angular spacing of the points on the perimeter. A 3-dB mismatch contour for 200 MHz would lie a little to the left of the 300-MHz contour. It can now be seen how the principal factors combine to give the overall performance. From about 240 MHz to 290 MHz there is an approximate 3-dB mismatch loss. From about 290 MHz to 400 MHz, the trace lies within the 3-dB mismatch circle, compensating for the fall-off of the transistor gain. Above about 400 MHz, the trace leaves the mismatch circle and the amplifier performance quickly deteriorates. For a more accurate evaluation, a set of mismatch circles, for each of 200 MHz, 300 MHz, and 400 MHz would be helpful.

A program is available to produce similar page-printer Smith Chart plots using the RCA Spectra 70-45 computer. The authors should be contacted by individuals interested.

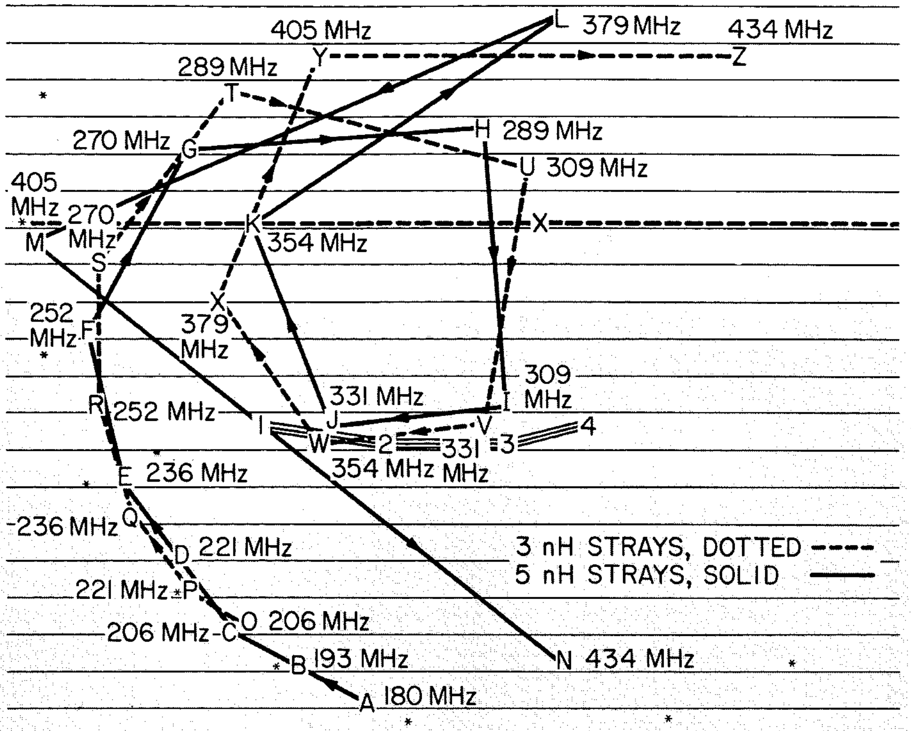

Fig. 4—Section of Smith chart plotted by page-printer (plotted points are load impedances for driver stage); this two-trace search is to determine most likely value of stray inductances.

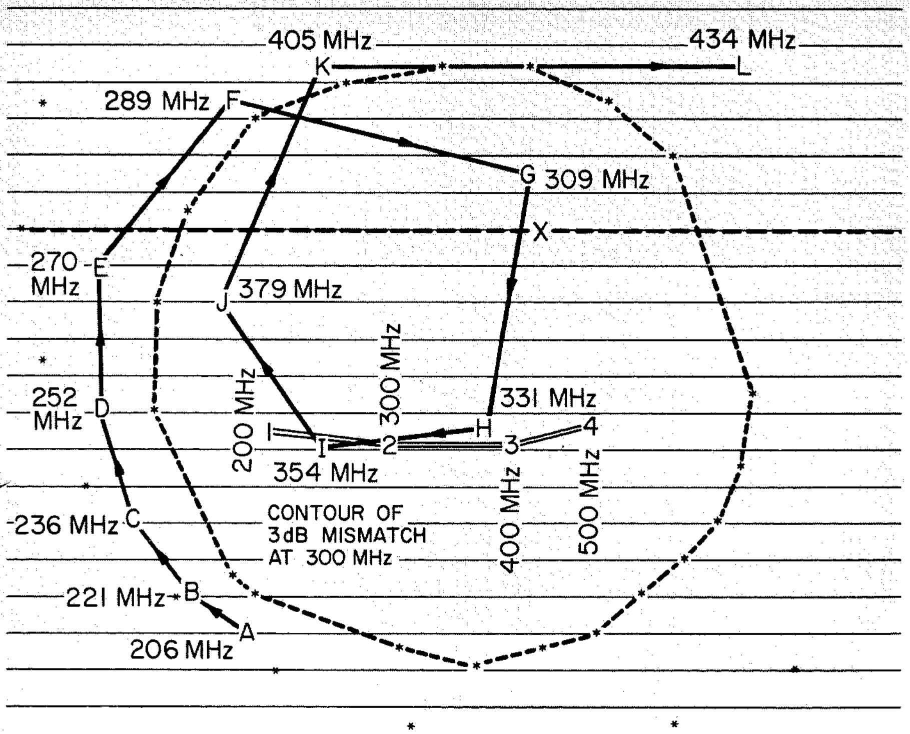

Fig. 5—Section of Smith chart plotted by page-printer (plotted points are load impedances for driver stage); this is the impedance trace versus frequency of final circuit, having stray inductance and transistor impedance from previous searches.

REFERENCE

1. Bandler, J. W., "Frequency Responses in the Reflection Coefficient Plane Plotted by Digital Computer," *IEEE Trans. on Microwave Theory and Techniques* (Aug. 1966) p. 399.

Color Video Switching Systems

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National Broadcasting Co., New York, N.Y.

This paper acknowledges the problems of switching color signals of different time references. Since the external signals cannot be guaranteed relative to timing, correction must be accomplished within the switcher itself. This paper gives the conceptual answer to inflexibility by providing the switcher with the capability of time reference correction.

PRESENTLY NBC has some thirty to forty color studios distributed among its network and owned and operated stations. Each is of a different vintage, and therefore represents the history of color switching. Studio 3K in Radio City, the first color studio, was used for field tests of the NTSC color system. Studio 3B and Mobile Units N3 and N6 represent examples of recent application of our knowledge to produce flexible switching systems.

Our goals at first were to produce high-quality low-distortion systems. This specification during the fifties and the early sixties was difficult because of the unavailability of necessary hardware from commercial sources. Today, many vendors meet the rigid specifications of our industry. Each problem in its turn was solved by introducing more stable, lower cost, and higher quality equipment. Having achieved quality, engineers were faced with an even greater task: to overcome the lack of system flexibility. Switchers were limited to non-composite operation because of the instability of early equipment. The first distribution amplifiers were large and costly. This seriously limited the size of the switcher by restricting the number of busses and the inputs available to the operator.

Advancements in technology coupled with the engineering ingenuity have resulted in studio switching systems that have twenty inputs and ten busses, effects capability of double re-entry, Chromakey, and Program Inserts.

The question is, "Have we reached the ultimate in studio switcher flexibility?" The answer is, "No." The subject of this paper is the switching problems of today.

PROBLEMS

Simply stated, the problems of color switching fall into one general category: the relationship of the switcher to both its sources and its loads (Fig. 1). Studio sources fall into two groups: 1) in-plant cameras, film chains, and video tape machines; and 2) outside remotes and the outputs of other studios.

Video Tape

First, let us locate the color switcher in its proper place midway between its sources and its loads (Fig. 2). All are aware that Fig. 2 is the true representation of Fig. 1. Yes, video tape as a recording device is the monster that governs all studio switching considerations. A video tape recorder will not accept favorably anything but a switch between two synchronous signals.

With this limitation in mind, let us consider our sources (Fig. 3) to see whether they will be acceptable when switched to video tape.

A switch from camera to camera?—OK
A switch from camera to film?—OK
A switch from camera to tape?—OK (providing time base correction has been applied).
A switch from camera to the output of another switcher (Fig. 4)—Watch out, the monster begins to spew out flame.

ROBERT J. BUTLER studied Electrical Engineering at New York University and joined the RCA Service Company in February 1947. He was transferred to the National Broadcasting Company in March of 1952 and has worked in all phases of color studio development. Mr. Butler was appointed Project Engineer in the NBC Engineering Planning and Equipment Development Group in October of 1966.

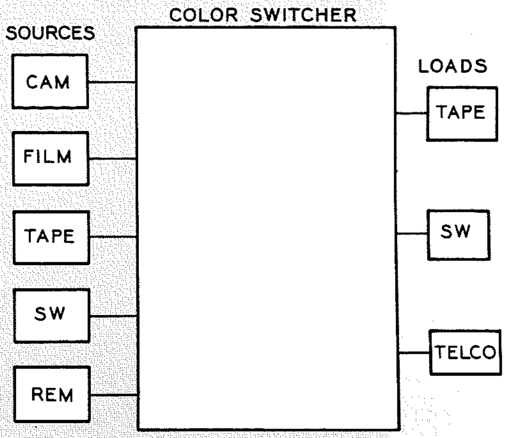

Fig. 1—Relationship of color switcher to its sources and loads.

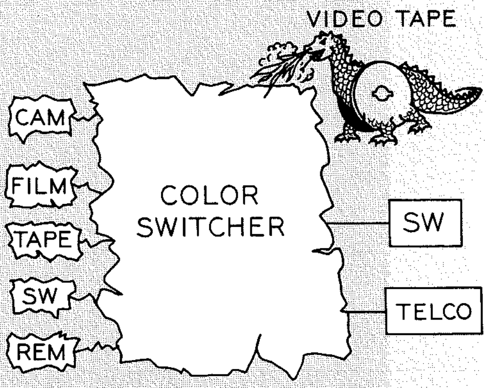

Fig. 2—Video tape (monster) governs all studio switching requirements.

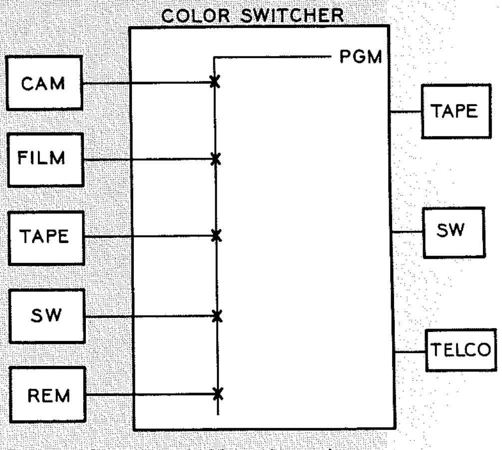

Fig. 3—Source switching alternatives.

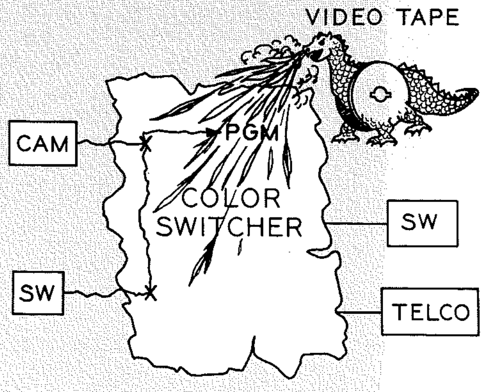

Fig. 4—A switch from camera to the output of another switcher is again dominated by the video tape monster.

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Let's try a switch from camera to a remote (Fig. 5). Well, if we have only the one remote and employ Color Genlock—our demon will remain passive. If not, our tape end product will be disrupted by rolling, loss of tracking, color phase error and a generally dissatisfactory picture transition of unacceptable duration.

Two-Camera Switching

Fig. 6 shows us why a switch from a camera to a second camera routed through another studio can produce trouble. It is most desirable to have all sources of video generated so that their scan phase relationships are the same at the point *T*-0. The inputs to the second studio switcher have the same requirements as those entering studio switcher number one. Unless some special provision is made to counteract the additional delay via Studio 1, a non-synchronous switch will occur in Studio 2 whenever we switch to, or away from, this input.

The solution NBC is contemplating to solve this problem is the construction of a switcher having zero insertion delay. Now, before you think we have increased the speed of light to infinity, let us examine Fig. 7 which will make the zero delay statement more palatable.

The composite output of the studio is stored in a delay medium to increase the total switcher length to exactly *2H*. Before entering the delay medium, a Genlock sync generator produces a set of pulses exactly studio delay time earlier than the signal it receives. These pulses produce a black burst signal composed of sync and burst which occur at time *T*-0. An electronic switch at the output allows all trace time to be delivered to the output via the *2H* delay path. The *T*-0 blanking from the sync generator activates the electronic switch during all retrace time and exactly *2H* prior to the beginning of vertical blanking delivered from the studio path. Picture content is depressed in the vertical plane by four lines because of interlace, and vertical blanking width is increased by *2H*, but in all other respects the studio switcher acts as if it had zero delay. The reason for using *2H* rather than *1H* is because of the odd harmonic relationship between subcarrier and line rate.

Our switchers will now behave as *T*-0 sources of video. This allows flexible integration of shows which require assembly studio techniques.

The switch from camera to remote could only be handled if genlock systems were employed. This method will never be 100% satisfactory because of the need for closed-loop feedback between the multiple originators and the ultimate user. The solution proposed is an all-electronic color translator. At this point, let us defer the concept of such a translator and first consider a related problem and its solution. This solution will later serve as the basic building block for such a device.

Color-Phase Accuracy

To this point, color-phase accuracy of studio switches has not been put into perspective as it relates to various video sources (Fig. 8). There are two variables regarding color phase, which by their nature make them impossible to control. One is the arbitrary setting of subcarrier phase shifters at the various video sources; precise distribution path length is the other factor. At present, unless all sources are previewed shortly before use and phased through the exact switching paths that they will eventually be routed through, color-phase error will result. If then we cannot guarantee externally the delivery of in-phase color signals, we must provide a device within the switcher that corrects the error before the internal switching junctions.

The synchronous color phaser provides the solution for this problem (Fig. 9). A variable delay mechanism in series with the input jack serves the dual purpose of isolation amplifier and automatic phase corrector so that all input signals arrive correctly phased at later internal switching junctions. Black burst within

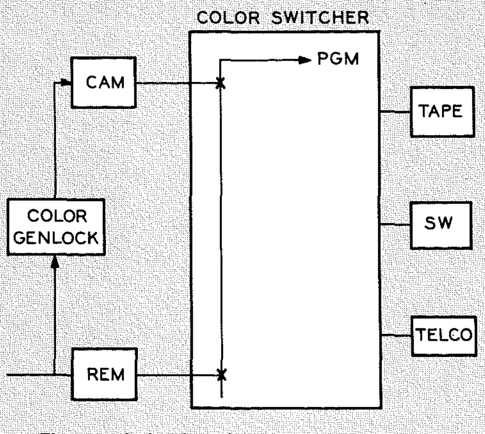


Fig. 5—Switching from camera to remote using color Genlock.

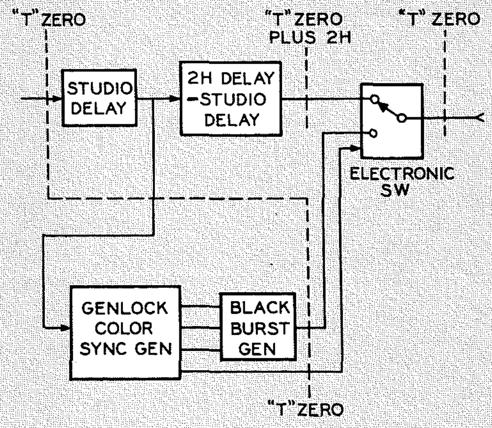


Fig. 7—Zero studio delay arrangement.

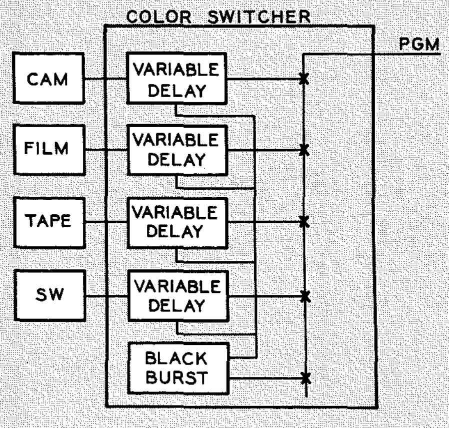


Fig. 9—A synchronous color phaser solves the color-phase-error problem.

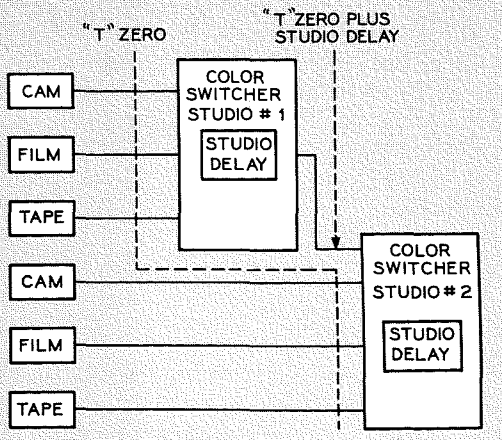


Fig. 6—Timing problems in switching from one camera to a second camera routed through another studio.

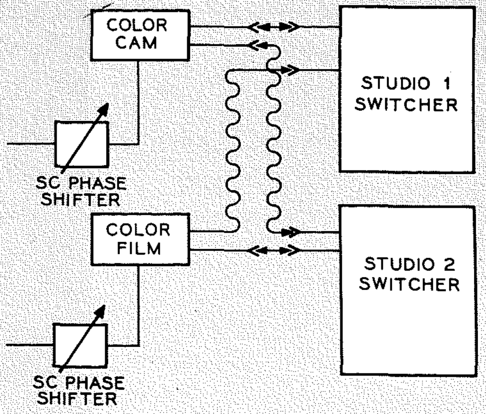


Fig. 8—Color-phase accuracy of studio switches related to various video sources.

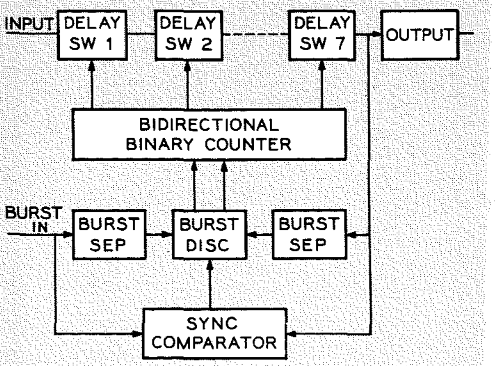


Fig. 10—Color phaser.

the studio serves as the color phase reference for all other inputs.

A block diagram of the phaser is shown in Fig. 10. A total delay of 279 nanoseconds (360° of subcarrier phase) is divided into 7 binary sections. Each section of delay can be switched in or out on command of the bi-directional binary counter which addresses the delay system. The output of the switchable delay continues on to become the amplifier output. Both sync and burst are separated from the output signal and compared respectively with the sync and burst of the black-burst reference. If horizontal sync of both signals is within one microsecond, no inhibit is sent to the burst phase discriminator. A bi-directional output from the burst discriminator will activate the counter, either increasing or decreasing the input path length. Eventually the discriminator output will cease, when the phase of the output signal has been corrected to that of the reference black burst. The bi-directional counter can be addressed manually by a remote switch if desired. Any signal not possessing burst will have no effect on the burst discriminator, thus leaving the delay in its last set position. Non-synchronous signals are automatically rejected by the sync comparator as inputs to the burst discriminator.

The problem of color-phase error falls both inside and outside of the color studio facility. However, the burden of correction lies within the color switcher. The color phaser, therefore must become an integral part of studio switching.

Non-Synchronous Color Remote

If two color signals started exactly in phase, but had a 20-Hz difference in their respective subcarrier frequencies, they would depart from one another at a rate of 7200 degrees/sec., 120 degrees/field, and less than ½ degree/line. At this rate, delay could be either added or subtracted from the remote path allowing the signals to remain in phase until all switchable delay had been utilized. If the color phaser were used as the basic element of a translator; it could hold two such signals in phase for three fields.

The color translator could be composed of some 19 switchable elements of delay, the largest of which would be equal to one-half a field. Referring to Fig. 11, this represents some 8,415 μs. Each section of delay bears a binary relationship to all other sections, the resolution of the system being equal to the smallest bit, some forty degrees of subcarrier phase.

Fig. 12 is a block diagram of the color translator. Black burst is used to supply scan and subcarrier phase reference to the nineteen elements of delay. An odd or even field detector corrects the output of the delay switcher by adding or deleting one-half a line of delay making the remote signal coincident with the local field situation. A color automatic time corrector similar to those used in video tape recorders zeroes the remaining color phase error. A standard processing amplifier with burst and sync regeneration completes the operation.

If the maximum allowable error existed between two color signals, the delay switcher after initial synchronization would maintain synchronization by changing delay at a rate of three bits per field. It would take 50 minutes for the delay switcher to accumulate one field of error. At this point the cycle would start over by resetting all delays back to zero.

CONCLUSIONS

Fig. 13 illustrates a color studio incorporating the corrective devices described in this paper. Please note that the old demon, tape, is now quiet as a lamb. We have accomplished this by the use of three new pieces of equipment:

1) The Zero Studio Delay Amplifier
2) The Color Phaser
3) The Color Translator

DELAY BIT			
1	— 8415.933750	MICROSECONDS	
2	— 4207.9668	"	
3	— 2103.9834	"	
4	— 1051.9917	"	
5	— 525.9958	"	
6	— 262.9979	"	
7	— 131.4989	"	
8	— 65.7494	"	
9	— 32.8747	"	
10	— 16.4373	"	
11	— 8.2186	"	
12	— 4.1093	"	
13	— 2.0546	"	
14	— 1.0273	"	
15	— .5136	"	
16	— .2568	"	331 DEGS.
17	—		165.5 "
18	—		82.7 "
19	—		41.3 "

Fig. 11—Binary elements of the color translator.

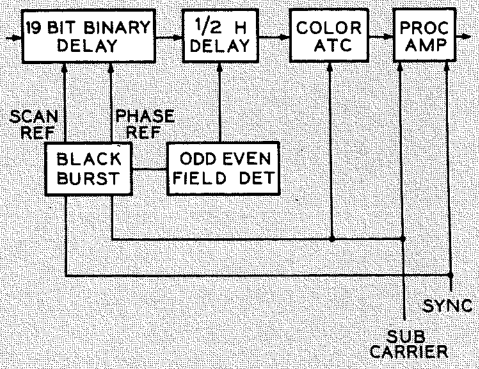


Fig. 12—Color translator.

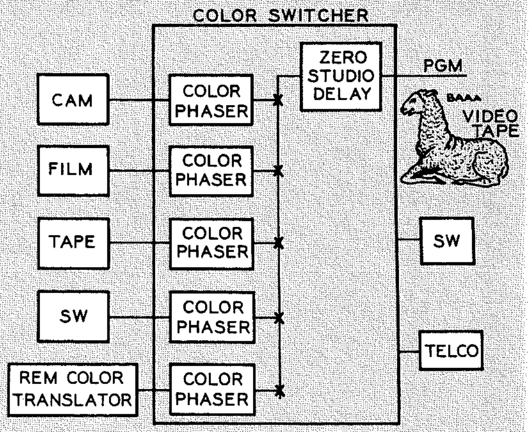
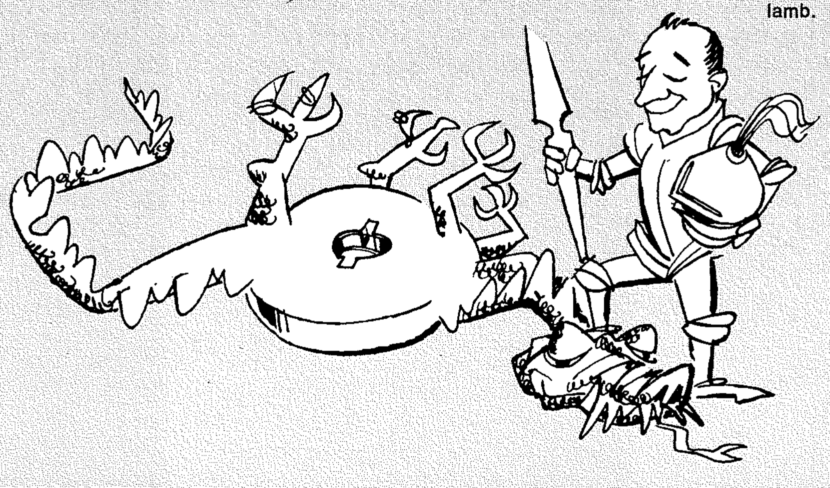


Fig. 13—Color studio incorporating the corrective devices necessary to make the video-tape monster as quiet as a lamb.



Pointing Requirements for Satellite Tracking from Earth

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Because computers are not always available to determine satellite tracking requirements, simplified equations have been developed to describe the motions required for an Earth-based unit to track satellites orbiting about the Earth. This paper develops the equations describing range and angular motions required. The equations for both types of commonly used two-axis trackers (azimuth-elevation and elevation-traverse) are presented.

IN THIS STUDY the Earth is assumed to be non-rotating. This approach is conservative for satellites launched in an easterly direction since tracker angular velocities greater than those required for a rotating Earth are predicted at synchronous altitudes or lower. Since synchronous satellites can not exist for a non-rotating Earth, the approach is invalid for satellites near or above synchronous altitude. The problem may be further simplified by assuming the satellite is in a circular orbit concentric with the Earth's surface.

The errors due to orbit eccentricity will normally be small; for highly eccentric orbits the performance required can be bounded by evaluations at the maximum and minimum satellite altitudes.

Angle position equations have been derived for a three-axis tracker. Angular velocity and acceleration equations are presented for two types of orthogonal two-axis trackers: azimuth-elevation and elevation-traverse types with one axis always parallel or perpendicular to local vertical. In addition, range equations and visibility criteria are presented.

SATELLITE MOTION AND COORDINATE SYSTEM

The coordinate system is shown in Fig. 1. All coordinate systems are orthogonal and obey the right-hand rule, and all displacements are positive as shown.

For this study the satellite is assumed to be in a circular orbit concentric to a non-rotating earth. If the earth's radius and the satellite orbital radius are represented as R_E and R_S, the satellite angular velocity (rad/sec) is:

$$\omega = \frac{R_E\sqrt{g/R_S}}{R_S}$$

where $g = 32.2/5280$ miles/sec^2 and the unit of R_E and R_S is miles. The satellite angular displacement, as a function of time, is then ωt. (With the exception of ω all angular and linear derivatives are defined using the Newtonian dot convention.)

The subscript-S system describes the satellite at some time t where the satellite is at distance R_S from the origin and lies on the $+Z_S$ axis. Thus, $X_S = Y_S = 0$ and $Z_S = R_S$. At some future time, the satellite will attain its closest approach to the ground station. The closest approach, or target crossover, will be defined as time zero ($t = 0$). The coordinate system at time zero is the subscript-o system obtained by a positive rotation about $+X_S$ (the satellite axle) through the angle ωt. The transformation equation is:

$$\begin{bmatrix} X_o \\ Y_o \\ Z_o \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\omega t & \sin\omega t \\ 0 & -\sin\omega t & \cos\omega t \end{bmatrix} \begin{bmatrix} X_S \\ Y_S \\ Z_S \end{bmatrix} = [S] \begin{bmatrix} 0 \\ 0 \\ R_S \end{bmatrix} \quad (1)$$

where S is the satellite angle transformation matrix.

The subscript-1 system is obtained by a positive rotation about $+Y_o$ through the angle γ where the ground station lies on $+Z_1$. The transformation equation is:

$$\begin{bmatrix} X_1 \\ Y_1 \\ Z_1 \end{bmatrix} = \begin{bmatrix} \cos\gamma & 0 & -\sin\gamma \\ 0 & 1 & 0 \\ \sin\gamma & 0 & \cos\gamma \end{bmatrix} \begin{bmatrix} X_o \\ Y_o \\ Z_o \end{bmatrix} = [G] \begin{bmatrix} X_o \\ Y_o \\ Z_o \end{bmatrix} \quad (2)$$

where G is the ground-station-angle transformation matrix.

The tracker is located at the origin of the subscript-G system which is displaced from the subscript-1 system origin (or earth's center) by distance R_E along $+Z_1$. The transformation equation is:

$$\begin{bmatrix} X_G \\ Y_G \\ Z_G \end{bmatrix} = \begin{bmatrix} X_1 \\ Y_1 \\ Z_1 \end{bmatrix} - \begin{bmatrix} 0 \\ 0 \\ R_E \end{bmatrix} \quad (3)$$

The tracker azimuth axis is parallel to Z_G (or local vertical); representing azimuth angle by θ yields:

$$\begin{bmatrix} X_2 \\ Y_2 \\ Z_2 \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_G \\ Y_G \\ Z_G \end{bmatrix} = [A] \begin{bmatrix} X_G \\ Y_G \\ Z_G \end{bmatrix} \quad (4)$$

where A is the azimuth angle transformation matrix and where the subscript-2 system is fixed to the rotating structure.

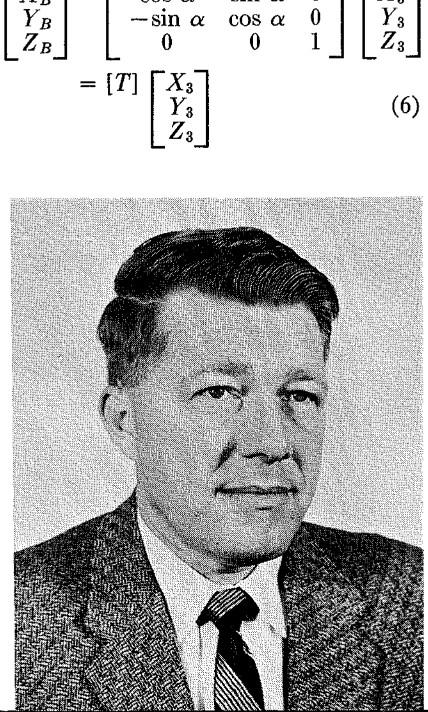
The tracker elevation axis is parallel to X_2 (in the local horizon plane); representing elevation angle by ϕ yields the following transformation equation:

$$\begin{bmatrix} X_3 \\ Y_3 \\ Z_3 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi & \sin\phi \\ 0 & -\sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} X_2 \\ Y_2 \\ Z_2 \end{bmatrix} = [E] \begin{bmatrix} X_2 \\ Y_2 \\ Z_2 \end{bmatrix} \quad (5)$$

where E is the elevation angle transformation matrix and where the subscript-3 system is fixed to the structure rotating about the elevation axis.

The tracker traverse axis is parallel to Z_3; representing the traverse angle by α produces the transformation equation:

$$\begin{bmatrix} X_B \\ Y_B \\ Z_B \end{bmatrix} = \begin{bmatrix} \cos\alpha & \sin\alpha & 0 \\ -\sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_3 \\ Y_3 \\ Z_3 \end{bmatrix} = [T] \begin{bmatrix} X_3 \\ Y_3 \\ Z_3 \end{bmatrix} \quad (6)$$



Reprint RE-14-1-12/Final manuscript received December 4, 1967.

where T is the traverse angle transformation matrix and where the subscript-B system is fixed to the tracker radiating surface and $+Y_B$ is parallel to the tracker beam centerline. The satellite must be on $+Y_B$ at distance R from the tracker origin; thus, $X_B = Z_B = 0$ and $Y_B = R$.

Combining Eqs. 1 through 6 yields the basic tracking equation:

$$\begin{bmatrix} X_B \\ Y_B \\ Z_B \end{bmatrix} = \begin{bmatrix} 0 \\ R \\ 0 \end{bmatrix} = TEA \left[GS \begin{bmatrix} 0 \\ 0 \\ R_S \end{bmatrix} - \begin{bmatrix} 0 \\ 0 \\ R_E \end{bmatrix} \right] \tag{7}$$

Eq. 7 is then multiplied by the inverse matrix product $A^{-1}E^{-1}T^{-1}$. In this case, the inverse of each given matrix is obtained by interchanging the signs of the sine elements only.

$$A^{-1}E^{-1}T^{-1} \begin{bmatrix} 0 \\ R \\ 0 \end{bmatrix} = GS \begin{bmatrix} 0 \\ 0 \\ R_S \end{bmatrix} - \begin{bmatrix} 0 \\ 0 \\ R_E \end{bmatrix}$$

The reduced tracking equation, consisting of three cartesian equations, is obtained by performing the indicated matrix multiplications.

$$R \begin{bmatrix} -\cos\theta \sin\alpha - \sin\theta \cos\phi \cos\alpha \\ -\sin\theta \sin\alpha + \cos\theta \cos\phi \cos\alpha \\ \sin\phi \cos\alpha \end{bmatrix} = \begin{bmatrix} -R_S \sin\gamma \cos\omega t \\ R_S \sin\omega t \\ R_S \cos\gamma \cos\omega t - R_E \end{bmatrix} \tag{8}$$

The tracker beam centerline must be parallel to the ground station horizon plane when the tracker angle ϕ is zero. From Eq. 8, the term $\sin\phi \cos\alpha$ is zero; therefore, $R_S \cos\gamma \cos\omega t - R_E$ is zero if the satellite is on the horizon. Thus, the visibility limit is obtained when $\cos\omega t = R_E/(R_S \cos\gamma)$. Fig. 2 is a plot of visibility time versus orbital plane inclination, γ for several satellite altitudes.

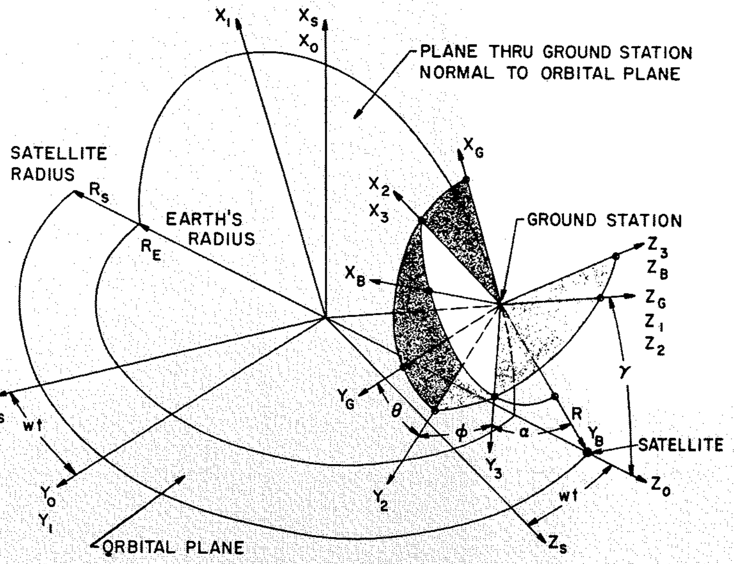


Fig. 1—Satellite coordinate system.

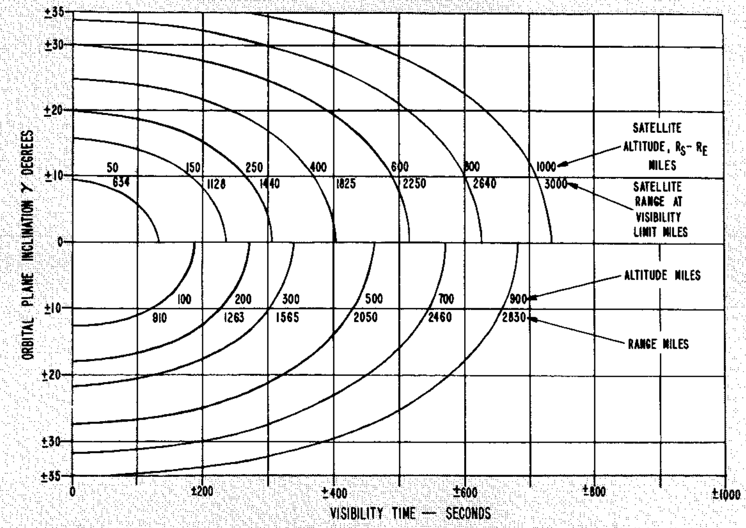


Fig. 2—Visibility time versus orbital plane inclination.

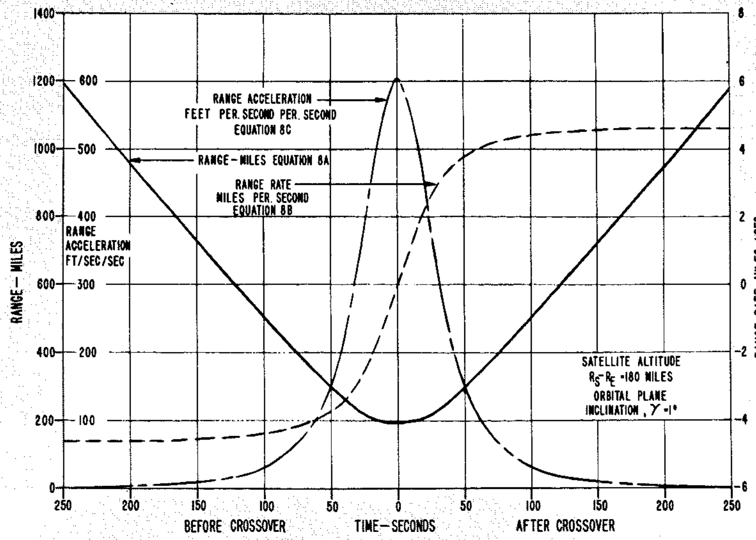


Fig. 3—Range equation, plotted for an altitude of 180 miles and inclination of 1°.

RANGE TRACKING

The range equation is obtained by squaring each of the three equations of Eq. 8 and adding; the resulting range equation

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is then independent of the tracker angle system:

$$R = [R_S^2 - 2\,R_E R_S \cos\gamma \cos\omega t + R_E^2]^{1/2} \qquad (8a)$$

By successive differentiation we may obtain the range rate and acceleration equations:

$$\dot{R} = R^{-1}(R_E R_S \omega \cos\gamma \sin\omega t) \qquad (8b)$$

$$\ddot{R} = R^{-1}(R_E R_S \omega^2 \cos\gamma \cos\omega t - \dot{R}^2) \qquad (8c)$$

Fig. 3 is a plot of the above range equations for a satellite at an altitude ($R_S - R_E$) of 180 miles above the Earth's surface and an inclination (γ) of 1° between the orbital plane and the ground station local vertical. This case is selected as a typical altitude for existing satellites; the selection of the angle γ is discussed in the next section. The above equations are readily examined at crossover by setting $\omega t = 0$; the values at the horizon are obtained by setting $\cos\omega t = R_E/(R_S \cos\gamma)$.

ANGLE TRACKING

As stated, Eq. 8 consists of three cartesian equations; however, the left side contains the four variables R, θ, ϕ, and α. The system is therefore redundant.

A closed-form solution for three-axis angle tracking can be achieved only by specifying the motion of any one of the three axes. The remainder of this paper is devoted to two-axis angle tracking, except that one of the many possible modes of operation of a three-axis system is discussed.

For a two-axis system any one of the three tracker angular degrees of freedom (θ, ϕ, and α) could be eliminated by fixing that axis at any arbitrary angle. This study will be restricted to orthogonal tracker arrangements, thereby limiting the fixity of the angles ϕ and α to cardinal angles only. Then, fixing ϕ at 0° or 180°, or fixing α at 90° or 270°, causes Eq. 8 to degenerate. The system in effect has only one angular degree of freedom for these conditions, thus only θ may be arbitrarily fixed.

The first type of two-axis tracker to be considered is the elevation-traverse system (also known as X-Y or double elevation). This configuration is obtained by fixing θ at any arbitrary angle.

The general case of the elevation-traverse system for arbitrarily fixed values of θ is obtained by multiplying both sides of Eq. 8 by the matrix A or by multiplying both sides of Eq. 7 by the matrix $E^{-1}T^{-1}$. Thus:

$$R\begin{bmatrix} -\sin\alpha \\ \cos\alpha\cos\phi \\ \cos\alpha\sin\phi \end{bmatrix} = \begin{bmatrix} R_S\sin\theta\sin\omega t \\ \quad -R_S\cos\theta\sin\gamma\cos\omega t \\ R_S\sin\theta\sin\gamma\cos\omega t \\ \quad +R_S\cos\theta\sin\omega t \\ R_S\cos\gamma\cos\omega t - R_E \end{bmatrix} \qquad (9)$$

Reidentifying the angles ϕ as β and θ as ψ, we obtain:

$$\beta = \tan^{-1} \frac{R_S\cos\gamma\cos\omega t - R_E}{R_S\sin\psi\sin\gamma\cos\omega t + R_S\cos\psi\sin\omega t} \qquad (10)$$

$$\alpha = \sin^{-1} \frac{R_S\cos\psi\sin\gamma\cos\omega t - R_S\sin\psi\sin\omega t}{R} \qquad (11)$$

The second type of two-axis tracker considered is the azimuth-elevation configuration; the applicable equations are obtained from Eq. 8 by letting $\phi = 90°$ or by letting $\alpha = 0°$. These two cases are equivalent since the tangents of the angles of one case are the co-tangents of the other case.

For $\alpha = 0$ (azimuth-elevation configuration)

$$R\begin{bmatrix} \sin\theta\cos\phi \\ \cos\theta\cos\phi \\ \sin\phi \end{bmatrix} = \begin{bmatrix} R_S\sin\gamma\cos\omega t \\ R_S\sin\omega t \\ R_S\cos\gamma\cos\omega t - R_E \end{bmatrix} \qquad (12)$$

Then:

$$\theta = \tan^{-1}\frac{\sin\gamma\cos\omega t}{\sin\omega t} \qquad (13)$$

$$\phi = \sin^{-1}\frac{R_S\cos\gamma\cos\omega t - R_E}{R} \qquad (14)$$

The angle derivatives for the two systems are obtained by direct differentiation and are as shown in Fig. 4 where $A = (1 - \cos^2\gamma\cos^2\omega t)$ and $D = R^2 - R_S^2(\sin\gamma\cos\omega t\cos\psi - \sin\omega t\sin\psi)^2$.

Fig. 5 is a plot (at crossover, $\omega t = 0$) of selected elevation angles (ϕ) versus altitude ($R_S - R_E$) and orbital inclination (γ).

The angles and angle derivatives are plotted in Fig. 6 for the same conditions used in plotting the range equations ($R_S - R_E = 180$ miles and $\gamma = 1°$). The equations for the elevation-traverse system are plotted for two fixed orientations of the axis system with respect to the orbital plane ($\psi = 0$ degrees and $\psi = 90$ degrees).

Inherent in all two-axis trackers is the pole problem. This problem occurs

$$\dot{\beta} = D^{-1}\,[R_S\omega(R_E\cos\omega t - R_S\cos\gamma)\cos\psi - R_E R_S\omega\sin\gamma\sin\omega t\sin\psi] \qquad (10a)$$

$$\ddot{\beta} = \frac{-R_S\omega}{D}(\sin\gamma\cos\omega t\sin\psi + \sin\omega t\cos\psi)\,[R_E\omega + 2\,\dot{\beta}\,R_S(\cos\omega t\cos\psi - \sin\gamma\sin\omega t\sin\psi)] + 2\,\frac{\dot{\beta}R_S\omega}{D}\cos\gamma\sin\omega t\,(R_S\cos\gamma\cos\omega t - R_E) \qquad (10b)$$

$$\dot{\alpha} = \frac{R_S}{RD^{1/2}}\,[(\dot{R}\sin\omega t - R\,\omega\cos\omega t)\sin\psi - (R\omega\sin\omega t + \dot{R}\cos\omega t)\sin\gamma\cos\psi] \qquad (11a)$$

$$\ddot{\alpha} = \frac{R_S}{RD^{1/2}}(\ddot{R} + R\,\omega^2)(\sin\omega t\sin\psi - \sin\gamma\cos\omega t\cos\psi) - \frac{\dot{\alpha}\dot{R}}{R} - \frac{\dot{\alpha}R\dot{R}}{D} - \frac{\dot{\alpha}R_S{}^2\omega}{D}(\sin\gamma\cos\omega t\cos\psi - \sin\omega t\sin\psi)(\sin\gamma\sin\omega t\cos\psi + \cos\omega t\sin\psi) \qquad (11b)$$

$$\dot{\theta} = \frac{-\omega\sin\nu}{A} \qquad (12a)$$

$$\ddot{\theta} = \frac{2\dot{\theta}\omega}{A}\cos^2\gamma\sin\omega t\cos\omega t \qquad (12b)$$

$$\dot{\phi} = \frac{-1}{RR_SA^{1/2}}\,[RR_S\,\omega\cos\gamma\sin\omega t + \dot{R}\,(R_S\cos\gamma\cos\omega t - R_E)] \qquad (13a)$$

$$\ddot{\phi} = \frac{-1}{RR_SA^{1/2}}\,[RR_S\,\omega^2\cos\gamma\sin\omega t + \ddot{R}\,(R_S\cos\gamma\cos\omega t - R_E)] + \frac{\dot{\phi}}{RR_SA^{1/2}}\left[\frac{\dot{R}}{R} + \frac{\omega}{A}\cos^2\gamma\cos\omega t\sin\omega t\right] \qquad (13b)$$

Fig. 4—Angle derivatives for the elevation-transverse system and the azimuth elevation system.

whenever the target approaches the extension of the lower axis (the axis fixed to ground) centerline and is manifested as an increase in the lower axis angular rates as the target approaches either of the two poles.

For the azimuth-elevation tracker, the poles are located at the ground station zenith and nadir. The orbital plane inclination (γ) of 1° used in plotting Fig. 5 was selected to illustrate the azimuth axis rate increase occurring at crossover. Eq. 13a also illustrates the problem in that at crossover the azimuth rate ($\dot{\theta}$) approaches infinity as the orbital plane angle (γ) approaches zero. Fig. 4 provides a direct measure of the angular distance from the target to the pole; for the azimuth-elevation configuration, the target is at the pole when $\phi = 90°$.

With the elevation-traverse system, the poles remain on the horizon. For $\psi = 0°$, a pole exists at crossover for satellites near the horizon, as shown in Eq. 10a, and Fig. 4 is again applicable. However, the satellite is at the pole when $\phi = 0°$ in this case. For $\psi = 90°$ the poles exist at the satellite rise and set points as illustrated in Fig. 5 or by Eq. 10a. The advantage of the azimuth-elevation configuration is that low rates are required for acquisition and tracking at the lower elevation angles. The advantage of the elevation-traverse configuration is that low tracking rates are required for near-zenith targets.

For systems where the pole or pole locations of the two-axis configurations are objectionable, a three-axis configuration is necessary. For continuous control of all three axes, a suitable mechanization might consist of operation as an azimuth-elevation configuration at the horizon and as an elevation-traverse system at the zenith, the azimuth axis motion being transferred to the traverse axis as a function of the elevation angle. In certain applications, intermittent control of one of the three axes may be acceptable. In this case, the azimuth axis would be intermittently controlled such that the elevation-traverse configuration with $\psi = 0°$ is realized. Thus, when the satellite is invisible, the azimuth axis is repositioned such that $\psi = 0°$ is achieved for the next orbit at crossover.

CONCLUSION

The description of the motion required of a tracking radar in satellite tracking is presented in an easily followed manner by use of matrix algebra. The accuracy is improved over the usually assumed flat Earth analysis without invoking the complications of a rotating Earth.

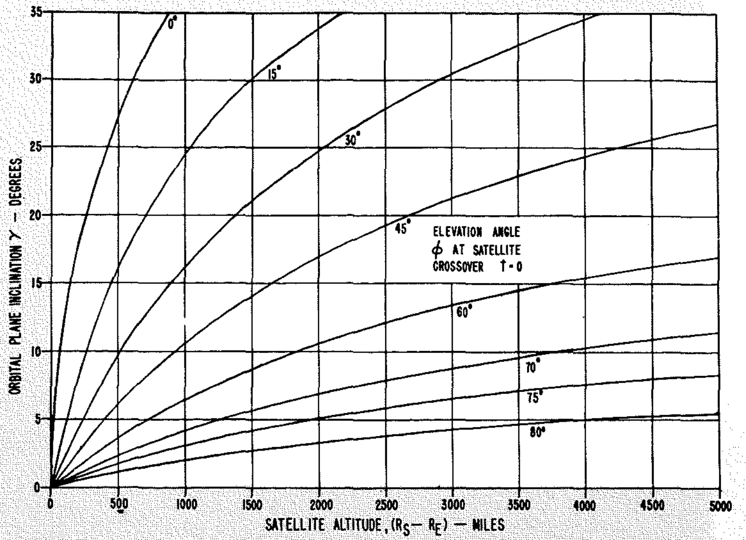

Fig. 5—Selected elevation angles versus altitude and orbital inclination.

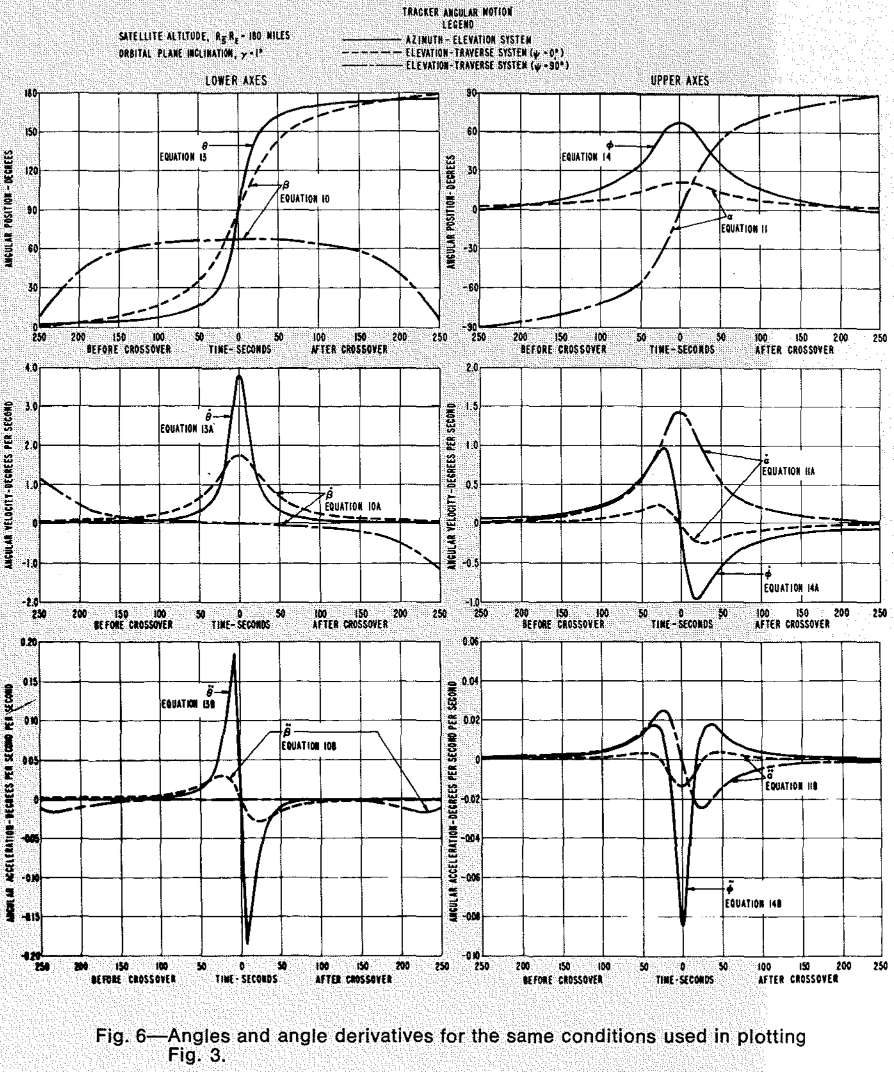

Fig. 6—Angles and angle derivatives for the same conditions used in plotting Fig. 3.

The Third RCA Engineer Readership Survey

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Professional Personnel Programs
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This is the third readership survey of the **RCA Engineer** that has been conducted. The first study was made in 1956, the second year of publication. The second one was made in 1959. Both surveys have been used by the editor and the editorial board in planning to achieve the aim of the publication—a journal "by and for the RCA engineer." With this, the thirteenth anniversary number coming up, it was felt advisable to assess again the acceptance and value of the magazine among the engineer readership in order to further guide editorial decisions.

A QUESTIONNAIRE was distributed with the August-September, 1967, issue of the RCA ENGINEER asking that it be answered and returned anonymously to the editor; 2,250 questionnaires were returned which is considered a very good return for mailed surveys, based on the total circulation.

A number of findings from the survey analysis show that the publication is well-accepted by the engineer population. In answer to the question "How would you rate the RCA ENGINEER?" over 90% rated the publication *excellent* or *good.* Fig. 1 shows the response to this question.

Another indication of the publication's acceptance is shown by the following:

> 87% of the engineer readership say the publication schedule should remain the same with only 8% saying it should be published more frequently and 5% saying less frequently.
>
> 86% say the number of pages should remain the same with only 6% saying there should be an increase and 8% saying there should be a decrease in the number of pages.

The population for which the publication is prepared is a diverse one. Of natural concern to the editor and the editorial board is the development of a periodical that can serve the many interests of the many engineers in a complex organization who perform many different engineering and research tasks in many different fields of endeavor—space programs, entertainment products, defense systems, information processing, etc.

It appears that the publication is germane to the diverse interests of engineers as shown in Table I. In each of the major operating units shown, over 85% of the engineers rated the RCA ENGINEER as *excellent* or *good.*

INTEREST IN TYPE OF ARTICLE

One item in the questionnaire asked the engineer to "please indicate by checking the appropriate box the degree of interest you have in the following type articles:

> *Technical* (descriptions of design techniques, mathematical analyses and scientific papers on specific technical subjects);
>
> *Semi-technical* (generalized papers on technical subjects);
>
> *Engineering activities, engineering services and plant facilities* (descriptions of engineering functions at various plant locations);
>
> *Editorials and business planning articles* (orientation of engineer in his company and his society; economics of the corporation and case studies of interdepartmental projects);
>
> *Magazine departments* (Patents Granted, Pen and Podium, and News and Highlights)."

Table II shows the percent of engineers who have a *strong* or *moderate* interest in the various types of articles. Each type of article appears to attract enough interest to maintain it in the publication. However, it appears the publication, to maintain readership, should continue to concentrate on semi-technical articles.

"IMAGE" OF THE RCA ENGINEER

Several statements about the magazine were used in the study in an attempt to establish an "image" of the RCA ENGINEER as held by the engineer readership. The questionnaire asked that the respondent assess each statement by checking whether or not he *strongly agreed, agreed,* was *neutral, disagreed,* or *strongly disagreed* with it. From these responses it is possible to develop a "composite image" of the magazine as viewed by its readers.

These statements were scored by giving a weight of +2 or −2 if the reader checked *strongly agree* or *strongly disagree*, respectively, in responding to the statement; +1 or −1 if he checked *agree* or *disagree*, respectively, to the statement. A weight of zero was given to the neutral responses.

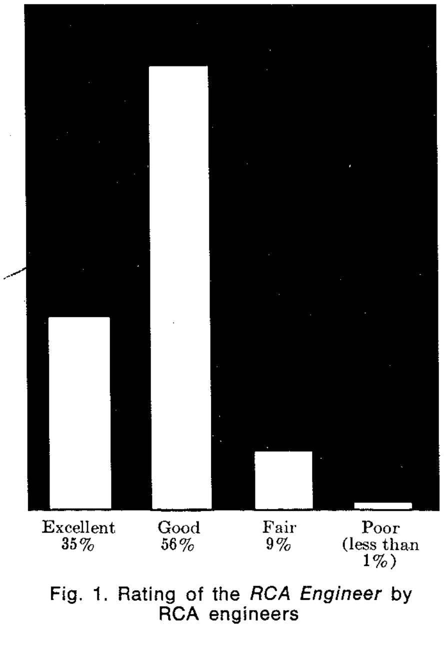

Fig. 1. Rating of the *RCA Engineer* by RCA engineers

The image of the magazine shown in Table III is made up of those statements which reflect the opinion of more than one-half of the respondents. They are listed in order of the strength of the engineers' feelings based on the score described above.

FUTURE ARTICLES

The questionnaire asked the respondents to suggest articles which would be of interest to them and to suggest possible authors for these articles. A large proportion of the respondents suggested ideas for articles and authors. These are on file in the office of the editor and will be used by the editor and editorial board in planning future issues.

ENGINEER'S COMMENTS

Two "open-ended" items were included in the questionnaire: "I like the RCA

TABLE I—Percent Who Rate the *RCA Engineer Excellent* or *Good*

	%
Commercial Electronic Systems	86
Consumer Electronics	97
Record Division	86
Laboratories	87
RCA Victor Co., Ltd.—Canada	94
Electronic Components	92
Defense Electronic Products	90
RCA Communications, Inc.	98
Information Systems	93
RCA Service Company	100
Total Corporation	91

Only major operating units with 20 or more questionnaire returns are listed.

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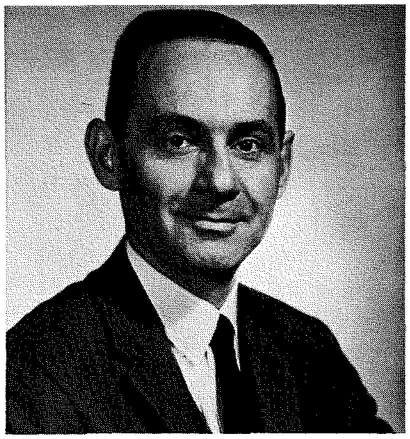

PATRICK C. FARBRO received the AB and MS degrees in psychology from the University of Tulsa (1947) and Purdue University (1948) respectively. His occupational experience includes work as a graduate teaching assistant in psychology at Purdue University, 1947-1948; Personnel Research Analyst, RCA Victor General Office, 1948-1949; Employment Supervisor, Lancaster Plant, 1949-1951; Manager, Personnel Research, RCA Staff, 1951; Manager, Training and Personnel Research, 1957; and Manager, Professional Programs, 1959. In 1965, Mr. Farbro was appointed to his present position of Director, Professional Personnel Programs, RCA Staff. Mr. Farbro is a member of the American Psychological Association, the N. J. Psychological Association, the New York Academy of Science, the American Association for the Advancement of Science, the American Personnel and Guidance Assocation, the Industrial Relations Research Association, the American Society of Training and Development (1967 National President), the International Association of Applied Psychology, Psi Chi (honorary in Psychology), and Sigma Xi. Mr. Farbro is also listed in **American Men of Science** and **Who's Who in the East.**

ENGINEER because . . ." and "I would like to see the following changes made in the RCA ENGINEER." Following is a sample of the comments given. They are reproduced verbatim and are typical.

Like *RCA Engineer* because

"It keeps me up-dated on activities throughout the company without overloading on tedious details."

"It is informative and educational on subjects not too well known to me."

"It increases professionalism and gives increased stature to the engineering personnel as well as RCA's image as an engineering company."

"I find most of it readable without detailed prior knowledge on the subject."

"It publishes articles which are understandable to an engineer not working in the same area."

"It is well written and well presented."

"It stimulates my desire to increase my education and become more advanced."

"It keeps me posted on developments throughout the entire corporation."

"It demonstrates the company's genuine interest in their engineers and development of these engineers."

TABLE II—Percent of Engineers Who Have a *Strong* or *Moderate* Interest in Each Type of Article

Type of Article			*Total*
Technical	45	46	91
Semi-technical	60	37	97
Engineer Activities	31	47	78
Editorials	40	42	82
Magazine Departments	27	49	76

■ indicates strong interest

▨ indicates moderate interest

"I find that the issues which emphasize a single technical product area are especially useful for reference. The current issue on integrated circuits is an example."

"It promotes company-wide recognition of individual and/or group effort."

"One can keep abreast of developments throughout the corporation."

"It keeps you up-to-date on new products and designs."

"Excellent technical journal."

"Presents a good technical image."

"It is well written and edited, easy to read and accurate—also informative."

"It is a strong marketing tool. Helps me present the company's goals to prospective computer customers."

"It gives me information on technical development and progress within RCA. It also has the 'personal touch' so badly needed to build up the image of the professional individual."

"Generally well written; magazine is well composed and printed."

Would like to see the following changes

"I was involved in the original issue in which it was pretty much agreed that the journal would be kept on a level readable to all. The IRE Proceedings was used as a model *not* to approach. Some issues have been too theoretical."

TABLE III—Readers' "Image" of the RCA Engineer

Respondents agree that:

The publication helps the company's engineers to be better informed.

The journal has a professional character.

The *RCA Engineer* is valuable to the experienced as well as the younger engineer.

The reputation of RCA and its engineers is increased by the journal.

There should be more papers by engineering managers and top management on plans and objectives.

The Annual Papers Index, made up of "Pen and Podium" listings, is a good reference source.

The publication encourages engineers to write.

The *RCA Engineer* encourages "professionalism."

The listings of Dates and Deadlines for engineering society meetings and publications are good reference sources.

There should be more papers devoted to business planning, economics, and company objectives.

The *RCA Engineer* is not primarily an instrument of management.

Statements presented in order of strength of response; statements shown reflect the opinion of more than one-half of the respondents.

"More emphasis on new product design and development—use of computers by RCA and others in engineering design or related work."

"Higher technical level—basic theory; new developments in electronics, business objectives."

"In many instances, articles are too detailed for engineers in other fields. Articles should be more of general interest (similar to *Scientific American*). . . ."

"More reports by top management as to what they are thinking and planning."

"The technical articles are too specialized. I would like to see them similar to those published in *International Science and Technology*."

"More articles directed toward manufacturing engineering—a few articles of basic instruction in areas such as solid state physics."

"More articles on home entertainment devices."

"I am unable to get full value from publication due to personal limitations in EE areas. . . ."

"More articles giving detailed principles of operation of entire product units. Detailed math to illustrate some of the more refined features of the design. Theoretical explanations that are clear and that teach, similar to *Scientific American* articles."

"An increase in the Engineering and Research notes. Each section, division, etc. should be encouraged to contribute to this section of RCA ENGINEER. . . ."

"More diagrams and pictures to better illustrate the various articles."

"Larger type particularly on charts and graphs."

"Each issue could include a tutorial article . . . to update older engineers. . . ."

"Increase articles in M.E. activities. . . ."

"Add more articles pertaining to plant facilities, plant operations and financial administration and planning."

"Occasional tutorial paper on the theoretical background of a new area(s) of interest."

WHAT "OUTSIDERS" HAVE TO SAY

The RCA ENGINEER distribution list includes selected libraries and engineering professors. Since the questionnaire was distributed as an insert in the magazine, these "outsiders" had access to the questionnaire and thirty-three responded.

Their responses are interesting. One hundred percent rate the RCA ENGINEER as *excellent* or *good.* They, like the RCA engineer sample, have strongest interest in the semi-technical and technical articles, but also appreciate the other types of articles.

Their "image" of the RCA ENGINEER closely parallels that of the RCA engineer sample.

Eighty percent of this group say they agree with the statement, "the RCA ENGINEER is superior to most companies' technical journals"

Electron Optics of Vidicons

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Vidicon Product Engineering
Electronic Components, Lancaster, Pa.

This tutorial article discusses the electron optics of vidicons—drawing on the electron optics of television picture tubes as well as some classical optics. From the cathode through the various anodes to the target mesh, the vidicon is treated as a complete optical system—light source through lenses to target.

A VIDICON is a small TV camera tube used to convert light energy from a scene into electrical energy that can be televised. It consists principally of two sections: a storage-type photoconductor that produces an electrical charge pattern corresponding to the imaged scene, and an electron gun that reads out the information as a time-based video signal. In many respects, the vidicon electron gun is very similar to that used in a television picture tube. One common vidicon type, the "hybrid" (Fig. 1) operates with electrostatic focusing and magnetic deflection, and is directly analogous to the "straight-gun" television picture tube. In fact, vidicons use many gun parts that were first used in picture tubes.

For discussion, the electron optics of a vidicon can be broken down into four main sections.

1) *The "triode" emission system,* which generates a beam of electrons and accelerates them toward the photoconductor. It consists of a thermionic cathode, a control grid (grid No. 1), and an accelerator grid (grid No. 2).
2) *The focusing section,* which focuses the beam into a very sharp spot at the photoconductor. In magnetic types, the beam is focused by an axial field produced by a short solenoid outside the tube. In electrostatic types, focusing is accomplished by a three-cylinder "einzel" lens.
3) *The deflection components,* which deflect the beam to produce a scanned raster. Scanning can be accomplished either by magnetic coils outside the tube, or by an electrostatic device inside the tube.
4) *A collimating lens,* which has no equivalent in the picture tube. Its purpose is to make the beam land perpendicular to the photoconductor across the entire scanned area to eliminate a drop-off in signal toward the raster edges. In many vidicons, the collimating lens is simply a piece of very fine wire mesh at wall potential placed close to the target. In separate-mesh and electrostatic-focus types a collimating electrostatic lens is added to improve landing further.

TRIODE EMISSION SYSTEM

In a cathode-ray tube, such as a vidicon or picture tube, a beam of electrons is projected toward a target: a photoconductor in the case of the vidicon, a phosphor in the case of the picture tube. In most of these tubes, the cathode consists of a coating of barium oxide on the closed end of a nickel cylinder. The cathode is indirectly heated to emission temperature by an insulated tungsten heater placed inside the cylinder. The electrons must be emitted into a region having a positive potential with respect to the cathode.[1] This positive potential is provided by an anode which usually takes the form of an apertured disk (grid No. 2 of the vidicon). To converge the electrons into a beam, another electrode (grid No. 1 of the vidicon and also an apertured disk) must be inserted between the cathode and anode. This electrode is commonly held at a potential equal to, or slightly less than, cathode potential to form an electrostatic converging lens of very short focal length. Because grid No. 1 is negative with respect to the cathode, it can also be used to control the emission intensity and thus can be called a control grid. A schematic representation of a vidicon triode section is shown in Fig. 2.

CROSS-OVER CONCEPT

The emission system of cathode-ray tubes is commonly called an immersion lens because the object (the cathode) is immersed in the field of the lens. In practice, the cathode is placed at or near the first focal point of the lens. In the absence of aberrations, principal rays emitted perpendicular to the cathode surface are brought to a focus at a point X (Fig. 3). In analogy with light optics, the point X can be called the exit pupil point of

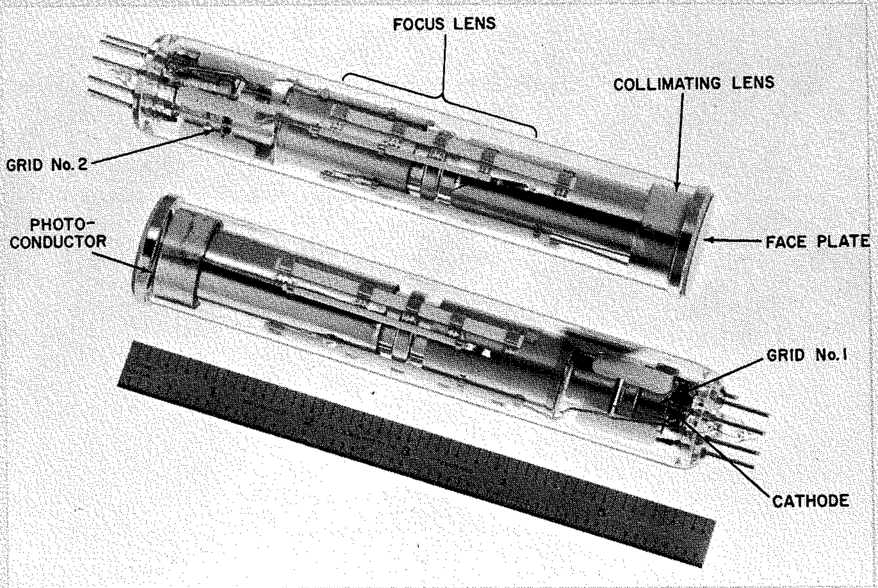

Fig. 1—1-inch diameter hybrid vidicon, type 8134.

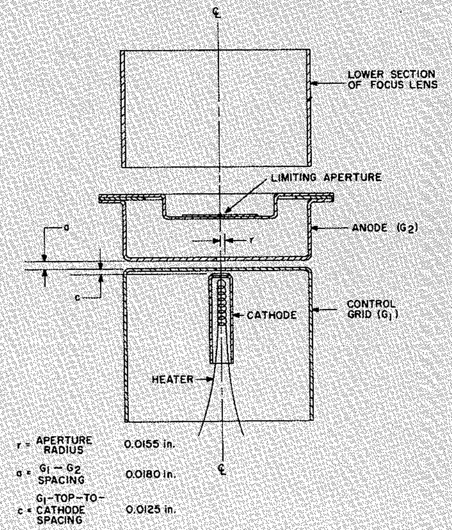

Fig. 2—Triode section of a vidicon.

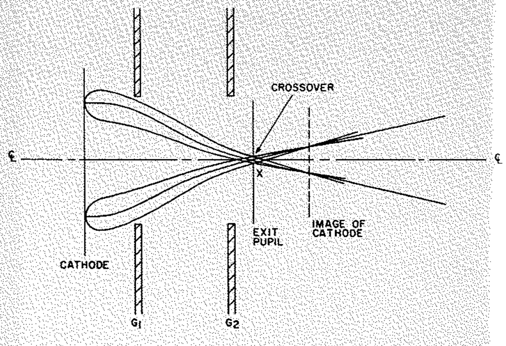

Fig. 3—Electron trajectories in triode emission system.

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the system.[2] However, unlike optical systems, in which the index of refraction is uniform and about the same magnitude in both image and object space, the refractive index in an immersion lens increases very rapidly toward the anode. Consequently, all the rays of an elementary bundle are constricted to pass through the apertures. Even rays emitted at grazing incidence to the cathode are focused into the beam. At the exit pupil, these peripheral rays converge to form a *disk of least confusion*,[3] which in electron-optical terminology is called the *cross-over*. In picture tubes, it is this cross-over that is imaged onto the phosphor screen by the main focusing lens of the tube. (In light optics, however, the image formed by the elementary bundles leaving a point of the object is of prime concern.) The size of the cross-over can be estimated from the work done by Law,[4] who found that current distribution across the cross-over assumes a Gaussian form. If the radius of the cross-over is defined as the distance from the axis to the point where the current density is 5% of its peak value, the cross-over diameter of a vidicon is computed to be about 0.006 inch.

In practice, the immersion emission system is an exceedingly complicated thing to analyze theoretically. Lens aberrations are a serious problem. Electrons are emitted with a Maxwellian distribution of speeds[5]—a condition that produces the electron-optical equivalent of chromatic aberration. Space charge, which can amount to as many as $2\text{x}10^{11}$ electrons per cubic centimeter[6] affects the electron focusing drastically and can play a dominant role in determining the characteristics of the triode system. Furthermore, the effects of space charge vary as the beam current is varied. Although recent computer techniques have aided in the theoretical analysis of triodes, the elementary empirical and semi-empirical work performed in the early 1930's and 1940's remains of the most practical interest.

Many of the important parameters of an electron gun can be expressed in terms of the cutoff voltage V_c. Gun parameters can be changed over relatively broad ranges with little effect on gun performance so long as the cutoff voltage is maintained. For instance, according to Gundert[7], the emission current I_{em} is given by

$$I_{em} = G V_d^{5/2} V_c^{-1} \qquad (1)$$

where G is a constant having a value of $2.8\text{x}10^{-6}$ ampere/volt$^{3/2}$ and V_d is the grid drive, which is the absolute difference between cutoff voltage and operating control-grid voltage. For zero-bias operation, the equation reduces to the following useful approximation:

$$I_{em} = G V_c^{3/2} \qquad (2)$$

The cutoff voltage is related to the anode potential V_a as follows:[8]

$$V_c = D\, V_a \qquad (3)$$

where D is a "penetration factor," which is the fraction of the anode field that penetrates through the grid region to the cathode. The penetration factor is related to the physical gun parameters[9] as shown in Fig. 4.

As will be shown later, the divergence of the beam as it leaves the cross-over is of prime importance because of the aberrations produced in the main focus lens which tend to defocus the spot on the target. For large drive voltages, the semi-angle of divergence of the beam Θ may be expressed by the following linear relation:[10]

$$\Theta = \Theta_o V_d / V_c \qquad (4)$$

where Θ_o is the maximum angle that occurs at zero bias. Θ_o is commonly on the order of 20°. For the small drive voltages commonly used in vidicon operation, the curve of V_c as a function of V_d becomes sublinear, and the expression for Θ is as follows:

$$\Theta = \Theta_o \sqrt{V_d / V_c} \qquad (5)$$

The television picture tube is normally operated throughout the entire range from cutoff to near zero bias. One concern of the picture tube designer is that the modulation swing must be kept low enough to be handled by conventional amplifier circuits. The size and position of the cross-over, as well as the divergence of the beam, vary as the grid voltage is varied; consequently, highlights and lowlights cannot be focused simultaneously. Furthermore, a bright picture with good definition requires high beam-current density. Thus, the picture tube designer must select the best compromise of gun parameters to obtain a bright picture with good dynamic focusing properties.

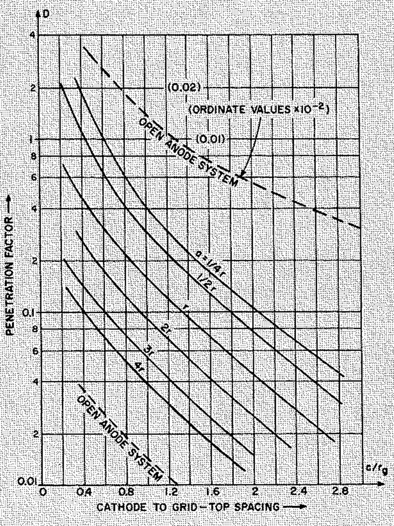


Fig. 4—Penetration factors, *D*, of symmetrical two-diaphragm systems and of diaphragm-tube systems.

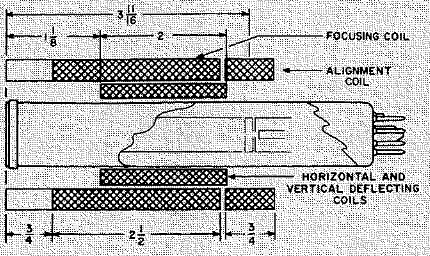


Fig. 6—Location of components for magnetic-focus and -deflection vidicon.

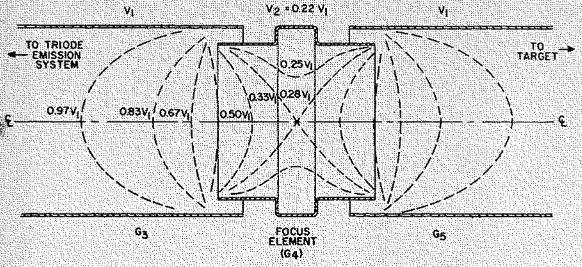


Fig. 5—Focus lens of type 8134 vidicon with equipotential lines.

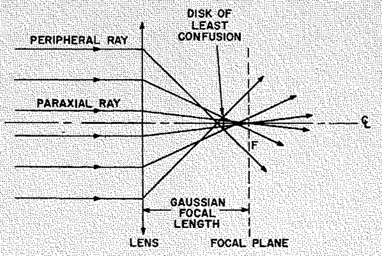


Fig. 7—Effect of spherical aberration on focusing of parallel incident electron rays.

In contrast to the picture tube, the vidicon requires a very small beam current; only a few microamperes are necessary to discharge the brightest highlights. Also, because the raster dimensions of a one inch vidicon are only ½x⅜ inch, the spot size must be very small. To limit the beam current in the vidicon, a 0.0015-inch aperture is inserted about 0.10 inch on the target side of the cross-over of an otherwise-normal picture tube triode section. This aperture then becomes the "floodlit" object of the main focusing lens of the vidicon. Because it is well removed from the cross-over, this aperture simultaneously serves as an entrance stop to the focus lens, and limits the beam divergence semi-angle into the focus lens to 2° at the most.

In serving as the object of the electron-optical system, the limiting aperture has the advantage that its size and position do not change (as would a cross-over object) with changes in beam current. However, the divergence angle of the beam as it leaves the aperture does vary with bias. This variation causes some spot defocusing at high current levels in both vidicons and picture tubes. Usually the defocusing is small enough that a vidicon can be somewhat "overbeamed" to handle unusual picture highlights, but in many applications where resolution is of utmost importance, the bias is set to "just discharge" the picture highlights. Whatever the case, the bias, once set, remains fixed, with the beam being periodically switched off during horizontal and vertical blanking time by the application of sufficient bias to the grid.

Because the limiting aperture defines a fixed exit pupil, the beam divergence depends on the radius of the emitting area of the cathode. According to Moss, the cathode emitting radius y_c varies as follows:[11]

$$y_c = r_g V_d / V_o \qquad (6)$$

where r_g is the radius of the grid aperture. As in the case of the divergence angle, the radius of the emitting area varies as the square root of the drive voltage for small grid drives.

If Eqs. 6 and 1 are combined, it can be seen that for the same beam current, the radius of the cathode emitting area, and hence the beam divergence, decreases as the cutoff voltage is increased. As a result, vidicons are designed to be high cutoff devices, having cutoff voltages as great as −100 volts with only 300 volts on the anode. Because the emitting area of the cathode is very small, being typically only 0.010 inch in diameter, a vidicon cathode surface must be made as smooth as possible. Furthermore, the cathode must be operated properly to maintain high emission levels since, in general, vidicon performance depends on the condition of the cathode.

VIDICON FOCUSING

The diverging beam of electrons leaving the object, be it the cross-over or limiting aperture, must be reconverged into a sharply focused spot at the target. In vidicons, as in most picture tubes, the beam is focused by the electron-optical equivalent of a simple magnifying glass. The focusing lens may be formed by a short solenoid around the vidicon, or by a suitable combination of cylinders or disks at different potentials to form an electrostatic lens. It is perhaps most instructive to examine the properties of a three-cylinder "einzel" lens since it is most analogous to a simple thin optical lens. This type of lens (Fig. 5) is used in all electrostatic-focus vidicons and in the straight-gun picture tube.

The einzel lens is generally operated with the same potential V_1 applied to the outer two electrodes. The center electrode is then operated at some potential V_2, which is either higher or lower than that of the outer ones to form the converging lens. In this case, the einzel lens properties can be calculated by Gaussian optical methods by placing the midplane of the lens at the center of the focus electrode. Having the same potential in image and object space is the equivalent of having the same refractive index on either side of the lens, so that the familiar lens-makers' equation becomes

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \text{ and } M = \frac{v}{u} \qquad (7)$$

where u is the object distance, v is the image distance, f is the focal length, and M is the magnification.

The focus lens in a picture tube is designed so that the voltage of the central electrode is zero. Under such conditions the outer electrode may be operated at any voltage other than zero. In other words, only one voltage is necessary for focusing, and thus this lens is called a "unipotential" lens and is characterized by a fixed focus. Picture tube magnifications are generally greater than unity.

For the very sharp focus needed in a vidicon, a unity magnification is used; that is, the image distance equals the object distance. For optimum focusing of the vidicon, the einzel lens is designed so that the focal length may be varied by adjustment of the voltage applied to the central electrode. This voltage is between 50 and 100 volts when the outer electrodes are operated at 300 volts.

Aberrations of the Focus Lens

Electron lenses are subject to the same third-order aberrations that affect light optical lenses: curvature of field, astigmatism, distortion, coma, chromatic error, and spherical aberration.[12] Because the limiting aperture appears as a point source to the focus lens, the first three are rather unimportant. It should be noted, however, that astigmatism, which causes an otherwise round spot to be pulled into an ellipse, can occur if the focus lens is not symmetrical. Tolerances, therefore, are very critical. For instance, an out-of-round distortion of 0.004 inch in a 0.750-inch-diameter electrode would render a vidicon unusable. Chromatic error is also negligible because the electrons have been accelerated to many times their emission velocities. Coma, which distorts the focused spot into a comet shape, can occur if the beam enters the focus lens off the axis. To minimize coma, the beam is aimed through the center of the focus lens by a pair of alignment coils placed in the vicinity of grid No. 2 (Fig. 6). These coils generate very weak magnetic fields and act on the beam in a manner similar to the action of the deflection coils.

Spherical aberration is the principal lens distortion. It is caused by the fact that peripheral rays are refracted by the electron lens more strongly than are the paraxial rays (Fig. 7). This inequality in refraction causes a disk of least confusion, the spot actually focused on the target. Unlike spherical aberration in light optics, spherical aberration in electron optics cannot be corrected conveniently, but can only be minimized. The spot diameter, d_s, of a vidicon can be estimated as follows:[13]

$$d_s = M d_l + \frac{u^4}{2f} S_8 \alpha^3 \qquad (8)$$

where d_l is the diameter of the limiting aperture, S_8 is the spherical aberration coefficient, and α is the beam divergence angle. The first term is the contribution due to Gaussian optics. The second term represents the addition due to spherical aberration and shows the strong dependence of spherical aberration on beam divergence and object distance.

In practice, the image distance of a vidicon must be long to minimize deflection aberrations effectively. As a consequence, the object distance must be kept long to preserve unity magnification. To achieve the best compromise of magnification, center-to-corner deflection defocusing, and spherical aberration defocusing, the designer must carefully choose image and object distances while keeping d_l and α as small as is consistent with sufficient discharge capability.

Magnetic Focusing

Because the resolution capability of a

long magnetic field produced by a solenoid (Fig. 6) is greater than that of the electrostatic lens, magnetic focusing is by far the most popular method of vidicon focusing. This greater resolution results from the magnetic lens' much smaller spherical aberration coefficient — only about 1/100 that of the einzel lens. Consequently, the spherical aberration component of spot size is negligible compared with the Gaussian component. The reduced spherical aberration gives the vidicon tube designer flexibility in two ways:

1) A smaller limiting aperture may be used, but placed nearer the cross-over to maintain sufficient beam discharge capability. The increased beam divergence does not significantly affect resolution.
2) The deflection field is completely immersed in the focus field without extensive defocusing at the corners, which makes a very short length tube possible.

Unfortunately, the magnetic focus system cannot be readily analyzed by theoretical methods because it is of intermediate length, being neither very long nor very short compared to its radius. Moreover, the field is contained by magnetic shielding material to minimize the focus-coil current. Finally, it is combined with deflection fields and, often, with an accelerating electrostatic field on the focus element of the tube itself. As a result, most of the design work has been done empirically.

The solenoid produces an axially directed field. The field acts on the radial component of velocity of diverging electrons and directs them in a helical motion back to the axis, where all the rays converge to form a focused spot. Fig. 8 shows the approximate paths of two electrons in the focus field.[14] The focus coil is designed to provide an adequate focusing field with a minimum of power input. The vidicon focus is adjusted either by varying the focus-coil current or by varying the voltage on the focus element of the vidicon so that the electrons revolve through one loop to cross the axis at the target. Typically, a vidicon will focus with a 40-gauss field and 275 volts on the focus electrode. Under these conditions, the vidicon will resolve more than 37 line pairs/millimeter. Some vidicons now in development can resolve up to 100 line pairs/millimeter.

VIDICON DEFLECTION

Electromagnetic

In vidicons, as in picture tubes, electromagnetic coils are used for deflection in nearly all applications. Because picture tubes generally employ very large deflection angles (up to 114°), magnetic deflection becomes a practical necessity. But in the vidicon where the deflection angle seldom exceeds 20°, magnetic deflection is used to take advantage of its inherently low aberration error. Analysis of deflection errors belongs in the class of the most complex electron optical problems, so only a few generalities can be presented here.

Magnetic deflection is accomplished by a pair of *saddle coils* (Fig. 9) that produce a magnetic field perpendicular to the axis of the vidicon. A schematic representation of deflection in a hybrid tube is shown in Fig. 10. The motion of electrons along the axis produces a force which deflects them in a direction perpendicular to both the axis and the magnetic field. While electrons are in the deflecting field, they move along a circular segment. If the line along which the electrons travel as they leave the deflection coils is extended back to the axis, the point located is defined as the center of deflection. It is the point from which all the electron rays appear to emanate. When magnetic deflection is combined with magnetic focusing fields, the two fields add vectorially, a condition that may be represented by a series of deflected flux lines, one of which is shown in Fig. 11. The electrons, then, move about the flux lines in a path approximating a single turn helix. Because of this helical motion of the electrons as they leave the deflection region, the concept of a "center of deflection" does not strictly apply to magnetic-focus and -deflection tubes. However, the concept is often loosely applied, and the center of deflection is assumed to be located at the physical center of the deflection coils.

The deflection angle ϕ is kept small for several reasons:

1) The most important consideration is field curvature and its related astigmatism distortion. A vidicon target is made flat because the conventional 16-mm movie camera optics used to place an optical image on the target present the image in a flat plane. If the deflection angle becomes too large, the spot at the edge of the raster is pulled into an enlarged ellipse that degrades corner resolution.
2) If the angle were very large, so that the beam could not be corrected to land perpendicularly over the scanned raster, there would be severe portholing, or dark corners, in the reproduced picture (discussed under *Correction of beam landing error*).
3) Scanning at a large angle can cause "pincushion" distortion; that is, the raster corners appear to pull out and away from the center. It should be noted that pincushion distortion in the vidicon shows up as its inverse, "barrel" distortion in the reproduced raster because the vidicon and picture tube operate on the same time base. A distorted raster of any kind, of course, is undesirable because special scan-correction circuits are necessary, as is the case for the 90° rectangular color picture tube.
4) When the electron beam is deflected within a magnetic focusing field, spiral distortion becomes noticeable if the deflection angle is large. This spiral distortion arises from the fact that the focus field acts to rotate the raster in the vidicon by as much as 90°. Straight lines appear as *S*-shaped lines because off-axis electrons are rotated further than paraxial electrons.

As stated before, the length of the vidicon deflection coils is not short compared with the axial distance that the electron beam must travel. Just the opposite is true for picture tube coils. Relatively long coils keep deflection currents and fields low and reduce the deflection aberrations associated with strong fields. When used in conjunction with a focus coil providing a 40-gauss field, a conventional 1-inch vidicon yoke having a horizontal inductance of 1 mH and a vertical inductance of 40 mH requires about 185 mA peak-to-peak of horizontal current and about 25 mA peak-to-peak of vertical current. Most vidicon deflection and focus assemblies can produce a raster

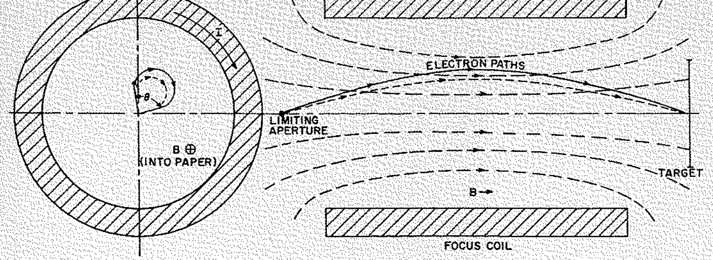


Fig. 8—Motion of electrons in magnetic focus lens.

Fig. 9—Vidicon magnetic deflection coils.

with 1 to 2% geometrical accuracy when linear deflection currents are applied to the components.

Electrostatic

The small deflection angle of a vidicon makes electrostatic deflection particularly attractive. But the additional requirements for a long deflecting region and for small field strengths have prevented the use of this type of deflection until recently. In a cathode-ray tube, such as an oscilloscope display tube, deflection plates are employed. These plates have the inherent disadvantage of producing extensive fringe fields which badly defocus the spot. Moreover, because their fields would otherwise interact, the horizontal and vertical deflection plates must be separated by a metal shield and must, consequently, act sequentially. However, when the throw distance from the plates to the screen is long compared with the plate length, as in the oscilloscope, the difference between horizontal and vertical deflection centers can be ignored.

Deflectron

The difference cannot be ignored with the vidicon, where the throw distance is comparable to the plate length. An ingenious device which does permit coincidental deflection horizontally and vertically is the Deflectron (Fig. 12). A good theoretical treatment of the Deflectron is given by K. Schlesinger.[16] The unique shape of the deflection plates essentially eliminates field fringing and interaction between plates. In practice, the Deflectron is placed in relation to the focus lens in a manner very similar to the magnetic yoke. Because the deflection sensitivity of the Deflectron is only about 2/3 that of a plate system of comparable dimensions, the device is tapered into a cone to improve this parameter. About 30 to 100 volts peak-to-peak are required to deflect a vidicon beam over a normal scanned raster. Performance of electrostatically deflected vidicons does in fact approach that of their magnetically deflected counterparts.

CORRECTION OF BEAM-LANDING ERROR

A vidicon is normally operated in a low-velocity mode; that is, the target is operated at a potential low enough to keep the secondary-emission ratio less than unity. This potential is consequently lower than that of the other electrodes. Also, the signal current from the photoconductor is very voltage-dependent, varying approximately as the square of the applied target voltage.[17] Thus, it is necessary to establish a uniform decelerating field in the vicinity of the target. In all but a few experimental vidicons, such a field is produced by a very fine wire mesh (having about 1000 lines/inch) placed close to the target, as shown in Fig. 13. The mesh is generally held at 300 to 500 volts, and the signal-electrode voltage V_t is held at about 30 volts. When the beam arrives at the target at normal incidence after passing through the mesh, it drives the target surface down to cathode potential and establishes a full 30-volt target voltage. However, normal incidence occurs only at the axis of the tube. When the beam is deflected and traverses the mesh-to-target region at an angle, only the axial component of velocity is reduced to zero, but the radial component remains, establishing the minimum surface potential of $V_m \sin^2 \theta_i$, where V_m is the potential on the mesh electrode and θ_i is the incident angle of the beam at the mesh.[18] The applied target voltage at an off-axis point becomes $V_t - V_m \sin^2 \theta_i$. This difference in effective target potential gives rise to a drop-off in signal from the picture center to edge which is called "porthole." The voltage difference from center to edge is called "beam-landing error." For a deflection semi-angle of 5° and a mesh potential of 500 volts, a vidicon would have about 4 volts beam-landing error (BLE), which corresponds to a 25% shading at a target voltage of 30 volts. At 10 volts, which is approximately the minimum useful target voltage, the shading would be about 65%. So it is clear that some means of landing correction is necessary to reduce BLE to a manageable level.

Because of its helical motion, the beam in a magnetically focused vidicon has a radial and tangential component of velocity as well as the axial component. It is possible to use the flair of the magnetic focus field, which in other applications is undesirable, to reduce the tangential component to zero by proper positioning of the coil on the tube. In addition, it is possible to minimize the radial component independently by proper positioning of the deflection components. Proper component location reduces beam-landing error to about 1½ volts, which results in about 10% shading at a target voltage of 30 volts, about 25% at a target voltage of 10 volts.

In electrostatically focused vidicons, deflection also imparts a radial component of velocity, but there are no magnetic fields present which can remove this component magnetically. As a result, the addition of an electrostatic collimating lens, shown in Fig. 13, becomes a necessity. The mesh is electrically insulated from the other electrodes in the tube and is supported mechanically on the final electrode (the wall electrode) of the einzel lens. The wall electrode is sufficiently long to prevent the electrostatic field produced by it and the mesh electrode from interacting with the focus field. The strength of the lens is adjusted so that the deflected beam is collimated in the vicinity of the mesh to arrive perpendicular to the mesh and target. This arrangement is equivalent to placing the center of deflection at the focal point of the lens. By definition of a focal point, the electron rays, or the paths which the electron beam follows, exit parallel to the axis and perpendicular to the image plane.

The collimating lens is the direct electron-optical equivalent of a plano-convex lens. However, because the scanned raster occupies more than 85% of the lens diameter, an unmodified plano-convex lens would, like the electrostatic focus lens, be subject to serious spherical aberration. The dashed lines of Fig. 13 illustrate the field produced by a strictly plano-convex lens, that is, where the wall

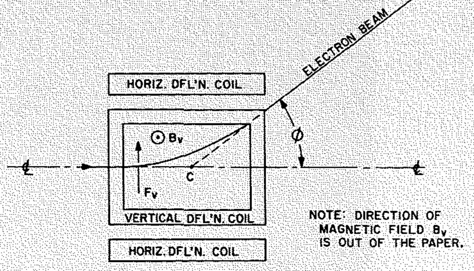


Fig. 10—Magnetic deflection of electron beam in hybrid vidicon.

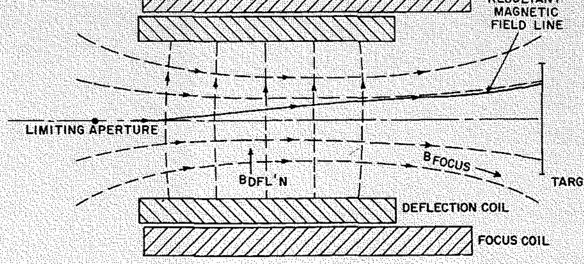
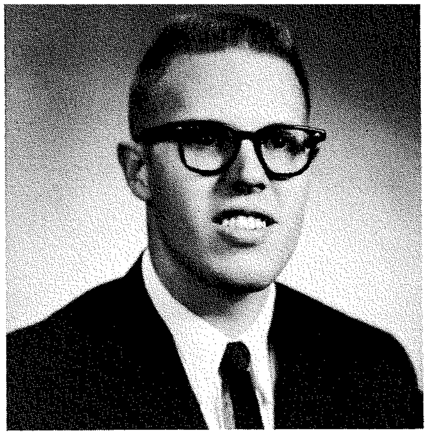


Fig. 11—A magnetic field line resulting from the addition of the focusing and deflecting fields.

electrode extends to the mesh, but does not touch it. As shown, sufficiently perpendicular beam incidence is achieved only throughout the outer 60% of the lens. Fortunately, the spherical aberration can be conveniently corrected by spacing the collimating lens a short distance away from the mesh itself, with a short skirt extending from the mesh toward the wall electrode. Placing the physical center of the lens a short distance away from the mesh produces a diverging field in the outer 40% of the lens, as shown by the solid lines of Fig. 13. The diverging field almost completely counteracts the over-converging effects of spherical aberration. Beam-landing error in electrostatic tubes can be reduced to less than ½ volt, which corresponds to about 10% shading at a target voltage of 10 volts. (The shading figures quoted here are those resulting from BLE only. Other sources of shading, such as slightly non-uniform photoconductors or nonlinear scanning, typically add from 5 to 10% to the figures.)

The same type of electrostatic collimating lens can be used in magnetic focus tubes to improve shading by reducing the radial component of velocity. In addition, the separate-mesh types offer other advantages over the integral-mesh types. In integral-mesh types, for example, overbeaming to discharge high signal levels tends to defocus the beam badly in the center of the picture. As a result, the center and corners come into focus at two very different values of focus voltage or focus-coil current. However, the mesh in a separate-mesh type can be operated at a potential higher than that of the focus electrode. Consequently, the dependence of resolution on beam current is reduced to a minimum. Even at ordinary signal levels, the resolution of separate mesh vidicons is significantly higher than that of integral-mesh vidicons. Moreover, the additional collimating action of the electrostatic lens enables the deflection angle to be increased, and thus permits the deflection components to be moved forward, somewhat, toward the target. Because there is less interaction of the deflection and focus fields there is less corner defocusing and, consequently, increased corner resolution.

The use of a separate mesh electrode in a vidicon does give rise to a minor problem. After the beam has deposited sufficient charge to bring the target down to cathode potential, the excess electrons are repelled and are directed back to the gun. The presence of the collimating lens causes the return beam to scan the entire grid No. 2 cup, from where it frees secondary-emission electrons. Some of these electrons are turned back toward the mesh. As the electrons are intercepted by the mesh, they produce a signal across the mesh load resistance, particularly in high-impedance circuits. The signal thus produced is a faithful image of the grid No. 2 cup, which is an irregularly shaped circle. The signal then capacitively couples to the target circuit. This "ghost" image of the grid No. 2 cup can be eliminated by heavy bypassing of the mesh connection at the vidicon socket.



J. R. LEAMAN received the BA in Physics, cum laude, from Franklin & Marshall College in 1963. He joined RCA Lancaster immediately after graduation, working in the vidicon product engineering group for six month. He was transferred to the vidicon factory as a production engineer, remaining there for eighteen months, and working primarily on photoconductor evaporation and thermionic cathode processing. Returning to the product engineering group, Mr. Leaman has participated in the development of the separate mesh, all-magnetic 1" vidicon (RCA 8507), and the development of 1" and 1½" vidicons, used in the TK22 B&W camera, and the TK27 and TK42 color cameras. He has a patent pending for work on black reference and reticle deposition on faceplates. Mr. Leaman is a member of Phi Beta Kappa and Sigma Pi Sigma.

REFERENCES

1. Klemperer, O., *Electron Optics* (2nd ed., Cambridge University Press, New York, 1953) p. 237 ff.
2. *Ibid,* pp. 247 and 248.
3. *Ibid,* p. 241.
4. Law, R. R., "High Current Electron Gun For Projection Kinescopes," *Proc. IRE* Vol. 25, No. 8 (Aug 1937) pp. 954-976.
5. Maloff, I. G. and Epstein, D. W., *Electron Optics in Television* (McGraw-Hill Book Co., Inc., New York, 1938) p. 127.
6. *Ibid,* p. 134.
7. Gundert, E., "Das Triodensystem Zur Kathodenstrahlerzeugung," *Z. Techn. Phys.* Vol. 24 (1943) p. 274.
8. Klemperer, *op cit,* p. 260.
9. *Ibid,* p. 266.
10. *Ibid,* p. 263.
11. Moss, H., "The Electron Gun of the Cathode Ray Tube," *J. Brit. Instn. of Radio Engrs.* Vol. 6 (1946) p. 105.
12. Jacob, L., *An Introduction to Electron Optics* (John Wiley & Sons, Inc., New York, 1951) p. 58 ff.
13. Zworykin, V. K., et al, *Electron Optics and the Electron Microscope* (John Wiley & Sons, Inc., New York, 1948) chaps. 16 and 17.
14. Klemperer, *op cit,* p. 85.
15. Klemperer (p. 320 ff.) for good general treatment of deflecting fields.
16. Schlesinger, K., "Progress in the Development of Post-Acceleration and Electrostatic Deflection," *Proc. IRE* Vol. 44, No. 5 (May 1956) pp. 659-667 and "Internal Electrostatic Deflection Yokes," *Electronics* Vol. 25, (Jul 1952).
17. Neuhauser, R. G. and Miller, L. D., "Beam-Landing Errors and Signal Output Uniformity of Vidicons," *J. of SMPTE* Vol. 67 (March 1958) pp. 149-153.
18. Castleberry, J. and Vine, B. H., "An Improved Vidicon Focusing-Deflecting Unit," *J. of SMPTE* Vol. 68 (April 1959) pp. 226-229.

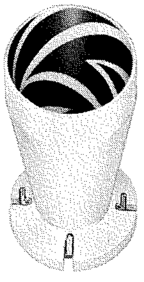


Fig. 12—Deflectron: electrostatic deflection yoke.

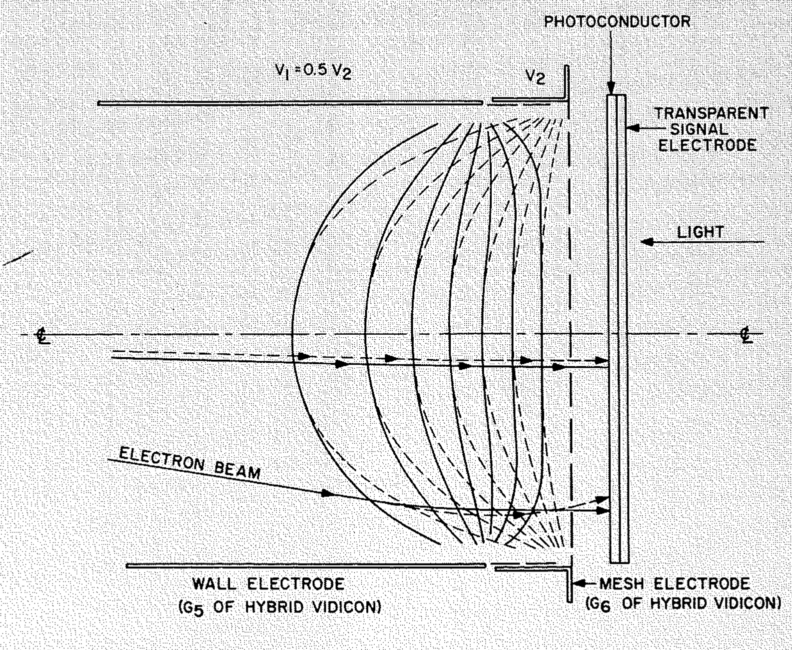


Fig. 13—Electrostatic beam landing correction lens.

The Application of Vidicons in Modern TV Systems

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Vidicon performance is characterized by high sensitivity and resolution, low lag, uniform signal, clean target surface, long life, low cost, and simplified operating requirements. Thus, this device is excellent for live television pick-up and for film reproduction. Its inherent compactness and ruggedness make it exceptionally suited to operation in severe environments—particularly the space environment where its storage characteristics may also be exploited for reduced bandwidth.

THE VIDICON CAMERA TUBE is a light-conversion device originally designed for optimum performance in a conventional-scan television system. It employs a photoconductive sensor generally made from antimony tri-sulfide, which has a resistance that varies with light intensity. Thus, a target coated with this material stores discrete electrical charges corresponding to picture elements, and can then be scanned by an electron beam in an orderly fashion to generate a television picture signal.[1]

VIDICON TYPES

Commercial vidicons are currently standardized in diameters of ½, 1, and 1½ inches; developmental designs up to 4½ inches have been given serious consideration. Tubes of larger diameter generally provide higher resolution or more fine detail in the picture, but have the disadvantage of longer signal retentivity, or "lag," which may show up as a trailing smear on rapidly moving objects in the scene.[2,4]

Each of the vidicon sizes can be manufactured with a choice of electro-optical gun designs related primarily to the focus/deflection mechanism. Thus, vidicons can be designed, with approximately equal ease, to employ magnetic focus and deflection, electrostatic focus and magnetic deflection, magnetic focus and electrostatic deflection, or electrostatic focus and deflection. The requirements of the specific application dictate the configuration. The primary commercial types available from RCA representing these basic options are listed in Table I.

TABLE I—Typical RCA Vidicon Types in Wide General Use

Type	*Description and Service*
7038	1-inch-diameter magnetic-focus and -deflection type for film pickup.
7735B	1-inch-diameter magnetic-focus and -deflection type for live pickup.
8572	Separate-mesh version of the 7038.
8507A	Separate-mesh version of the 7735B.
8134	1-inch-diameter electrostatic-focus, magnetic-deflection, separate-mesh vidicon for film reproduction and live pickup.
8480	1½-inch-diameter equivalent to the 8134.
4503	Ruggedized version of the 8507.
8567	Ruggedized version of the 8134.
4514	1-inch-diameter ruggedized electrostatic-focus and -deflection vidicon for special military and space.
C23073*	1-inch-diameter ruggedized magnetic-focus, electrostatic-deflection vidicon for special military and space.
C73496B*	½-inch-diameter magnetic-focus and -deflection type for very compact camera systems; ruggedized construction.
C23052*	½-inch-diameter electrostatic-focus, magnetic-deflection type for ultra-compact cameras with minimum power requirements.

* Developmental Numbers.

Secondary options in the form of low-power heaters, radiation-resistant faceplates, faceplate reticle markings, ruggedized construction, and special photoconductors can be provided either singly or in combination on any of these basic types. Most modern vidicon designs also incorporate a separate electrical connection to the mesh electrode to provide high resolution and more uniform signal characteristics with a minimum operating-power requirement.

APPLICATIONS

Following their introduction in 1954, the 1-inch-diameter, magnetic-focus and -deflection vidicon types having no separate mesh connection were most widely used in television systems. The type 7038 enjoyed almost exclusive use in early film system; its high-sensitivity counterpart, the 7735B, has been used extensively in live-pickup cameras. However, most new very-high-performance camera designs use the separate-mesh equivalent types 8572 and 8507 for film and live service, respectively. There is also a very strong trend toward electrostatic-focus, magnetic-deflection types such as the 1½ inch diameter 8480 and 1 inch diameter 8134 in new camera designs.[3] The savings in space and power consumption are substantial and, when properly employed, these new types can provide competitive or superior picture quality. The advantages of the 8480 and 8134 can be of paramount importance in space and military systems, as well as in simultaneous color systems, where a number of individual tubes are required for each camera unit.

All-electrostatic vidicons, and vidicons having magnetic focus and electrostatic deflection, have experienced only limited specialized use to date.

VIDICONS IN FILM-PICKUP (TELECINE)

The vidicon filled a great need in Telecine service and has subsequently made outstanding contributions to television broadcasting. By comparison with the iconoscope, which it replaced, the vidicon is small, uncomplicated, and capable of excellent performance.[5] Its small photoconductor and transparent electrode backing greatly reduced total light requirements and permitted head-on image projection to eliminate the severe optical- and scan-geometry problems associated with iconoscope operation. Furthermore, the mosaic construction of the iconoscope target leads to poor shading characteristics and unstable life characteristics. In contrast, the vidicon's low-velocity-scan principle provides high signal uniformity combined with high resolution and exceptionally long life. In short, the vidicon has generally come to be regarded as a nearly ideal pickup device.

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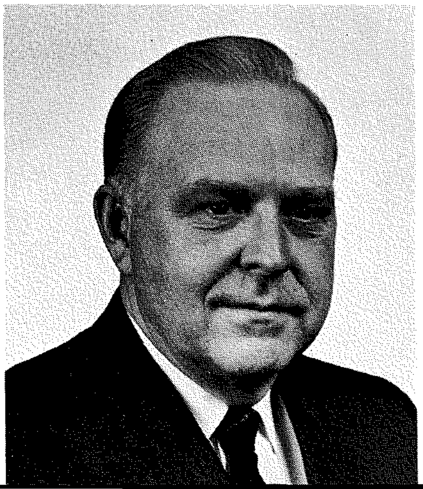
R. E. JOHNSON received the BS in Electrical Engineering from the University of Pittsburgh in 1942. He joined RCA in June of 1942, working on design and development of Radar Indicators until 1946, when he transferred to similar activities on camera tubes. His work in this area included a wide variety of tube types including iconoscopes, orthicons, multiplier orthicons, image orthicons and isocons; probably the most prominent result of this effort was the development of the first commercial image orthicon to be employed in Broadcast Television Service, the RCA 5820. From 1950 until 1960 he was active in field sales engineering activities with RCA. In 1961, he returned to the Lancaster plant to his present position as applications engineer for camera tubes.



For optimum operation, the vidicon with an antimony tri-sulfide sensor requires about the same intensity of illumination (50 to 100 footcandles) as the iconoscope. However, because of its smaller size, the total light requirement is greatly reduced (8 lumens to 0.1 lumen) and small, compact projector systems can easily be provided for Telecine service. As shown in curve *C* of Fig. 1, the vidicon can be operated in the highly preferred low-dark-current mode, and can deliver peak signal currents in the range of 0.2 to 0.4 µA. Photoconductor noise at these signal amplitudes is negligible, and modern cascode tube amplifiers or field-effect-transistor amplifiers can provide video signals having ratios of visual-equivalent peak signal to RMS noise as high as 300:1. Television pictures generated at this performance level are commonly regarded as noise-free by the viewer. Fig. 1 (Curve *B*) shows that the same signal levels can be obtained at lower light levels by operation of the vidicon in a higher-sensitivity mode if a higher level of dark current can be tolerated. Also, such higher-sensitivity vidicon types as the 8134 and 8507A can be operated at the same signal level with less than one third the light, as shown by Curve *B* of Fig. 2. In general, these tubes may show a greater tendency toward image retention after exposure to extreme highlights, and they may exhibit more lag than the vidicons (7038 and 8572) previously recommended for film service. However, this effect is not especially serious in practical operating systems, and all other basic vidicon advantages are retained undiminished.

Gamma

The "gamma" of a camera-tube device is also a very important characteristic in the design of a modern television system. Gamma is the slope of the light-transfer curves, shown in Figs. 1 and 2, as determined by the exponential in the relationship $I_{sj} = k\ I_{fp})^{\gamma}$, where I_{sj} is the vidicon signal output, I_{fp} is the faceplate illumination, and γ is the slope of the transfer curve (k is a proportionality factor to rationalize the selected measuring units). For antimony tri-sulfide vidicons, the gamma is nominally 0.65, a value that is almost the exact complement of the gamma of the picture tube in the television receiver. Consequently, the natural over-all system gamma is 1.0, which is a necessary condition for true fidelity in picture reproduction. Thus, natural picture tones or gray-scale gradations are reproduced on the receiver without the complicated gamma-matching circuits required with pickup devices having gamma values approaching unity. The gamma of the vidicon also remains essentially constant over the normal operating signal range of 0.04 to 0.40 µA. Individual tubes, therefore, not only produce closely matched, natural-looking pictures in black and white, but also permit close tracking in chrominance channels for color reproduction of high fidelity. The constant gamma value also exercises a moderate control over highlight-signal levels so that the vidicon is capable of operation over a wider light range than is possible with a unity-gamma device.

Color Sensitivity

The spectral-response curve of the vidicon is panchromatic and very similar in shape to the response curve of the human eye. Consequently, the tubes have good sensitivity to all primary colors, and properly designed color systems can produce pictures in all the natural half-tone color brightnesses and hues normally seen by the eye. Because the response to wavelengths outside the visible spectrum is negligible, natural colors are not masked by extraneous energy wavelengths in the light source. These features can be a great asset in selecting film suitable for broadcast purposes, because anything that looks good to the eye should reproduce well in the vidicon system. Infra-red filters are normally employed in film projectors to avoid undesirable heating effects and in chrominance-channel optics where extremely pure color separation is essential.

Lag—an advantage

Although any appreciable lag in a camera tube is usually considered undesirable, the lag of the vidicon in Telecine applications is of approximately the right magnitude to be advantageous. The 24-frame-per-second exposure sequence of motion-picture film is not directly compatible with the 30-frame-per-second television system. This discrepancy ordinarily necessitates the use of an ingenious, closely synchronized matching arrangement for a compatible system with reasonable audio and video fidelity in the reproduced picture. However, the lag of the vidicon enables the tube to be used in non-synchronous projection systems, and film frame exposures do not have to be rigidly confined to the relatively narrow time boundaries of the blanking interval. In addition to greatly simplifying projector design and operation, vidicon lag greatly improves the over-all sensitivity of the system by permitting the frame-exposure time to be increased to as much as 50% of the television-field scan interval. This characteristic of the vidicon smooths out sequential picture information so that the effect of the shutter bar and other transient effects are not noticeable. More sensitive camera tubes having very low lag characteristics usually suffer by comparison in such applications. Other incidental stray or reflected light is also usually more objectionable in its effect on picture contrast in such high-sensitivity, high-gamma devices.

Resolution

The resolution of vidicons in film-pickup service is normally 700 to 800 lines. However, this performance can easily be increased to as much as 1000 lines or more by proper choice of tube types which operate at maximum potentials. Vidicons of larger diameter are, of course, capable of operation at much higher limiting resolution values approaching 2000 TV lines. Relative response values in the range of 50 to 75% at 400 TV lines are attainable with either size tube.

Dark Signal Reference

When operated at constant target voltage, the vidicon provides a relatively constant dark-signal reference at the very low absolute levels important in television broadcasting. Another unique characteristic of the vidicon is its ability to deliver a varying level of signal output over a wide range by simple target-voltage adjustments, which do not have a first-order effect on other operating parameters. Thus, if a rectified signal is properly fed back from the video amplifier, target voltage can be adjusted automatically to maintain constant peak-signal amplitudes from peak highlights that may vary more than 100:1 in brightness. Although film

Fig. 1—Light-transfer characteristic of 7038 vidicon (illumination uniform over photoconductive layer; scanned area = ½ × ⅜ inch; faceplate temperature ≈ 30°C).

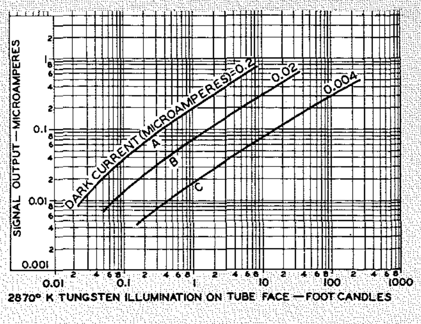
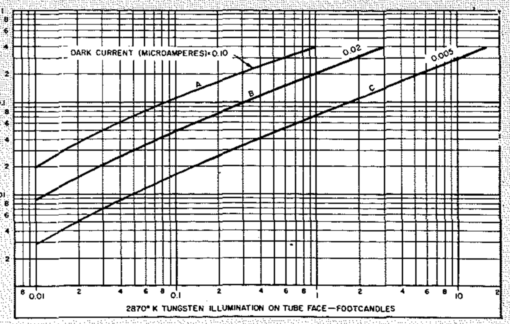


Fig. 2—Light-transfer characteristic of 7735B vidicon (illumination uniform over scanned photoconductive; scanned area = ½ × ⅜ inch; faceplate temperature ≈ 30°C).



exposure and processing are normally very carefully controlled, abnormally dense films edited in sequence with over-exposed segments can frequently occur in broadcast operations. This very useful and much appreciated vidicon feature cannot be duplicated in any other camera tube currently available.

TABLE II—Vidicon Vibration and Shock Capabilities

Type	*Vibration*								*Shock*	
	Operational				Non-Operational					
	Sinusoidal		Random		Sinusoidal		Random			
	g	*Hz*	*g*	*Hz*	*g*	*Hz*	*g*	*Hz*	*g*	*ms*
4503	10	2000	12	2000	15	2000	25	2000	100	6
8567	3	1000	10	1000	5	2000	10	2000	30	11
4514			6	1000	5	500			35	60
C23073*	10	2000	12	1000	15	2000	25	2000	100	6

* Development Number

VIDICONS IN LIVE-SCENE TV

Vidicons did not immediately find and satisfy a critical need in live-pickup service as they did in film-pickup service. Image orthicons have very high sensitivity, excellent light-range stability, low lag, and good resolution. They also fit in a reasonably small camera package with fair signal-to-noise capabilities. Eventually, however, the compact size of the vidicon combined with its very low cost, inherent reliability, and long life became very attractive for closed-circuit TV applications. The vidicon's sensitivity and lag, though inferior to that of the image orthicon, were adequate in the practical sense; resolution and signal-to-noise capability were much superior. On balance, the odds favored the vidicon and product demand grew rapidly. Today, unit sales of vidicons for live-pickup applications far exceed sales of image orthicons and film vidicons combined.

Improved Sensitivity and Signal Uniformity

Contributing greatly to this growth was the discovery of a variant processing of the photoconductive layer for increased sensitivity, and the development of a cold faceplate seal for improved signal uniformity.[6] As shown in Fig. 2, types 7735B, 8507A, and 8134 vidicons can normally be operated with dark currents in the range of 0.02 to 0.05 μA. Maximum sensitivity operation tolerates dark-current levels in the 0.10- to 0.20-μA range. The relationship between scene illumination and faceplate illumination is

$$I_{fp} = TRI_s/4f^2(m+1)$$

where I_{fp} is the faceplate illumination in lm/ft^2 (footcandles); I_s is the incident scene illumination in lm/ft^2; R is the scene reflectance; T is the lens transmission; f is the lens speed (iris f-number); and m is the image magnification $(m+1)$ may be taken as 1 in normal installations.

If typical values for each parameter are assumed, the 1-lm/ft^2 faceplate illumination required for an optimum signal level of 0.3 μA can be achieved with scene illuminations on the order of 25 to 100 lm/ft^2. Thus, the vidicon can operate very successfully at normal indoor illumination levels. In the maximum-sensitivity mode, target voltage can be increased and lenses opened to f-2 to provide very useful performance at scene illumination levels in the range of 1 to 5 lm/ft^2. Because the vidicon is small, it can operate under conditions of limited illumination while retaining a very acceptable depth-of-focus for most closed-circuit TV applications.

Gamma

The panchromatic response of the vidicon and the 0.65 gamma of its transfer characteristics are just as advantageous in live-pickup service as for film reproduction and for the same basic reasons described earlier. In fact, because scene illumination varies more in live than in film pickup, the less-than-unity gamma characteristics is especially effective in accommodating extreme light ranges and maintaining signal levels within the normal target-discharge capabilities of the device.

Use with Signal-Control Systems

In addition, automatic control circuits operating on the target voltage can be incorporated to maintain nearly constant peak-signal levels when highlight illumination varies as much as 1000:1. Principles of operation unique to vidicons permit the use of very simple signal-control systems; for example, a 500-megohm series resistor in series with the voltage-supply to the target can be effectively employed for automatic signal control in low-cost closed-circuit TV systems to gain further economic advantages not feasible with competitive devices.

Lag

Because of the lower light levels normally encountered, the lag of a vidicon in live-pickup service is generally more perceptible than in film operations.[7] The typical 20% residual signal at the end of the third field (approximately 50 ms, as shown in Fig. 3) gives rise to a noticeable smear (or trailing) on rapidly moving objects. Although lag reduction is often desirable, completely acceptable performance is achieved in all but the most critical applications. In a great many closed-circuit TV installations, objects in the scene to be televised are either stationary or have very limited motion, so that lag is not a problem. When vidicons are used in the chrominance channels of broadcast color cameras, a very-low-lag device such as an image orthicon is normally employed in a separate luminance channel. Under normal circumstances, the luminance channel tends to dominate the visual signal, minimizing any apparent vidicon lag and, in ideal conditions, completely over-riding any undesirable effects. A fairly recent breakthrough in photoconductor technology has produced a vidicon-type tube having high sensitivity and very low lag. Although this tube is currently very expensive and has some reliability and performance disadvantages for film and closed-circuit TV applications, it provides a welcome vidicon option where low lag and dark current are primary considerations.

VIDICONS IN EXTREME ENVIRONMENTS

Space and military applications are affected by essentially the same operating parameters discussed for commercial service. However, this type of service places much greater demands on the vidicon ability to withstand shock, vibration, and other environmental extremes such as temperature, pressure, and humidity.

Shock and Vibration

Since the vidicon is a small, compact device that is inherently rugged in construction, modification to the supporting gun structures and associated deflection components results in exceptionally high resistance to shock and vibration. Table II gives some examples of the typical performance required of some types readily available as regular product. TIROS, RANGER, and APOLLO space systems have used RCA vidicons that have given a phenomenally good account of themselves.[8] The operating life of these devices either during or after exposure to such vibrations has been positively established, extending in many instances to thousands of mission-operating hours.

Pressure and Humidity

Vidicons which operate in an evacuated glass envelope are also able to withstand the extremes of altitude, humidity, corrosion, and other quality tests routinely required of military equipment. Uniform envelope pressures as high as 70 atmospheres are also sustained by conventional vidicons without harmful effects. As a result, oceanographic exploration teams have used vidicons at the maximum depths of their submerging apparatus without practical limitation. However, recent depth probes with manned submerging vehicles have encountered some fundamental difficulties. The helium content of the artificial atmosphere used in these chambers passes rather readily through glass. It has, therefore, become difficult to maintain a satisfactory vacuum in the vidicon for long periods. Television operation is practical for several hundred hours, but the very long life expectancy normally associated with vidicon operation must be sacrificed.

Temperature

The vidicon can also operate over a wide range of ambient temperatures.[9] Without adjustments of operating voltages and other parameters, a useful performance level can be maintained over a temperature range of −25°C to +75°C. If adjustment of controls and operating parameters is feasible, the vidicons can be operated over this approximate thermal range with very little loss in picture quality. With a reasonable compromise in picture quality and with parameters adjusted for optimum performance at the particular operating temperature, the useful operating range might conceivably be doubled, covering a temperature spread of 200 degrees.

Vidicons designed for reliable military applications are limited to a maximum positive temperature of less than 100°C; absolute maximums much in excess of this value would require special designs. At the other extreme, temperatures as low as −250°C have been sustained by individual vidicons without catastrophic failure.

Radiation

Another currently important environment which does not exclude vidicons is the nuclear environment. By the use of nonbrowning faceplates made from quartz or fused silica, the conventional vidicon design can be readily adapted to withstand both neutron and gamma radiation dosages lethal to humans. Some typical limiting figures established by various research groups are reported as follows:

> *Neutron Radiation*
>
> Total dosage: 10^{15} neutrons/cm^2 (NVT)
>
> Exposure interval: 4.3×10^5 seconds, or ~ 120 hrs.
>
> Tolerable rate of exposure: 2.35×10^9 neutrons/cm^2/s.
>
> At radiation levels beyond these values, extreme heating caused the vidicons to become gassy; eventually (at 10^{17} NVT) the faceplate seals melted. It is apparent, therefore, that because the failure mode is thermally oriented, the *rate* of neutron bombardment is of primary concern with total dosage playing only a minor, associated role.
>
> *Gamma Radiation*
>
> Total dosage: 10^9 roentgens (accumulated at a rate of 10^6 roentgens for 1000 hrs).
>
> At this level, the vidicon may sustain a slight reduction in operating efficiency as a result of faceplate browning, and a slight deterioration in cathode emission. *Total* radiation dosage normally exerts the primary effect of deterioration with the rate playing a minor, associated role.

Up to these levels, special vidicons have survived such environments without serious loss in picture-making capabilities. In addition to their basic utility in space and military service, where extreme nuclear environments may be encountered, the tubes are also routinely used in reactor monitoring, critical-area surveillance, and other commercial or civilian applications where human life would be endangered.

Intense Illumination

Conventional vidicons can be operated without either temporary or permanent damage from continuous exposure to uniform illumination intensities as high as 10,000 lm/ft^2. As indicated in Table III, non-uniform visible radiation several orders of magnitude higher can be sustained for restricted periods of time without permanent damage.[10] However, the vidicon is susceptible to temporary image burn-in at relatively low light levels if the subject is of high contrast, is sharply focused, and is maintained stationary for a critical period of time. If the vidicon is exposed to this type of scene for very long, permanent image burn-in can often result.

TABLE III—Light-Exposure Damage Limits for Vidicons

Faceplate Illumination (lm/ft²)	*Time* *Definite*	*Probable*	*Possible*	*Unlikely*
33,200,000	⅓ sec.	—	—	—
20,700,000	½ sec.	—	—	—
10,300,000	1 sec.	—	—	—
1,890,000	12 sec.	3 sec.	—	—
1,170,000	20 sec.	5 sec.	1 sec.	—
619,000	1 min.	12 sec.	3 sec.	—
292,000	3 min.	30 sec.	5 sec.	—
150,000	8 min.	1 min.	9 sec.	—
103,000	15 min.	5 min.	12 sec.	—
37,000	45 min.	20 min.	1 min.	1 sec.
18,900	1.5 hr.	45 min.	5 min.	2 sec.
9,600	—	2 hr.	15 min.	6 sec.
9,200	—	2.5 hr.	20 min.	8 sec.
6,190	—	3 hr.	30 min.	10 sec.
2,920	—	—	1 hr.	20 sec.
1,890	—	—	2 hr.	30 sec.

SLOW-SCAN OPERATION

Reduced Bandwidths

The bandwidth of a video system is directly related to the readout rate and the amount of detail or resolution contained in the picture being transmitted. At an equivalent 60 fields/second, with approximately a 500-line raster and an equal amount of picture detail, i.e., 500 TV lines/picture height, commercial TV systems function quite well with camera TV amplifiers having a bandpass of 6 to 8 MHz. If the field time is extended to several seconds, a 1000-line raster with resolution of 1000 TV lines can be transmitted in a bandwidth of 50 to 100 KHz. A reduced bandwidth permits a great reduction in the size, weight, and complexity of equipment, which is particularly valuable in space and military applications.[11] It also reduces the noise in the pick-up system, which usually determines the signal-to-noise ratio in the final picture. Consequently the transmitter power, size, and weight required for equivalent receiving strength can also be greatly reduced.

Storage Characteristics

The excellent storage characteristics of conventional commercial vidicons permits operation at frame times as long as 2 or 3 seconds without appreciable picture degradation. However, field scan rates as long as 20 or 30 seconds can be accommodated with special photoconductors which provide excellent signal and picture quality.[12]

Use of an Optical Shutter

In slow-scan systems, an optical shutter is often used to avoid blurring of moving objects during the rather long scan cycle. As in photographic film, the sensitivity of the vidicon is directly associated with the total energy of the exciting light source. Therefore, the product of the light intensity and the exposure is the basic parametric reference, and either the illumination level or the exposure interval can be varied to obtain a given exposure index. For equivalent products of illumination and time, equivalent peak signals are generated—provided the scan or readout rate remains constant. However, peak signal for a given exposure index varies significantly in a predictable manner (Fig. 4) as the scan or readout rate is varied.

Signal-Storage Characteristics

In many special systems, a relatively long time between scene exposure and actual signal readout is desired. These so-called signal storage times may be many times longer than the frame-readout time established for the picture. As shown in Fig. 5, special photoconductors developed for

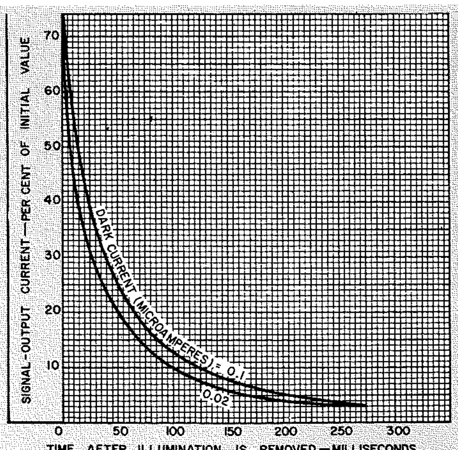


Fig. 3—Lag characteristic of vidicon in live-pickup mode (initial highlight signal output = 0.3 μA; scanned area of photoconductive layer = ½ × ⅜ inch).

slow-scan operation store images for as much as 50 seconds before readout with not more than 60% loss in signal amplitude—a feature not generally found in competing camera-tube devices.

Lag

Slow-scan systems offer additional advantages in solving the problems of lag. Although there is essentially no more decay of the signal between scans, the slower scanning beam discharges the target more effectively than does a fast scanning beam and results in somewhat lower residual signal levels after each scan interval. In addition, with field rates as long as 5 or 10 seconds, it is very easy to insert fast-scan erase sequences in the picture-generating cycle by speeding up the scanning beam during these intervals. Thus, three, or four fast-scan erase rasters can often be inserted between each exposed picture interval. Each new exposure, therefore, is focused on a "clean" target, one having virtually no residual picture information from the previous scan. No longer concerned with lag, users of slow-scan systems can specify photoconductors solely on the basis of greater sensitivity. The slow-scan photoconductor which has been used so successfully in such application has about twice the inherent lag of the standard photoconductor with no ill effects, while providing about three times the sensitivity.

Signal Uniformity

An ingenious black reference element can also be incorporated in the vidicons of slow-scan systems to maintain a constant DC level in the transmitted picture. Because of the slow rate of scan and low signals generated, changes in the dark current or background level of the scanned target can create undesirable variations in the composite picture transmitted. For a constant black reference signal, an opaque mask is placed vertically along one side of the scanned raster and the beam is allowed to strike this area at the beginning of each line scan. The video amplifier is designed to lock on to this signal and "build" the subsequent video or AC information on top of it. Thus, a uniform signal-output level, free of unwanted "shading" signal variations, is generated. This feature has done much to improve the over-all picture quality and half-tone reproduction of the slow-scan systems.

SPECIAL VIDICON APPLICATIONS

Medicine

There are a number of specialized areas in science and industry where vidicon cameras have made unique contributions, many directly affecting the health and welfare of the individual and society. For example, vidicon camera systems are used to view fluoroscopic images projected by X-ray devices on viewing screens.[13] A doctor or an expert radiologist may then directly observe the patient for immediate and more accurate diagnosis. The flexibility provided by the vidicon system, the reduction in X-ray dosage permitted by the amplified sensitivity of the device, and its ability to transmit the picture immediately to many consultants in widely separated locations has made this equipment virtually indispensable today in the field of medicine. In a similar application, surgery or other critical medical processes can be observed by any number of students or consultants.

Biology

The sensitivity of special vidicon photoconductors to ultra-violet radiation has been used to great advantage in the field of biology. Because many living cells are invisible or can be damaged or killed under ordinary illumination, ultraviolet microscopy using a vidicon camera has opened up new worlds of knowledge and investigation to biological research scientists.

Infrared Observation

At the other end of the spectrum, specially constructed vidicons sensitive only to infrared illumination contribute to many scientific, military, and industrial operations. A monitoring camera on the launching pads at Cape Kennedy can spot minute leaks in the hydrogen tanks of a rocket before they can grow to dangerous levels. Infrared surveillance for security and safety in both industry and the military can be supplied by a suitably installed vidicon camera system.

Astronomy and Navigation

Vidicons have also been very successfully employed in star trackers. These newly developed but now-indispensable devices provide precise navigational and orientation control of space vehicles and satellites. The same system can be used for sky mapping and other astronomical investigations where such exploration is enhanced by freedom from the earth's atmosphere. In another navigational application, very-long-lag vidicons have been used to view PPI radar indicators and present to the controller an air traffic pattern that can be easily viewed in high ambient light.

VERSATILITY FOR FUTURE USE

The versatility of the vidicon is illustrated by its adaptation to computer systems. In one ingenious application, a slightly modified version of the conventional vidicon having a single-line, high-frequency scan is complemented by mechanical scanner motion in the orthogonal axis. Such a device has been used as a character reader or script reader in some of the more advanced systems. Instead of merely responding to punched holes or other coded signals largely unintelligible to human senses, the vidicon can be made to read messages in languages that are equally intelligible to human beings. This same ability is also being exploited in the rapidly growing use of computers in advanced, automated educational systems where the vidicon or some similar camera tube device will surely play a vital part. Without doubt, the future of the vidicon camera tube looks exceptionally bright in nearly all television systems applications.

ACKNOWLEDGEMENTS

1. P. K. Weimer, S. V. Forgue, R. R. Goodrich. "The Vidicon-Photoconductive Camera Tube," *RCA Review*, Vol. 12, No. 3 (Sep 1951).
2. R. G. Neuhauser, "The Design and Performance of a High-Resolution Vidicon," *Journal SMPTE* Vol. 71, No. 11 (Nov 1962).
3. J. E. Kuehne, R. G. Neuhauser, "An Electrostatically Focused Vidicon," *Journal SMPTE* Vol. 71, No. 10 (Oct 1962).
4. A. D. Cope, "A Miniature Vidicon Of High Sensitivity," *RCA Review* Vol. 17, No. 4 (Dec 1956).
5. R. G. Neuhauser, "Vidicon For Film Pickup," *Journal SMPTE* Vol. 62, No. 2 (Feb 1954).
6. L. D. Miller, B. H. Vine, "Improved Developmental One-Inch Vidicon For Television Cameras," *Journal SMPTE* Vol. 67, No. 3 (Mar 1958).
7. R. G. Neuhauser, "Sensitivity And Motion-Capturing Ability of Television Camera Tubes," *Journal SMPTE* Vol. 68, No. 7 (Jul 1950).
8. R. E. Hoffman, "Vidicons For Space Applications," *Journal SMPTE* Vol. 76, No. 8 (Aug 1967).
9. R. E. Johnson, "Vidicon Performance in Extreme Thermal Environments," *RCA Review* Vol. 27, No. 3 (Sep 1966).
10. G. A. Robinson, "Operation Of Vidicons In Unusual Environmental Conditions," *Journal SMPTE* Vol. 70, No. 4 (Apr 1961).
11. Max H. Mesner, "Television's Toughest Challenge," *Electronics* Vol. 38, No. 10 (May 1965).
12. R. E. Johnson, "Vidicon Performance Characteristics At Slow Scan Rates," *RCA Review* Vol. 27, No. 1 (Mar 1966).
13. J. P. Mitchell and M. L. Rhoten, "Closed-Circuit Television System For X-Ray Inspection," *Journal SMPTE* Vol. 71, No. 6 (Jun 1962).

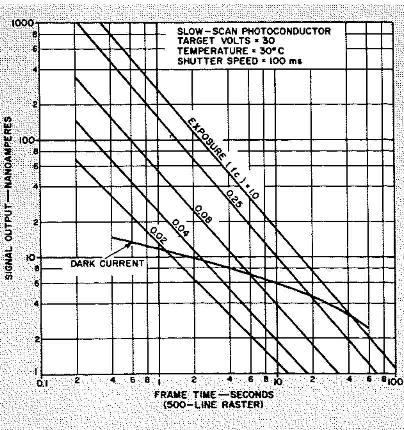


Fig. 4—Vidicon signal characteristics in slow-scan mode.

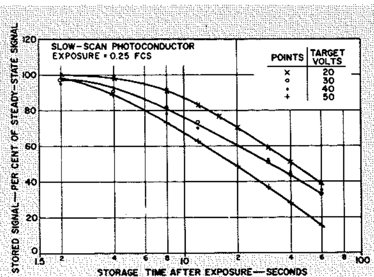


Fig. 5—Vidicon signal storage in slow-scan mode.

A Gallium Arsenide (GaAs) Laser-Diode Communicator

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A two-terminal communication system using commercially available Gallium Arsenide (GaAs) laser room-temperature diodes has been designed and constructed. Various component-selection techniques for the laser driver and their relation to system performance are described. The mechanical and optical construction plus design improvements and their effects on system performance are presented.

THE MOST compact and efficient coherent light source available is the semiconductor laser diode. These advantages exist because a separate optical pump is not required to achieve population inversion. A single GaAs laser diode is rectangular in structure with plane parallel cleaved surfaces forming the optical cavity and indium-coated surfaces permitting good thermal and electrical contact. Rather than using an external technique, modulation can be achieved directly by varying the drive current. The recombination of these injected charge carriers emits photons at 0.9 microns—a wavelength invisible to the unaided eye, yet near the responsivity peak of the silicon detector. The unique capabilities of GaAs as a light source have obvious uses in the fields of radar and communications. However, because of some radar circuit difficulties, a voice link was tried first.

GENERAL CIRCUIT OPERATION

In the receiver section, the output from a silicon photodiode is fed directly into a preamplifier and then into a low-noise integrated video amplifier which amplifies and limits the signal (Fig. 1). The threshold which the incoming signal must exceed in order to be amplified is maintained relative to the changing battery voltage. The output from the video amplifier is fed into a pulse stretcher which ensures the pulse uniformity necessary for proper demodulation. Demodulation is accomplished by passing the output pulses from the pulse stretcher through a low-pass filter with a 3-kHz cutoff frequency. The low-pass filter averages the pulse amplitude over several periods of the carrier so that the amplitude of the filter output varies as the pulse repetition frequency. Finally, the audio output from the filter goes through two stages of gain to the earphone.

In the transmitter section, the audio signal from a microphone is coupled through an emitter-follower stage to an amplifier stage. Output modulation from the amplifier is used to vary the charging rate of a capacitor in accordance with the audio signal. The capacitor is connected to a unijunction oscillator whose charging rate determines the final output pulse frequency. Thus, the output pulses are frequency modulated by the audio signal. The unijunction oscillator output is then amplified and transformer-coupled to the 30-amp, 50-ns laser diode drive circuit.

LASER DRIVER

The receiver and transmitter circuitry is straightforward. However, the driver electronics for the laser diodes is important; because without this type of switching (the very short pulse length), the room-temperature-diode duty factor would not allow a high enough repetition rate. The first driver used two silicon control rectifiers (SCR) as the switching elements.

Silicon Control Rectifier

The transformer-coupled driver SCR generates a high-current pulse by discharging a capacitor into the gate of the output SCR. These pairs are chosen with hold-off time differences so that the pulse from the first SCR can drive the gate of the

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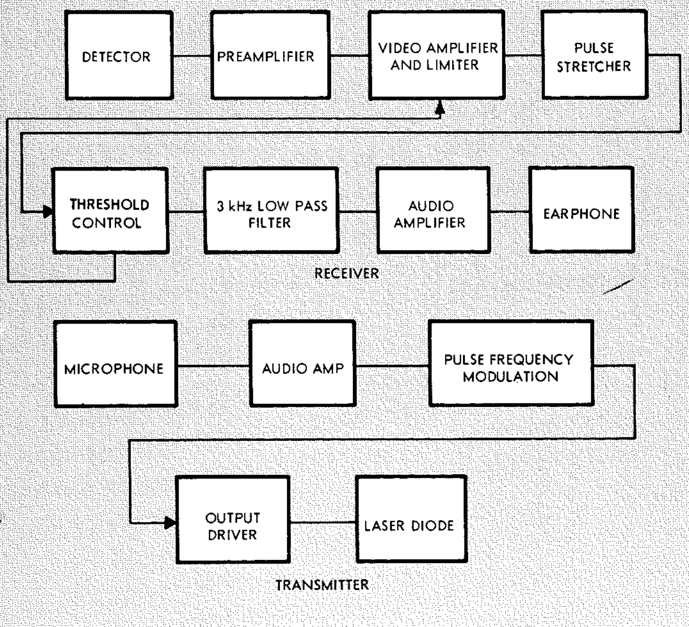
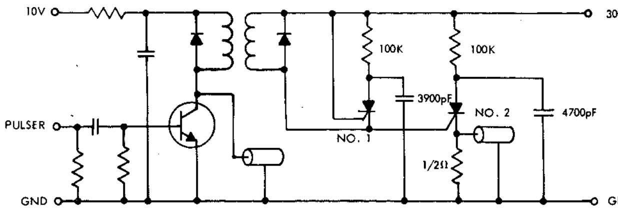
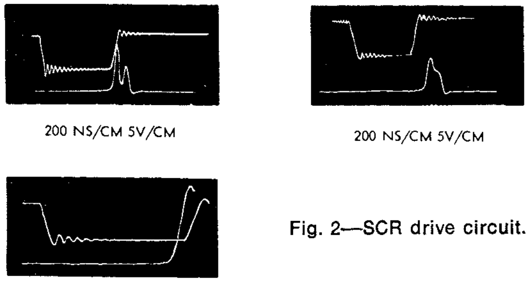


Fig. 1—GaAs of receiver-transmitter.



SCR PAIR SELECTION CIRCUIT

SCR NO. 1	SCR NO. 2	SINGLE MODE TIME DIFF (ns)	MEASURED TIME DIFF (ns)	MAX CURRENT (amps)
1-03	1-11	10	100	26
1-16	1-17	100	75	18
1-09	1-17	460	0	41



200 NS/CM 5V/CM

200 NS/CM 5V/CM

100 NS/CM 5V/CM

Fig. 2—SCR drive circuit.

second SCR as it begins to turn on. Thus, the output SCR is turned on quickly, discharging another capacitor through the laser diode and generating the required high-current drive pulses with 50-ns half widths. The SCR's must be initially selected for their holdoff time and maximum currents. Among the higher current SCR's, proper pairs are chosen whose time difference is from 400 to 500 ns (Fig. 2). The scope traces show both the correct and incorrect matching of the SCR's. Fig. 2 gives some of the values measured from their scope traces. When they are properly matched and biased at 300V, most of the current from the two capacitors can get through the output SCR in 60-ns even though it is still in a relatively high impedance state. This is important because most of the losses occur in this SCR (7 ohms) as opposed to the laser diode (0.2 ohm).

Avalanche Transistor

As a switch, the avalanche transistor is certainly better than the SCR and is perhaps the best available because 1) risetimes of 1 to 2 ns are possible; 2) pulse lengths less than 50 ns are a certainty; and 3) the circuit impedance is signficantly less. It is, however, still unnecessary to select individual components, but the general quality of available material has improved.

Several articles have been published[1,2] on methods of driving laser diodes with very short pulse lengths (Fig. 3). The most promising idea is to use a transmission line as the energy storage device.[3] The avalanche transistor is driven by another avalanche transistor to insure uniform switching and the most rapid risetime (1 to 2 ns). The transmission line makes it possible to choose any reasonable pulse length (e.g., 15 ns), and solves the more difficult problem of turning off the transistor. The discharge path, carrying the gigacycle signal, should have a minimum of inductive lead length. The shorter risetime lowers the preheating of the diode junction—something which normally happens when a gaussian pulse is used. These 15-ns high-repetition-rate light pulses are especially attractive for time-of-flight radar as well as communication.

OPTICS

In the case of the communicator, several detectors were considered. Even though an *S1*-surfaced photomultiplier has a much higher gain, the large size and poor quantum efficiencies make it unattractive for two-mile ranges.

For the preamplifier (Fig. 4), a small silicon diffused photodiode was used which is somewhat different in construction since it has three leads (the third lead going to an annular guard ring circling the active area of the diode). The guard ring serves to eliminate the surface leakage from passing through the active area thereby reducing the shot noise. This, together with the responsivity of 0.5 A/W, makes an ideal detector for the communicator.

Initially, two different types of telescopes were used: a modified Dall Kirkham f/6 Cassegrainian and a turret spotting scope with an 80-mm objective. The Cassegrainian used a beam-splitting prism with about 40% of the light transmitted and 40% reflected. A strong white light at "infinity" was imaged through the reflective optics and lens onto the surface of the photodiode. The prism was then inserted and the photodiode adjusted to its final position. The laser diode was turned on and the position adjusted until a person with a handheld IR viewer at "infinity" could see an intensity maximum. A four-power rifle telescope was used for aiming.

In the case of the spotting telescope, an unmodified eyepiece was used for alignment with the other link. The other two turret positions held the photodiode-preamplifier housing (Fig. 4) and a specially modified microscope objective lens assembly for the laser diode (Fig. 5). In aligning this telescope; the crosshairs of the sighting eyepiece were placed on the bright light, the photodiode was aligned on that light, and an IR detector was placed at the light's position to align the laser diode—placing all three elements on the same axis. With preliminary boresighting and the use of a 1 kilohertz alignment tone, communication alignment was simple.

For reasonable beam divergence from the GaAs laser diode, some type of optics was needed. Obtaining a laser diode which normally has a 5°x15° pattern to emit into (e.g., a 1° beamwidth) required a lens with a focal length of 0.17 inch (the laser diode junction width is 0.003 inch, so 0.003/tan 1° = 0.17 inch). Since the maximum divergence of the raw laser beam is 15°, a lens diameter of 0.125 inch is more than adequate to collect all the light. It will be necessary to modify the standard microscope objective to align the laser, heat sink it reasonably well, be able to reuse the diode, and keep the shop time to a minimum. The result (Fig. 5) was to invert the objective lens assembly and spring load it against the piece holding the diode. Then, by screwing in the threaded ring and, hence, the lens assembly, the laser diode could be focussed in the far field as a line or slightly defocussed to a circle. An adapter coupled the microscope objective to the telescope. Fig. 6 shows a preliminary electronics package without optics and Fig. 7 illustrates a smaller, more sophisticated receiver/transmitter optical and electronic package having a bandpass filter, a 4-inch diameter aluminized parabolic reflector, and more compact circuitry.

LASER DIODES

The GaAs laser diodes are the most important part of the system. The diodes used were of the low threshold variety running from 13 to 15 amps. The dimensions were 3-mils wide by 4-mils high by 10-mils long. Two packaging concepts were explored: a diode mounted in a modified TO-46 transistor can (Fig. 8), with a clear window at the top allowing axial operation; and a more rugged package that provides better heat dissipation and which is somewhat more difficult to mount and align (Fig. 9).

In an attempt to achieve long-term agreement of the diode optical properties, several measurement methods were considered for their stability and accuracy. By using a vacuum photodiode, photomultiplier, solar cell, thermopile, and radiometer, the various energies and peak powers could be used to detect relative changes in the measuring instruments. Accuracy is more difficult since no detectors can be calibrated directly at a micron at these energy levels. In comparing the peak and average power measurements, care was taken on getting the proper light pulse since the pulse width from the driver changed as the output current and frequency increased: $(P_{ave} = qP_{peak}, q = Tf)$.

CONCLUSION

The semiconductor laser diode can be a very useful device for communication, ranging, and tracking. Very compact communicators can be built capable of ranges in excess of two miles. The basic receiving and driving circuitry can be applied to GaAs as well as any new semiconductor material. Any new improvements on the bulk material toward higher peak and average powers and different wavelengths can be incorporated into existing devices; i.e., the diodes will still need adequate heat sinking and will still require short, fast pulses.

ACKNOWLEDGEMENT

The authors are indebted to RCA, Camden, New Jersey, for information on work done on the basic circuit design.

REFERENCES

1. Brown, Bond and Bloomquist, "Avalanche Transistors Drive Laser Diodes Hard and Fast," *Electronics*, (Nov. 14, 1966) p. 137.
2. Der, R. C., "Generate Pulses By Varying Length of the Termination Line," *Electronic Design* 3, (Feb. 1, 1967) p. 94.
3. National Semiconductor, Danbury, Connecticut, General Engineering Memo No. 12.

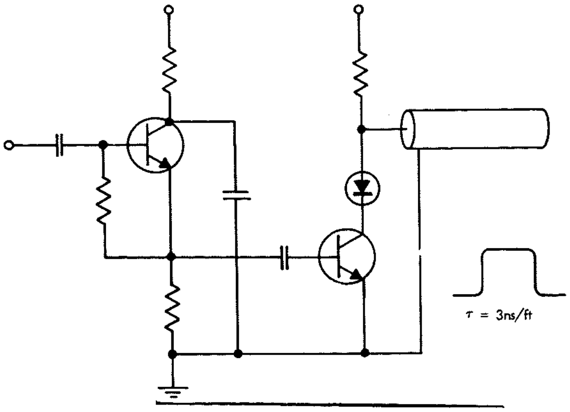


Fig. 3—Avalanche transistor drive circuit.

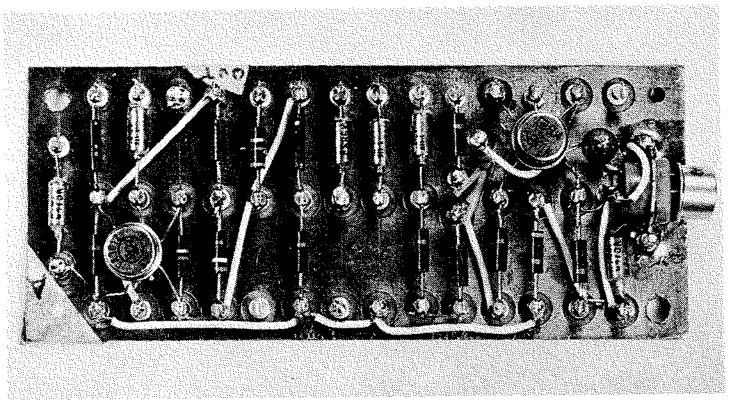


Fig. 4—Preamplifier breadboard layout.

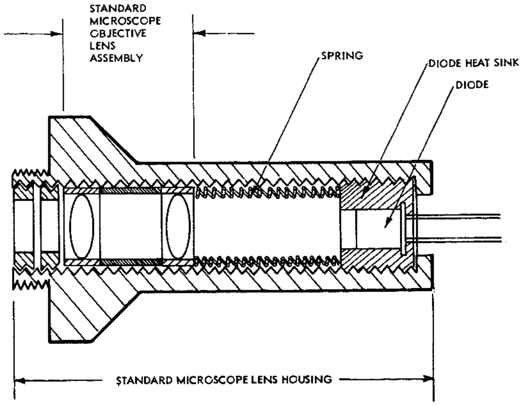


Fig. 5—Laser diode-microscope lens assembly.

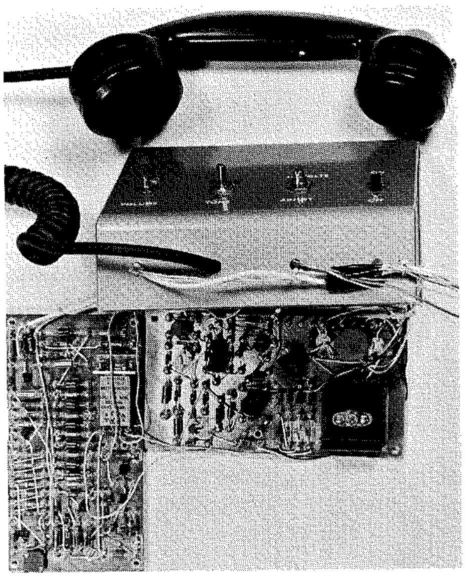


Fig. 6—Receiver-transmitter breadboard layout.

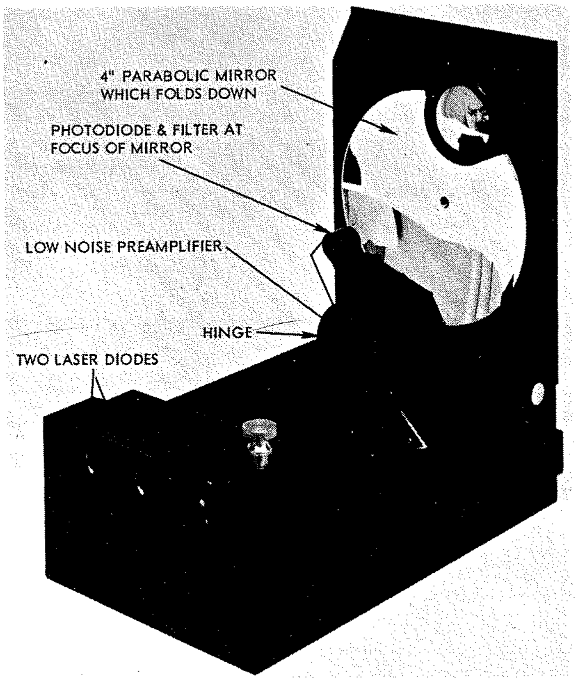


Fig. 7—Compact laser-diode communicator.

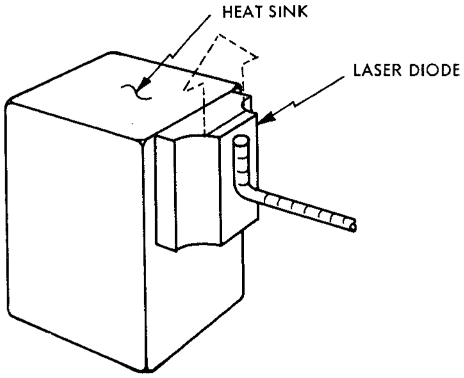


Fig. 8—Single-heat-sink laser-diode package.

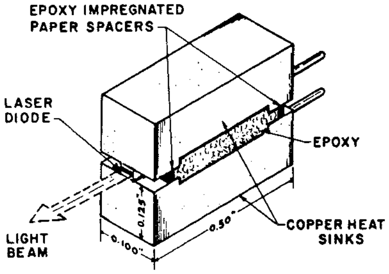


Fig. 9—Double-heat-sink laser-diode package.

The Neonatal Environment of the Premature Infant

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Funny things happened to all of us on our way to be born. We arrived in a space capsule in which we found shelter, food and warmth, and experienced weightlessness. But upon our arrival we suddenly became physiologically displaced persons and had to start doing things for ourselves: breathing, controlling our temperature, moving in air, feeding, etc. The trouble is, that some of us are in too much of a hurry to sever the umbilical connections and enter life as premature infants. This paper describes the premature infant, describes the requirements for his neonatal environment and gives some insight into the ways that RCA can help improve his chance for a normal life.

THE NEONATAL PERIOD is generally taken to be the first month after birth; however, for purposes of this paper, it is considered to be the entire period that the infant spends in an incubator. Very often, this period approximates the length of time by which the infant was premature. Thus, the incubator can be considered a waystation between the environment in the womb and that of the outside world.

This paper deals primarily with published parameters of this environment and some postulates based on these references that aid in designing equipment to be used in conjunction with RCA neonatal monitoring equipment. This is an integral part of RCA's efforts in the field of medical devices.

WHAT IS A PREMATURE INFANT?

Since estimates of the gestational period are often inaccurate, it is practical to define a premature infant by its physical characteristics (Fig. 1). Such an infant weighs less than 2500 gms (5 lbs., 8 oz.) at live birth, and has most of the following macroscopic external symptoms: a length of less than 45 cm (18 in.), a skull diameter (anterior-posterior) of less than 10 cm (4 in.), but still larger in circumference than the chest; a foot length of less than 7 cm (2.8 in.); thin, red, wrinkled skin with visible superficial blood vessels due to a deficit of subcutaneous tissue (tissue under the skin).

The proximity of the superficial vessels to the skin surface gives the premature infant a higher heat-transfer coefficient. This must be taken into consideration in the neonatal environment. The nearness of the vessels to the surface also provides clear visibility of the color of arterial blood which serves as a means for checking its oxygen content. Blueness (cyanosis) is frequent and signifies a depressed oxygen level of the blood. All of these characteristics have an important bearing on creating a rational physiological environment for the premature infant.

Good records on the birth rate have been kept since 1949. Since that time, about 8% of live births in the United States have been infants weighing less than 2500 gms. This is a higher proportion than in the Scandinavian countries (6%) and somewhat lower than in Japan (10%). Racial factors have a definite bearing on the incidence of prematurity; in the United States the percentage is 7% in whites and 12% in non-whites.[24] Altitude also appears to have an effect on the incidence of prematures (Denver, Colorado exceeds 14%). Multiple birth, socioeconomic factors, the mother's health and age, and even the legitimacy of the infant appear to be contributing factors in prematurity. Smoking by the mother doubles the incidence of prematurity.

Nutrition of the mother is often mentioned as a factor. Tysan[29] demonstrated this by placing 750 mothers on a protein, vitamin, and mineral-rich diet with low water intake, and a similar group on standard diets. There were no premature births in the controlled-diet group, but the other group had 37 (5%) premature live and still borns.

The first neonatal day is the most critical for the premature infants; about one half of the neonatal deaths occur during this first 24 hours of life.[9] Chances of survival increase with increasing birthweight (Fig. 2), and length of gestation (Fig. 3). Specialized nursing training is a decisive influence on survival rate, and special institutes have been established[7] to raise the standards of care. Indicative of the need for extra care is that one specialized nurse is recommended for each five prematures, compared to one maternity nurse for eight full-weight infants.

NEURAL AND AUDIOVISUAL STIMULATION

Ever since a midwife first whacked a newborn across its buttocks, the importance of neural stimulation has been appreciated. Yet, investigations conducted for this paper did not uncover any literature on studies of the importance of this earliest extra uterine trauma. (Psychoanalysts apparently have not connected later antisocial tendencies to this first encounter.) Be that as it may, it is postulated that important contributions can soon be made in this area of neural stimulation. Using techniques similar to heart pacers, the irregularly beating heart of the premature could possibly be guided into regular patterns. Similarly, irregular inhalation and exhalation might be patterned by pulsations in ambient air pressure. Guided by these periodic mechanical assists, the body's pacemakers could be stimulated and might subsequently take over, while the artificial assists were gradually reduced.

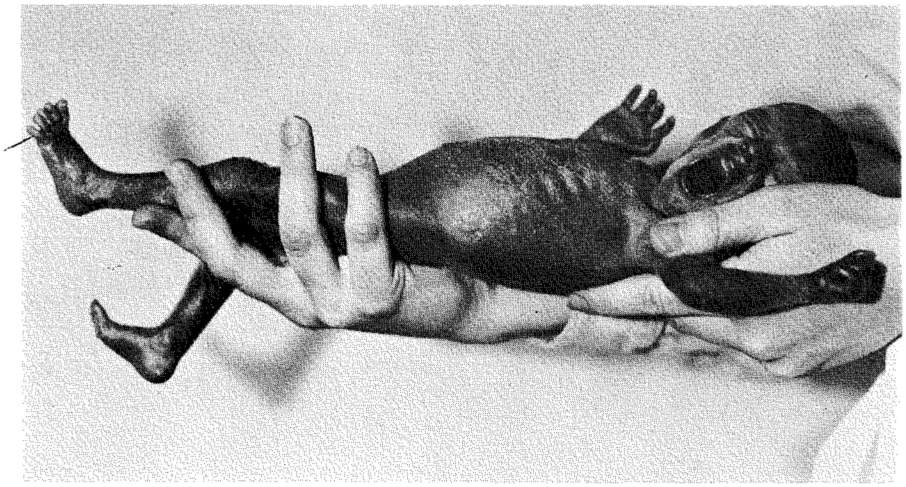

Fig. 1—A typical premature infant.

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A present practice is to tap the neonates' sole by the nurse during emergency periods of apnea (cessations in breathing) and, sometimes, to raise the ambient oxygen content in the incubator. However, considerable time can elapse between the cessation of breathing, the nurse's recognition of the episode, the grasping of the infant's foot in the incubator, etc. This apneic interval causes hypoxia (low oxygen pressure in the blood) and is a period of potential permanent brain damage and loss of life.

An automatic monitoring system that could detect periods of apnea would be an ideal addition to incubators. Such a system could initiate environmental changes when apnea was detected (a subject treated in greater detail under *Oxygen Management*) or could cause a sudden increase in noise level. For example, the sound of a buzzer might produce an initial gasp or "startle response." Of course, any such unusual audio stimulation assumes a low background noise, and 50 to 80 dB acoustic-noise levels have been recorded[6] in new incubators. The use of electric shock to reinstitute breathing is also a possibility, but not enough is yet known to safely apply this more drastic measure.

TEMPERATURE

In the literature dealing with premature infants no one topic receives more attention than ambient temperature. Early studies tended to deal with convective heat and overlooked the influence of radiant heat. But it now seems well established[24,25,27] that effective temperature control over the neonatal environment must include radiant heat.

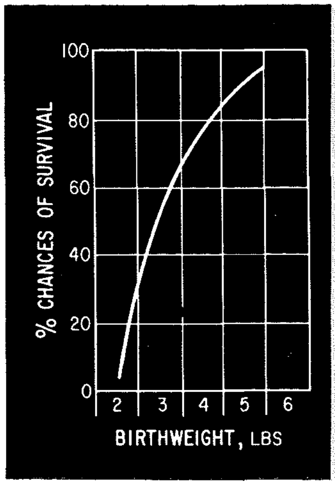
All infants, premature or full term, experience a large drop in body temperature immediately upon expulsion from the uterus; even the normal (full term) infant's temperature for the first neonatal day are a function of ambient temperatures (poikilothermy). In premature infants, this problem is more pronounced, and the development and maintenance of a constant body temperature, despite changes in environmental temperature (homoiothermy), takes much longer. The cause of poor initial thermal stability in the normal neonate is not completely understood.[1] But in prematures, the added slowness is attributed to the absense of certain mechanisms that the full term infant has at its disposal: the layer of fat under the skin, present in full term infants, is not generally available to lower the coefficient of heat transfer; musculature, important in the generation of heat due to movement and occasional shivering, is weaker; the surface area of the infant is larger due to the characteristic wrinkled skin of the premature; metabolic rate is often low; and, finally, the central nervous mechanism for the regulation of body heat is not as well developed.

There are three common locations for neonatal temperature measurement: anal, generally referred to as core temperature; inside the closed armpit designated axillary; and the skin on the stomach. The average difference between core and skin temperature tends to be unusually small (1 to 2°C) in non-perspiring premature infants. (Perspiration at an ambient temperature below 35°C is insignificant.)[9]

The maintenance of a skin temperature of 36 ±0.2°C was found to enhance chances of survival greatly, compared to a control group with a median skin temperature of 34.5°C.[9] This difference in temperature, significant between the second and fourteenth day, was of little significance on the first neonatal day. Another authority, Silverman,[24] mentions 37°C as a desirable ambient. But, lest there be the impression that unanimity had been reached in the medical field on at least the desirability of maintaining high skin temperatures, a widely used Textbook of Pediatrics[21] states "... subnormal temperature of the premature infant may be a protective phenomena, and efforts should not be exerted to elevate it too rapidly or too much."

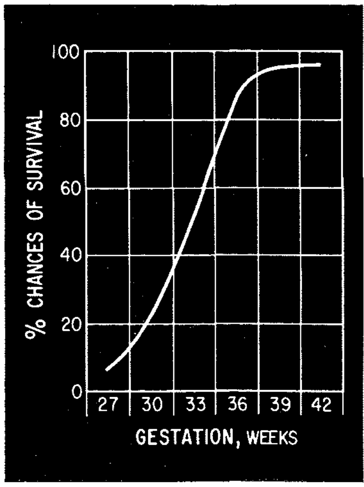
There is no longer any question that effective temperature control must include radiant heat. The use of this type of heat might reduce the importance of a rapid and uniform air flow and uniform temperature within the infant's compartment. Some references[2,24] state that under certain conditions heating the infant by radiant heat is far more important than warming by convective air. When using radiant heat, the air entering the baby's compartment is colder than the air leaving, and the infant's core temperature is slightly lower than its skin temperature during a significant initial period.

The use of electronics to automatically sense and control the temperature of the premature seems to be a real possibility. Such a system could use a thermistor to sense skin temperature. Putting this into practice runs into difficulty, however, because of the possibility of the thermistors becoming detached from the skin (means of fastening them to an infant's skin are limited). One solution might be the use of two thermistors and an alarm circuit that would actuate when one thermistor indicates a variance with the other (a loosened thermistor would sense the lower air temperature). The monitoring of core temperature would provide a place to securely anchor a thermistor but it could be used only for short periods because a rectal thermometer tends to irritate. Also the use of thermistors on a metallic black body near the infant could be used to provide an alarm at an overtemperature condition.



BIRTHWEIGHT (LBS)	% SURVIVAL
2	4
2 - 2 1/2	22
3	53
3 1/2	68
4	72
4 1/2	85
5	91
5 1/2	95

Fig. 2—Probability of survival versus birthweight.



GESTATION (WEEKS)	% SURVIVAL
26 - 28	6
30	21
32	47
34	68
36	86
38	94
40	95
42	95

Fig. 3—Probability of survival versus length of gestation.

OXYGEN MANAGEMENT

The partial pressure of oxygen in our atmosphere is 160 mm of mercury, or 21%. In normal babies, the oxygen pressure in the alveoli air sacks of the lung is about 105 mm, or 1/3 less. The difference is partially due to the reentry of air not completely expelled and filling the trachea and bronchi. The dissolved oxygen pressure in arterial blood is approximately 75-mm Hg indicating a pressure gradient of 30-mm Hg across the membranes. It is interesting to note that there is a preferential absorption of oxygen into the blood, i.e., it is absorbed 60 times faster than nitrogen at standard temperature and pressure. At lower ambient pressure, the ratio is further enhanced.[6]

Almost 40% of all premature babies have breathing difficulty to the extent that breathing is intermittent. Apnea lasts for periods of four seconds or more and these periods sometimes occur in succession. Sometimes apnea lasts 60 to 70 seconds, followed by 10 to 15 seconds of respiration, then another apnea. Where apnea is present, the blood is more basic than in regularly breathing infants (a pH of 7.444 ± 0.015 versus 7.396 ± 0.012); the average carbon dioxide pressure is lower than in the regularly breathing infants; and the average breathing rate is much lower than in the regularly breathing infants (30 versus 53 breaths/minute). Another secondary effect is the slowing of the heart rate, beginning 2 or 3 seconds after the onset of apnea. One of the most dramatic secondary effects of oxygen deficiency is the changing of skin color from pink (normal) to blue and varying shades of blue and ashen. This, if observed in time by the attending nurse, has generally been used to indicate the need for an increase in oxygen to the infant's inspired air.

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The relationship between oxygen consumption and ability to generate heat has been extensively studied[1,23] and has indicated that a baby's need for oxygen enrichment of inspired air can be determined from its ability to produce body heat. Indirect evidence of this has been demonstrated by measuring the core temperature under very controlled conditions. Again, while this oxygen-temperature relationship is widely held as valid, it is not universally accepted. It is contradicted by some of the findings of Drs. Adamsons, Gandy, and Janus, who found cases where oxygen consumption at 32°C ambient was no different than at 37°C.[30]

The short- and long-term effects of low oxygen tension are very dramatic. There is some evidence that lack of oxygen itself disrupts the periodicity of breathing. The long term effect of insufficient oxygen is the stunted development of various organs, including the brain. The obvious answer to the problem, i.e., the administration of high oxygen dosages is not desirable because damage to the retina (retrolental fibroplasia) is caused by a high oxygen pressure. Meningitis and intracranial hemorrhage have also been connected with excessive oxygen.[18,23,24,28]

For some time, the practice of doubling the ambient oxygen pressure (to 40%) was prevalent. However, this in not always enough,[23] and in some cases 40% oxygen is excessive. The alternatives must be correlated to the total clinical picture of the infant: disease, color, respiration and general state. Periodically, the enhanced oxygen content should be reduced and the infant checked for continuing need of enhanced oxygen pressure. Oxygen therapy then, reduces itself to the minimum enhancement of atmospheric ozygen required to support vital functions in apneic prematures.

Potentially, of course, an automatic monitoring system could be used to detect many of the symptoms of oxygen deficiency. But measurements of partial oxygen pressures, blood acidities, and color are difficult to implement. Further, these symptoms are not always present to the same extent in every case, and there has not been complete agreement on their relative validity. Certainly, the capability for monitoring the coincident occurrence of several symptoms would be of greater significance than that of monitoring one symptom at a time.

Since oxygen pressure in the blood is hard to monitor and requires a subcutaneous probe, it is likely that some secondary phenomena will be used for automatic monitoring. These phenomena might be the difference in oxygen pressure between incoming and outgoing air; incoming or outgoing carbon dioxide; core temperature and its dependence on ambient; skin and cuticle color; acidity of the blood; and breathing rate and regularity. However, as noted, while all of these have been cited as having some relationship to oxygen management, no single symptom, nor, for that matter, any practical combination of these symptoms have been shown to be totally valid for all infants.

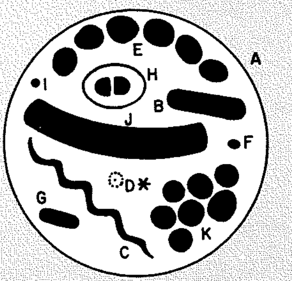
HUMIDITY

Early studies placed a great deal of emphasis on the importance of high relative humidity (RH). In these studies it was determined that, at a constant temperature of 28.9°C, survival during the first week was significantly higher at 80 to 90% RH than at 30 to 60%, but that the risk of contamination and infection was increased in a dripping wet incubator. Subsequent studies[25] have tended to confirm the suspicion that high RH, by itself, is not beneficial, and the earlier successes with high RH appear to have been due to the purely thermal effect of a decreased evaporative heat loss. In the later studies, no important effect on survival was observed when body temperatures were kept the same at moderate and high RH.

The use of extra oxygen places additional demands on moisture, because dry air with high oxygen content tends to "burn" tender mucous membranes in trachea and lungs. Thus, in such cases a high RH must be maintained to avoid the undesirable side effect.

CLEANLINESS

"Cleanliness is next to Godliness" always seemed like a blasphemous slogan for a soap company. However, in the neonatal nursery, cleanliness is essential to life and, at least in this case, the phrase is justified. Good housekeeping, bright lights and adequate space are necessary.[27] Next to the operating room, the neonatal intensive care ward should be the most antiseptic place in the hospital.[8] What applies to the ward room is even more the case with the high humidity incubator. Fig. 4 shows the sizes of some of the microorganisms that cause problems in the incubator. The "huge" circle around this collection represents the proportional size of a single red-blood cell for comparison. Conventional filters can not cope with some of the smaller microorganisms, but the positive pressure that prevails due to the forced air circula-



A. red blood cell (for comparison only)
B. e. coli, 2-3μ X 1-1.2μ
C. tr. pallidum, 0.2μ X 4-14μ
D. yellow fever virus, 0.018μ*
E. s. pyogenes, 0.6μ-1.5μ
F. rickettsia prowazekii, 0.3μ X 0.3-0.5μ
G. h. influenzae, 1-1.5μ X 0.3-0.4μ
H. d. pneumoniae, 0.8-1.25μ X 1.5-2.5μ
I. vaccinia virus, 0.15μ
J. b. anthracis, 3-8μ X 1-1.2μ
K. s. aureus, 0.7μ-0.9μ
*approximately three times larger than a molecule of serum globulin.

Fig. 4—Morphologic relationships of infectious organisms.

tion helps in preventing entry of untreated bacteria-laden air.

Present incubators are sharp cornered enclosures containing heaters, fans, ducts, sensing bulbs and nebulizers (ultrasonic humidifiers). "Adequate cleaning of incubators poses almost insurmountable problems. Ingenious engineering solutions are badly needed."[26] The use of gaseous disinfectants such as flammable ethylene oxide is good (if properly outgased), but is not a substitute for scrubbing, a tedious and time consuming activity. A common cleaning practice is to run the incubator hot for a day to outgas and dry it.

Clearly, every effort should be made to separate the required apparatus such as fan motors, nebulizers, monitoring and sensing devices from the potentially contaminated enclosure. Sterile water in a closed system and totally sterilizable nebulizers would help. The possibility of adding disinfectants to the nebulizer reservoir as a routine measure has not been thoroughly investigated. Certainly dilute solutions of silver nitrate cannot be used. Even very dilute acetic acid (0.25%), sometimes used to clean pipes and nozzles, cannot be used near the infant. Distilled water prepared by the ion exchange method has been found to contain significant amounts of microorganisms. The use of molded generous corners, nylon and teflon materials and coatings would facilitate cleaning.

THE EX-PREMATURE

Asher found that among those of abnormally low mentality there were four times as many very low birth weight (less than 1250 gms for females and 1475 gms for males) individuals as there were normal birth-weight individuals. Drillien,[15] in a study of two-year children, found that a high proportion of retarded and defective children had had a birth weight of 2000 gms or less. He[15] also reports that only 9% of the cases of low-birth-weight children studied had an IQ of over 100. Of the total group only 36% were educable in normal schools, and 76% were of poorer ability than their full term siblings.

Of course, the best solution to the problem of premature children is to minimize their occurrence by means of better prenatal care. However, a better neonatal environment is also essential. It will provide a major step toward better physical and mental development of the viable short-term infants that are born, but will also result in the survival of formerly non-viable babies. (The moral, social, and economic implications of keeping a larger number of prematures viable are beyond the scope of this article.)

CONCLUDING REMARKS

Background information has been presented on the premature infant and its neonatal environment. Reasonable agreement exists on cleanliness, temperature monitoring (both radiant and convective), and the levels of relative humidity required. Far less certainty exists in the areas of oxygen management and automatic stimulation. However, it is precisely in these areas where the possibility exists for RCA to make its most significant contribution. By utilizing the combination of data from an RCA neonatal monitor on heart rate, breathing rate, and temperature of the infant, the multifaceted problems of oxygen management and stimulation can be rationally investigated.

Each neonatal monitoring unit placed in the field will be more than a monitor and incubator to keep neonates alive and well. Each will be a powerful research instrument capable of providing correlated monitored events in the life of a premature infant in a carefully controlled environment. Thus, our knowledge of the interrelationships between environment and neonatal life will rapidly become more complete and medicine and medical engineering will stimulate each others growth.

ACKNOWLEDGEMENT

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BIBLIOGRAPHY

1. Adamsons, K., Jr., Gandy, G., and James, L. S., "Thermal Factors Influencing O_2 Consumption in the Immediate Neonatal Period," *J. Pediat.* 66:495 (1965).
2. Agate, Frederic, Jr., and Silverman, William A., "The Control of Body Temperature in the Small Newborn Infant by Low Energy Infra-Red Radiation," *Pediatrics* Vol. 31, No. 5, (May 1963) p 725.
3. *American Academy of Pediatrics Standard Recommendations for Hospital Care of Newborn Infants* (American Academy of Pediatrics, Inc., Hinman Avenue, Evanston, Ill., Rev. 1964).
4. Anderson, W. A. D., *Pathology* (M. V. Mosby Co., St. Louis, Mo., 1966) p 192.
5. Asher, C. and Roberts, J., "A Study of Birth-weight and Intelligence," *British Journal Social Med.* 3:56 (1949).
6. Avery, Mary Ellen, "Some Effects of Altered Environments, Relationships Between Space Medicine and Adaptations at Birth," *Pediatrics* 35:345 (1965).
7. Bauer, C., Davidson, M., and Levine, S. Z., "Institutes for Physicians and Nurses in the Care of Premature Infants," *J. Med. Educ.* 36:1606 (1961).
8. Bowie, J. H., Tonkin, K. W., Robinson, J. S., and Dixon, A. A., "The Control of Hospital Infection by Design," *Lancet* 2:1383 (1964).
9. Buetow, K. C., and Klein, S. W., "Effect of Maintenance of 'Normal' Skin Temperature on Survival of Infants of Low Birth Weight," *Pediatrics* 34:163 (1964).
10. Chernick, V., Heldrich, F., and Avery, M. E., "Periodic Breathing of Premature Infants," *J. Pediat.* 64:330 (1964).
11. Craig, *et al*, *Care of the Newly Born Infant* (The Williams and Wilkins Co., Baltimore, Md.).
12. Dann, M., Levine, S. Z., and New, E. V., "Long-Term Follow-up of Small Premature Infants," *Pediatrics* 33:945 (1964).
13. Day, Richard L., "Maintenance of Body Temperature of Premature Infants," *Pediatrics* Vol. 31, No. 5 (May 1963) p 717.
14. Drage, J. S., Kennedy, C., and Schwartz, B. K., "The Apgar Score as an Index of Neonatal Mortality," *Obst. & Gynec.* 24:222 (1964).
15. Drillien, C. M., "A Longitudinal Study of the Growth and Development of Prematurely and Maturely Born Children," *Archives Dis. Childhood* Vol. 34 (1959) p 37.
16. Drillien, C. M., *Growth and Development of the Prematurely Born Infant* (Williams and Wilkins, 1964).
17. Gandy, G. M., Adamsons, J., Jr., Cunningham, N., Silverman, W. A., and James, L. S., "Thermal Environment and Acid-Base Homeostasis in Human Infants During the First Few Hours of Life," *J. Clin. Invest.* 43:751 (1964).
18. Hasselmeyer, E. G., *Behavior Patterns of Premature Infants* Washington, D.C., U.S. Department of Health, Education, and Welfare, Public Health Service, Division of Nursing, Public Health Service Publication No. 840 (1961).
19. Levenson, S. M., Trexler, P. C., La Conte, M., and Pulaski, E. J., "Application of the Technology of the Germ-free Laboratory to Special Problems of Patient Care" *Am. J. Surg.* 107: 710 (1964).
20. Levenson, S. M., Trexler, P. C., La Conte, M., and Pulaski, E. J., "Environmental Control for the Premature Infant." Presented to the Conference on the Low Birth Weight Infant, *Centre Internationale de l'Enfance*, Paris (June 9, 1965).
21. Mitchell-Nelson, *Textbook of Pediatrics* (W. B. Saunders Company, Philadelphia, Pa, 1955).
22. Rodaway, K. A., and Oliver, T. K., Jr., "Incubator Accessory for Exchange Transfusion" *Lancet* 1:1220 (1965).
23. Scopes, J. W., and Ahmed, I, "Indirect Assessment of Oxygen Requirements in Newborn Babies by Monitoring Deep Body Temperature," *Arch. Dis. Childhood* 41:25 (1966).
24. Silverman, W. A., *Dunham's Premature Infants* (3rd ed. New York, Paul Hoeber, Inc., 1966).
25. Silverman, W. A., Agate, F. I., Jr., and Fertig, J. W., "A Sequential Trial of the Non-thermal Effect of Atmospheric Humidity on Survival of Newborn Infants of Low Birth Weight," *Pediatrics* 31:719 (1963).
26. Silverman, William A. *et al.*, "Decontamination of Fomites in Neonatal Units," *Pediatrics*, Vol. 38, No. 1, (1966) p 142.
27. *Standards and Recommendations for Hospital Care of Newborn Infants Full Term and Premature*, American Academy of Pediatrics, Evanston, Ill. (1957).
28. Smith, C. A., "Use and Misuse of Oxygen in Treatment of Prematures," *Pediatrics* 33:111 (1964).
29. Tyson, R. M., "A Fifteen Year Study of Prematurity," *J. of Pediatrics* 28:648 (1946).
30. Warley, M. A., and Gairdner, D., "Respiratory Distress Syndrome of the Newborn: Principles in Treatment," *Arch. Dis. Childhood* 37:455 (1962).

Airborne Weather Radar

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Federal regulations require that commercial airliners be equipped with C- or X-band weather radar to promote passenger comfort and safety. This paper provides a general description of these airborne radars, describes basic design parameters, and describes design tradeoffs necessitated by airframe constraints. The inter-relative effects of these tradeoffs can be meaningfully approximated using the standard radar-range equation. This paper describes the trade-offs required and gives some insight into capabilities and uses of modern airborne radar systems.

THE PRIMARY PURPOSE of airborne weather radar is to enable the pilot to detect, analyze, and avoid direct encounters with hazardous storm cells. A secondary use is ground mapping. In this latter application, the radar serves as an especially useful navigational device that can function anywhere in the world because it is *noncooperative,* i.e., it is a self-contained system requiring no ground station or other remote reciprocal device.

In its simplest form, weather radar transmits bursts of electromagnetic energy through a highly directional antenna to illuminate a portion of a target (Fig. 1). The echo, in the form of backscatter from the target, is picked up by the same antenna, amplified by the receiver, and then displayed on an indicator for analysis by the pilot. The intensity of the backscatter varies proportionately to the densities of the various portions of the target. (For the purposes of this discussion it is assumed that at the radar frequency the target reflects a small portion of the transmitted energy.)

In operation, a horizontally scanning antenna beam is used to slice through the storm cell in a cross-sectioning cut. The intensity of the backscatter from the elements within this cross-section is displayed on a cathode-ray tube (CRT), as illustrated in Fig. 1. Since the backscattering characteristics of the storm cell vary from point to point, the map-form brightness of the display also varies. Variations in the brightness of the display are interpreted as varying rainfall densities within the storm cell in the radar beam.

WEATHER AS A TARGET

It has been found that water drops are readily detectable targets, especially when the proper radar frequency is used, also that ice droplets, normally poor targets, become highly reflective when coated with water.

The basic problem in radar storm detection is the absorption and scattering of a plane electromagnetic wave by a sphere. At a particular radar frequency, the back scatter cross-section of the relatively spherical raindrop is approximately proportional to D^6, where D is the raindrop diameter. The reflectivity of the storm (density) in terms of unit volume is, therefore, a function of ND^6, where N is the number of drops per unit volume. Although this relationship is not valid for all drop sizes, the signal level of the target backscatter is always proportional to rainfall rate.

In cumulus clouds, down-drafts are usually associated with precipitation. Since turbulent forces thrive in the shear area between the down-drafts and the up-drafts, the radar observer is more interested in the return from these areas than from the entire cross-section of the target. If a weather target exhibits a sharp edge, it indicates that some place within the cloud there is a considerable accumulation of droplets and that closely adjacent to it there is none. This condition is called a *sharp rain gradient.* Sharp rain gradients are associated with sharp shear zones which, in turn, generate turbulence. An airborne weather radar must be able to show the pilot where the sharp rain gradients lurk.

To facilitate detection of these gradients, most airborne installations include a contour feature. Before this innovation was developed, the intensity of the radar signal on the plan-position indicator (PPI) had to be gaged visually by observing the degree of brightness of the display. To overcome this difficulty and to aid the pilot in differentiating between lighter and heavier storms, all signals exceeding a predetermined brightness (weather intensity) are not shown on indicators with the contour feature. This change in presentation is shown in Fig. 2. The PPI presentation at the left is from a noncontoured radar; it shows the target as being equal in intensity throughout. The presentation at the right is from a contoured radar; the dark area within the target indicates an area of greater intensity of return. If the target appears as a thin *circle* of light, it is indicative of a very sharp rain gradient capable of fostering considerable turbulence.

THE INDICATOR

The translation of the target return signals to a visual display is accomplished by using a CRT (Fig. 3). The intensity of the electron beam, which represents target density, is regulated by the control grid, *D.* At the same instant that the transmitter emits a short pulse of radio

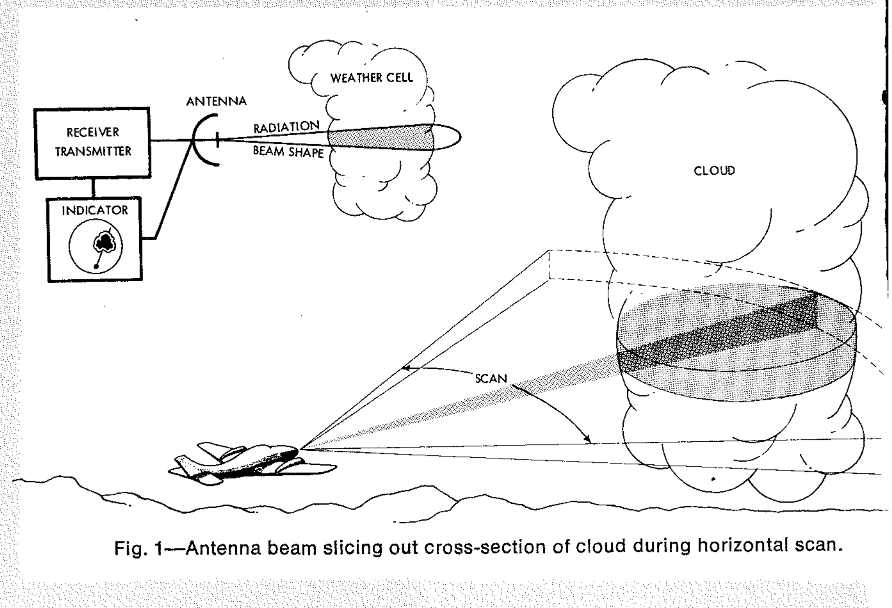

Fig. 1—Antenna beam slicing out cross-section of cloud during horizontal scan.

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waves, a current begins to flow through the deflecting coils. The resultant beam-generated series of dots called the "sweep" begins to be written at a uniform rate from the origin, *A*, towards the tube edge, *B*. Concurrently, the receiver regulates the CRT grid so as to correlate the display brilliance with the target density. When the range sweep reaches point *B*, it immediately returns to origin *A* to stand ready for the next pulse-transmission cycle. This pulsing generally occurs at a rate of 200-800 Hz, depending on the radar type.

ANTENNA CHARACTERISTICS

All present weather radars permit tilting of the antenna beam above and below the aircraft line of flight either to examine the weather at other altitudes or to ground map. The backscattering from flat fields and lakes is considerably less than that from hills and large buildings. Therefore, it is possible to display a usable representation of the terrain scanned or mapped by the antenna. The narrow pencil-shaped antenna beam, while ideal for weather targets, is not wholly adequate for ground mapping because it scans a relatively narrow strip of terrain and does not display this area with a uniform signal level, owing to greater attenuation of the radar signal at longer ranges. This undesirable feature is overcome in the more sophisticated radar systems by purposely distorting the antenna beam in the ground-mapping mode (Fig. 4). The distortion causes equal radar-signal intensity over the expanded vertical beamwidth. This beam shape is commonly called a cosecant squared ($\csc^2$) beam.

Some of the more costly, higher-performance weather radar systems, especially those with narrow antenna beamwidths, utilize gyroscopically stabilized antennas. Regardless of the aircraft attitude (within limits) the antenna reflector mount is held fixed relative to the earth (rather than to the air frame). Antenna stabilization is a desirable feature for narrow-beam systems as it reduces smearing of the display when the aircraft suddenly changes flight attitude because of pitch or roll maneuvers or turbulence.

RANGE EQUATION

The range at which a radar system can detect and display targets is defined by the modified standard radar equation

$$R_m = K(P_pT\sigma\,\lambda^2G^2/VN)^{1/4} \quad (1)$$

where: R_m is the maximum free-space range in miles; P_p is the peak transmitter power; T is the transmitted pulse width; σ represents the target area and reflectivity characteristics; λ is transmitter wavelength; G is the antenna gain; K is a proportionality factor; V is the indicator visibility factor; and N is receiver overall noise figure (includes bandwidth restrictions).

According to the range equation, range can be increased either by decreasing the receiver noise figure or by increasing the following factors: peak transmitter power, transmitter pulse width, transmitter wavelength, transmitter and antenna gain.

The noise figure, N, is defined as the ratio of carrier power available from the antenna to theoretical noise power (KTB) when the mean noise power and the carrier power are equal. Therefore, the radar range may also be increased by using a narrower receiver bandwidth. However, the receiver bandwidth cannot be decreased to a value below $1.2/T$, or the receiver integration characteristic will introduce signal attenuation.[2] This is one of the system design tradeoffs.

The parameter V is assumed to be constant for the purpose of this paper. It is dependent primarily on the radar pulse rate, pulse width, and receiver sensitivity. The values of these parameters are selected to achieve predominant system performance which overshadows the visibility factor.

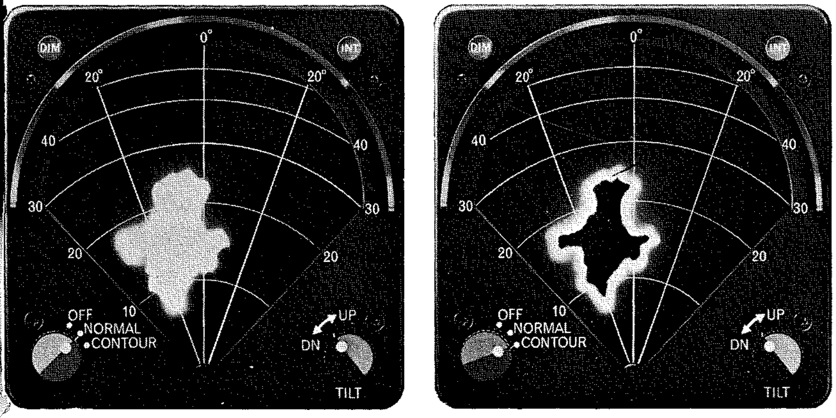


Fig. 2—Plan-position indicator showing normal and contoured storm presentations.

PARAMETER CONSIDERATIONS

Peak transmitter power (P_p)

An increase of P_p increases range by increasing target backscatter; if all other factors remain constant, then $R \propto P_p^{1/4}$. Thus, to double the radar range, a 16-fold increase in power (12 dB) is required. For small general-aviation radars, increasing power alone to improve range is generally an uneconomical method, because an unacceptable penalty in power consumption, size, weight, and cost offsets the advantage of increased range. How much power is reasonable can only be determined after establishing what range is desired, which components are available, and what power and cost penalties the system can support.

Transmitter pulse width (T)

As in the case of P_p, the transmitter pulse width must be increased by a factor of 16 in order to double the range. Most readily available magnetrons can transmit pulses up to 2.5 μs in duration; and some of the newer magnetrons can transmit even wider pulses. While a wider pulse permits the use of a narrow-band receiver for improved sensitivity (and hence increased range), other design considerations currently preclude great improvement in this regard. Further, because a wider pulse reduces target resolution, a tradeoff must be made between resolution and range. This resolution-range tradeoff must, in turn, be weighed against the increase in average transmitter power, magnetron type, and power drain associated with the wider pulse. As a result of these tradeoffs, even though high resolution is not a prime requirement in most weather radar systems (those used for ground mapping require better resolution than others) pulse width cannot be significantly increased over the 2 μs now in common use.

Antenna (G)

Since range varies as $G^{1/2}$, range can be doubled by increasing antenna gain by a factor of 4. To achieve this 6-dB increase in antenna gain (assuming a nontruncated paraboloidal antenna design at a fixed wavelength) the reflector area must be increased four fold. Limited nose space in most general-aviation aircraft prevents full exploitation of this parameter at weather-radar wavelengths, otherwise it would appear to be the most economical method to increase range. Another consideration is that if the antenna gain were increased by a factor of four by doubling the diameter of the reflector, the beamwidth would be reduced by approximately one half. The effect of this narrower beam would be to increase the stabilization required to assure detection of the smaller targets and to take advantage of the improved azimuth resolution.

Receiver overall noise figure (*N*)

The range equation indicates that range is proportional to $N^{-1/4}$. To double the range by improving the receiver noise figure by 12 dB (fixed bandwidth) can, for all practical purposes, be considered impossible.

Tunnel-diode amplifiers, which make it possible to achieve a noise reduction of several dB over conventional radar receivers, have found their way into the costlier high-performance airline radar systems in recent years. Other techniques are known to yield a significant reduction in system noise figures, but for the present these methods are impractical for commercial airborne radar systems.

Transmitter wavelength (λ) and target characteristics (σ)

These two radar parameters are sufficiently related to justify treatment as a unit. The range equation indicates that the relationship between range and wavelength σ is $R \propto \lambda^{1/2}$. This means that the range of the radar can be doubled by a four-fold increase in wavelength. The equation also indicates that range is proportional to $\sigma^{1/4}$. While these relationships are valid for most solid, flat targets, they cannot be applied indiscriminately to weather targets. The reason is that the two-way propagation through, and the backscattering by, weather is dependent on wavelength. This has been the subject of extensive investigation during recent years.

The atmosphere is almost perfectly transparent to radio waves, except for those with frequencies in the microwave band. Atmospheric attenuation is due to absorption of the radio waves by gases (oxygen and water vapor) and absorption and scattering by suspended particles (precipitation and dust). For weather radar wavelengths longer than 1 cm, atmospheric attenuation due to oxygen is relatively uniform and small (approximately 0.02 dB/mile), and, for

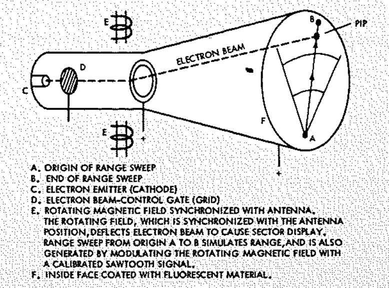


Fig. 3—Cathode-ray tube electronic beam sweep and scan control by magnetic deflection.

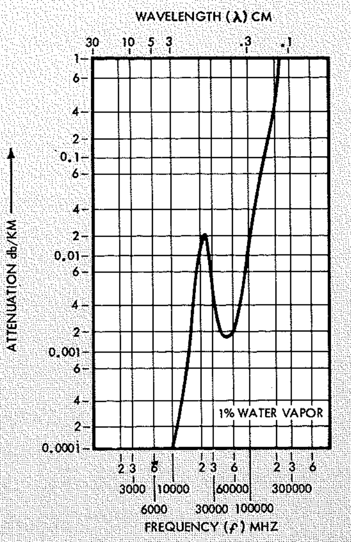


Fig. 5—Approximate attenuation due to water vapor in atmosphere in terms of altitude and distance.

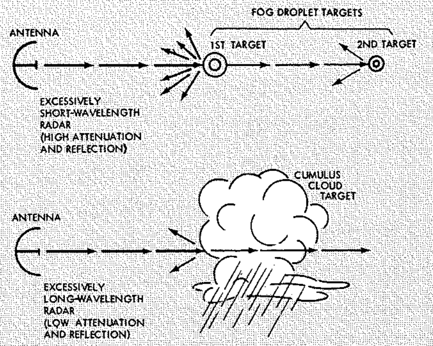


Fig. 6—Attenuation and reflection as function of radar wavelength.

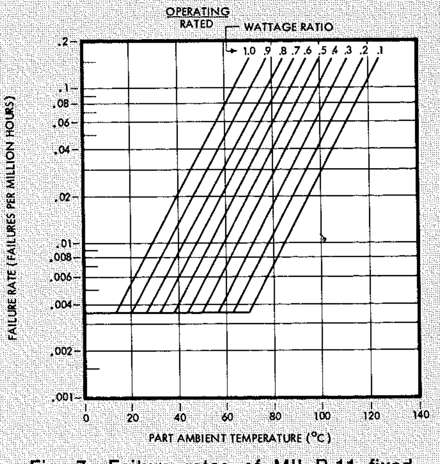


Fig. 7—Failure rates of MIL-R-11 fixed composition resistors.

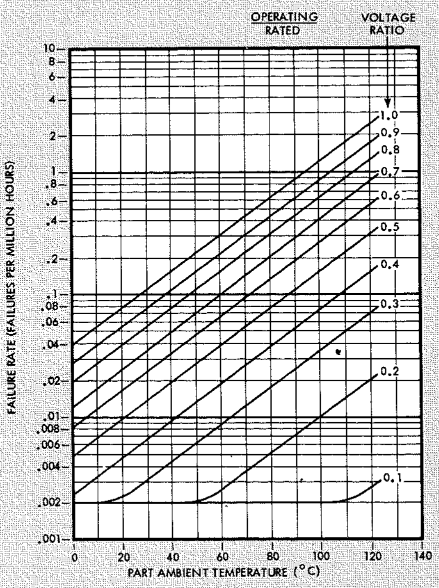


Fig. 8—Failure rates of MIL-C-20 temperature-compensating ceramic capacitors.

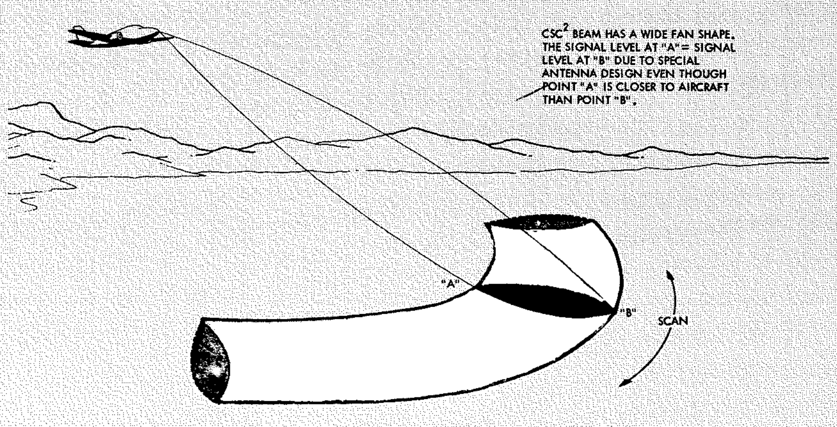


Fig. 4—Beam shape of $\csc^2$ antenna used in ground mapping by some radar systems.

the purposes of this discussion, can be disregarded. Atmospheric attenuation due to water vapor, however, increases quite rapidly as the wavelength decreases below 3 cm (X-band), as shown in Fig. 5. This figure shows the theoretical attenuation; empirical tests have shown that water absorption is actually higher by a factor of two or more.[3]

Solid particles suspended in, or falling through, the air affect radar operation both by attenuation of waves passing through them and by clutter due to backscattering value of water droplets varies as a function of wavelength and the size of the drops. The shorter the wavelength used, the smaller the droplet of water can be and still remain a good radar target. For example, if a very short wavelength were selected, even a fog condition (very small droplets) would reflect most of the signal and permit very little to pass through (Fig. 6). Under these conditions, a target behind the first target would not produce sufficient backscatter to be detected by the receiver, since most of the signal would have been reflected by the first target. Loss of signal in this manner is also known as attenuation. Attenuation due to backscatter from small drops would be considerably less for long-wavelength radars; therefore, the second target would be visible to the pilot. On the other hand, if an excessively long wavelength is chosen to overcome attenuation, there may be insufficient backscatter from water drops to enable detection. Obviously, then, for each condition there is an ideal weather radar wavelength band which yields the best weather detection capability.

The use of wavelengths at the lower (long wavelength) end of the band permits the design of a weather radar with maximum weather penetration for seeking out turbulent storm cells located behind deep intervening light precipitation. At the upper end of the wavelength band, weather penetration is limited by higher signal attenuation, but can detect even mild storm systems.

The two basic weather flying categories are weather avoidance and weather penetration. From the preceding description of the weather-penetrating capabilities of radar systems operating at various wavelengths, it can be concluded that the shorter-wavelength (2-cm, K_u-band) radars are better able to cope with the weather-avoidance condition because of greater sensitivity to light weather. It can also be concluded that the long-wavelength equipment (5.5-cm, C-band) are best suited for weather-penetration flying. However, the lesser weather-penetrative capability of X-band (3.2-cm) radars has been found adequate for navigation through generally encountered storm areas and are being used by many airline and general-aviation operators. X-band radars have found this wide acceptance because of the smaller size and lower power requirements than C-band systems.

WEATHER RADAR INSTALLATION

Because of the marked effect on range and performance, the installation of the waveguide and radome probably requires the greatest attention. In the location of the receiver-transmitter, particular attention must be given to the reduction of vibration and temperature extremes, while maintaining a minimum of waveguide length. The location of the indicator is generally established as being on the instrument panel, preferably within view of both control positions. In some instances, increased panel stiffness is required to reduce vibration.

Waveguide

Straight, well-matched X-band waveguide introduces approximately 3 dB of attenuation for each 100 feet of length. The attenuation is greater for higher radar frequencies. Further, when the transmission line becomes longer than 10 feet at X-band, greater care must be taken to provide well-matched loads to prevent long-line-effect losses. This effect amplifies the reflected signals down the transmission line and can cause rapid magnetron frequency shift. In addition, sharp bends must be avoided because they can introduce additional attenuation and standing waves.

Radome and Antenna

Transmission and reception signal losses (attenuation) for most radomes vary between 10 and 30%, resulting in range degradation of between 2 and 8%. To provide the best performance for horizontal scanning antennas, the radome shape should be hemispherical to minimize antenna boresight degradation. However, aerodynamics and aesthetics usually preclude the hemispherical shape. As a result, variations in radome refractions are encountered, deteriorate the antenna pattern and cause increased sidelobe radiation. For best performance, the radome should be of material of the lowest possible uniform dielectric constant at a thickness to minimize reflective losses. The principal radome problem is that sturdy dielectric materials inevitably possess high dielectric constants. The cost difference between a poor and a good radome is insignificant when compared with the advantages gained in radar performance.

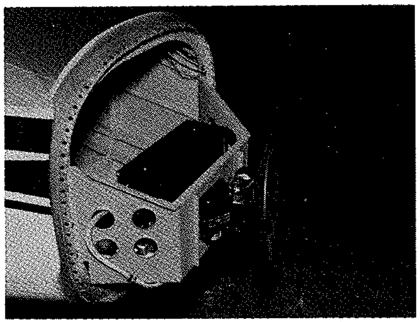
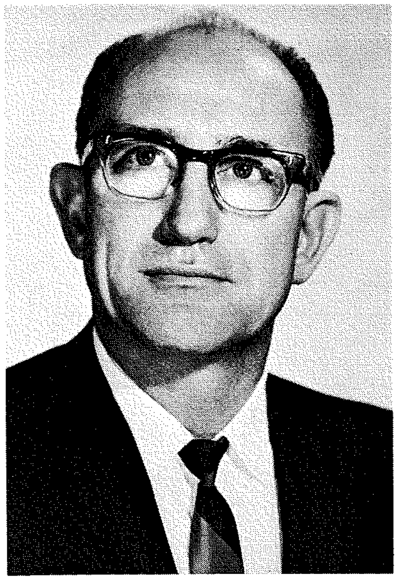


Fig. 9—Typical receiver-transmitter installation.



GEORGE A. LUCCHI received the BSEE from the University of California at Berkeley and completed graduate studies at the University of California at Los Angeles. Since joining RCA in 1955, he has been responsible for the design of the AVQ-60 and AVQ-65 ATC Transponders, the AVQ-70 DME, and the AVQ-45/46 Airborne Weather Radar. The holder of four patents on aviation electronic equipment, he has made significant contributions to other commercial and military products at RCA. Before joining RCA, Mr. Lucchi was with the CAA (now FAA) for eight years. A registered professional electrical engineer in the State of California, he holds both amateur and commercial radiotelegraph and radiotelephone licenses. He is a member of Eta Kappa Nu.

Receiver/transmitter location

The best location for the receiver-transmitter portion of the radar is close to the antenna to permit the use of a short, low-attenuation transmission line. However, other factors which are often overlooked creep into this choice. The most important is the effect of temperature and vibration on reliability.

Extensive reliability studies conducted on military electronic equipments have shown that the mean time between failure (MTBF) decreases rapidly when temperature extremes are endured for long periods of time. As shown in Figs. 7 and 8, the MTBF of simple passive components diminishes rapidly when the components are subjected to elevated temperatures, even though they are operated well within design limits. For this reason it is important that when a locational choice exists, the equipment be placed where environmental extremes are avoided. Fig. 9 shows a typical installation.

The Videocomp Systems Approach to Electronic Composition

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This paper describes the RCA 70/9300 Videocomp electronic composition system. The system has been delivered, installed, and placed into commercial operation during 1967 for more than five customers. This paper also emphasizes the Videocomp systems approach of providing integrated hardware/software electronic composition systems, rather than an assembly of equipments and software packages.

A PHOTOCOMPOSITION SYSTEM may be defined as a system that composes printed pages on photographic film or paper based on edited manuscripts which have been entered into a typesetting computer by keyboard. In typical first-generation photocomposition systems (Fig. 1), several operators keyboard manuscript data and elementary typographic instructions for *column* generation onto paper tape. Paper tape is read into a low-cost computer which automatically justifies, hyphenates, and composes a column, punching an output paper tape. The output paper tape is then read into a photocomposer (e.g., Photon 713 or Linofilm) which generates the composed column of text on typesetting film or paper. The text is proofread and corrections are punched on paper tape by reference to line number. A tape-merging unit is used to combine the original paper tape with corrections to obtain an updated paper tape. The cycle is then repeated. When a satisfactory column has been composed, it is pasted up to form a page for use in printing-plate generation. This type of photocomposition system has a low overall throughput speed and requires numerous manual operations. However, its original equipment cost is considerably lower than comparable line-casting systems.

THE RCA ELECTRONIC COMPOSITION SYSTEM

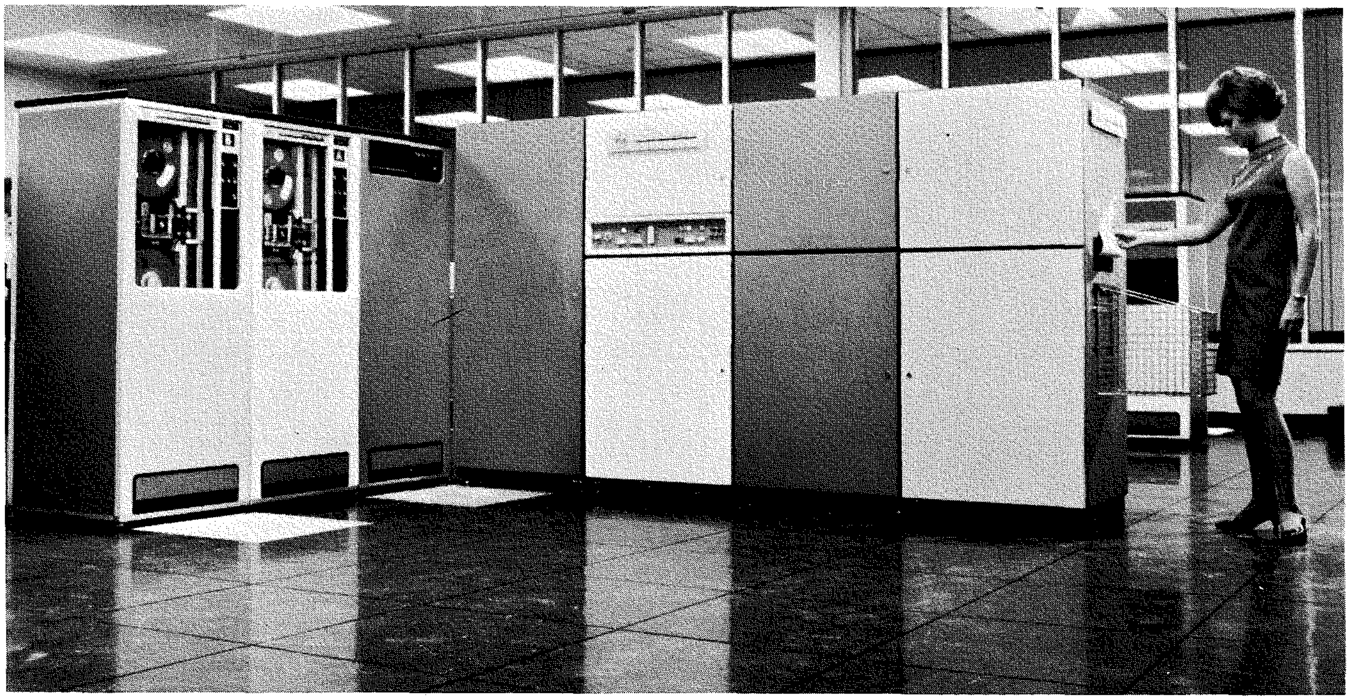
Videocomp is the generic name that RCA has given to its electronic composition systems and equipments that employ high-speed CRT (or equivalent) photocomposing techniques. These systems and equipments are capable of greater speed and flexibility than first-generation optical-mechanical photocomposers. The 70/822 Videocomp is the output subsystem which performs the actual photocomposition in response to magnetic tape data and control input. The 70/9300 Videocomp Electronic Composition System is an integrated system which includes the 70/822 Videocomp and executes the complete composition process from manuscript to final photocomposed page.

Approach

To fully exploit the electronic-composition capability, the functions performed in a typical photocomposition system (listed in Table I) were examined at RCA with the following objectives:

1) Reducing routine manual operations;

Reprint RE-14-1-21/Final manuscript received March 13, 1968.



2) Increasing overall throughput speed; and
3) Decreasing significantly the ratio of price to performance.

In addition, RCA was mindful of two questions often asked by prospective users of the RCA equipment:

> "Given a marked-up manuscript of a book chapter or newspaper article, how do we assemble the necessary equipment, computer programs, and operating personnel to convert a high volume of marked-up manuscripts and corrections into final photocomposed pages which are ready for plate making?" "How do we perform basic composition functions at high speed and efficiency?"

The ten typical composition functions listed in Table I, and the 70/9300 Videocomp electronic composition system that implements them, provide the answers to these questions. The 70/9300 Videocomp system (Fig. 2) consists of four major hardware-software subsystems

1) Keyboard input,
2) Composition data processing (hardware),
3) Composition data processing (software), and
4) Videocomp output.

Composition Process

Manuscripts are marked using typographic control codes which define both elemental and macro-typographic functions. The 70/9300 composition language has been developed for this purpose. This language permits the book designer to communicate with the computer using a minimum of control codes and keystrokes while permitting a wide variety of complex typographic formats. The marked-up manuscript is keyboarded, and paper tape is perforated by a number of operators. The torn paper tape is read into paper-tape readers. The Spectra 70 composition data processing subsystem acquires and stores the manuscript, performs composition language analysis and typographic composition, and generates proofs at high speed through the output subsystem (70/822 Videocomp). Proofs contain line-reference numbers in the margin, so that corrections can be entered on a line basis and merged with the previously-stored manuscript. When no further corrections are required, a final high-quality print is generated which is suitable for plate preparation.

TABLE I—Basic Composition Functions

1) Keyboarding text and control codes;
2) Acquiring and storing manuscripts;
3) Performing typographic language analysis and page composition;
4) Generating column and page proofs;
5) Proofreading;
6) Keyboarding proof corrections;
7) Merging corrections and updating manuscripts;
8) Repeating the proof-generating and correction cycle;
9) Generating final photocopy in page format at high speed; and
10) Maintaining supervisory control and recording necessary production and other statistics.

Videocomp vs. other systems

The Videocomp composition system differs from typical first-generation photocomposition systems now in use in five essential ways:

1) New hardware and software has been synthesized on an integrated, general-purpose-systems basis. Prior photocomposition systems have evolved as an assortment of equipments provided by different manufacturers.
2) A complete composition language has been developed which significantly reduces the designer's and keyboard-operator's labor. First-generation systems are restricted to primitive composition commands for use by a skilled

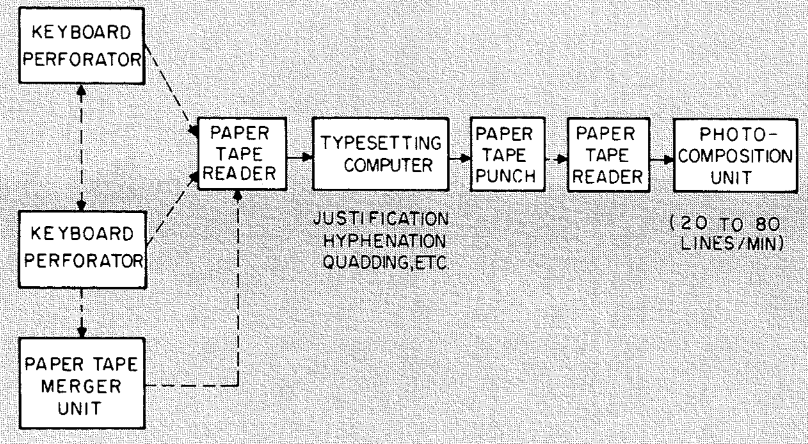


Fig. 1—Typical first generation photocomposition system.

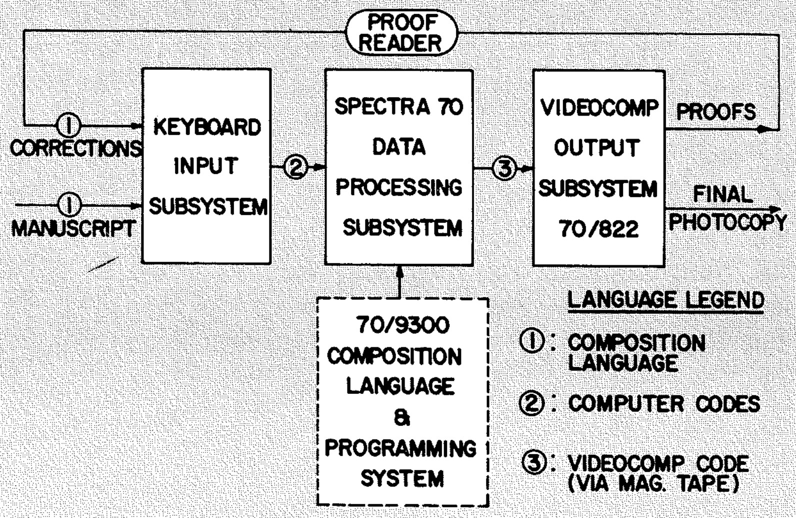


Fig. 2—The 70/9300 Videocomp electronic composition system.

operator in column (rather than page) composition.

3) Manuscripts in process are stored *digitally on magnetic tape or disc* and are automatically updated by keyboarded corrections. In first-generation systems, manuscripts are stored as individual items or "takes" on paper tape and are merged off-line with a paper-tape merger unit. A complete manuscript in page format is assembled and stored only in the form of "pasted-up" pages or final photocomposed film.
4) Complete, multi-column *pages* with varied typographic formats, are photocomposed, thereby reducing "paste-up" operations. Present photocomposition systems generate single columns which are assembled manually into pages.
5) A high-speed electronic photocomposition equipment, the 70/822 Videocomp, is driven by magnetic tape and generates both proofs (column and page) and final photocopy. Prior systems use relatively low-speed equipment driven by paper tape. Proofs are frequently produced with computer-type line printers.

KEYBOARD INPUT SUBSYSTEM

This subsystem is the same as used in present-day first-generation photocomposition systems. Substantial improvements in this area may be expected as this subsystem becomes a limiting factor in the improvement of the cost-to-performance ratio.

COMPOSITION DATA PROCESSING SUBSYSTEM

This subsystem is a conventional third-generation data processing system (Fig. 3). The processor is a Spectra 70/35 with a 65 k byte memory. Text input is through the 70/221 or 70/224 paper-tape readers which operate at 200 or 1000 characters/second, respectively. Magnetic tape is provided for manuscript files. A disc is provided as the input data-acquisition buffer and for the storage of the Videocomp font library.

OUTPUT SYSTEM

The 70/822 Videocomp is an electronic CRT photocomposition equipment which operates from magnetic-tape input. It generates characters line-by-line on the face of the cathode ray tube (CRT). The CRT is imaged upon phototypesetting film or paper which is transported past the CRT face. The major performance parameters of the 70/822 Videocomp are summarized in Table II. A simplified block diagram is shown in Fig. 4; Fig. 5 is a photo of the unit. Basically, the 70/822 Videocomp consists of three major elements: a magnetic tape unit, a digital-control unit, and a photocopy unit.

Digital-Control Unit

The digital-control unit reads data from the magnetic tape, first loading font data into the self-contained magnetic-core memory. The memory is divided into two sections—addressed by primary and secondary addresses. When text generation starts, the individual character codes from magnetic tape are used as primary addresses to interrogate the first area of the memory. The information obtained by the primary address is the secondary address or, in other words, the location of the actual character-writing information for control of the cathode ray tube. This scheme of primary and secondary address is used to obtain the most efficient use of the memory space. Since each of the characters may require a different number of memory locations, it permits packing of characters adjacent to each other, regardless of the number or sequence of characters in the font.

TABLE II—Major Performance Parameters of the 70/822 Videocomp

Input	Magnetic Tape
Speed	4 to 12 point up to 650 char/sec 8 to 24 point up to 325 char/sec
Line Length	Up to 32 pica
High-speed typeface access (approx)	325 char in 8 sizes with a 32 k byte memory; or 650 char in 8 sizes with a 65 k byte memory.
Output	Stabilization paper (typsetting film or paper 2.75) in 4- or 6-inch widths.
Mixing	Complete flexibility; all sizes and typefaces on one line.

Within the photocopy unit, character generation data is brought out of the font memory and is used to control the position and intensity of the CRT beam. Characters are generated by closely-spaced vertical strokes with resolutions up to 900 strokes/inch. After each character is completed, spacing information is read out of the font memory to form the inter-letter spacing. Then, the writing of the next character begins. The characters are generated one at a time across the face of the CRT and imaged through the lens onto the photographic material in the camera assembly. At the completion of each line, the photomaterial is advanced by a command from the magnetic tape, and the beam is restored to the beginning point for the next line.

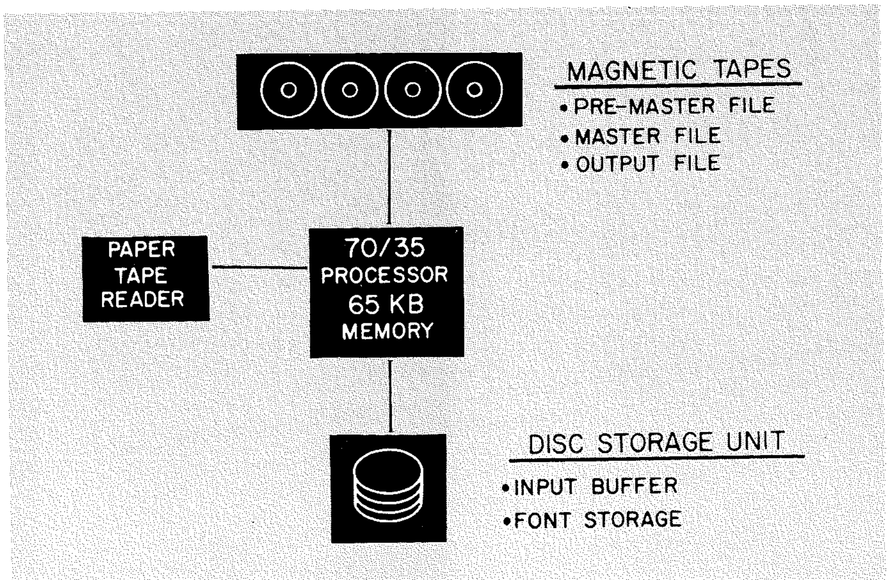


Fig. 3—Spectra 70 composition data processing subsystem.

Photocopy Unit

The photocopy unit accommodates stabilization paper, which is phototypesetting film or paper in roll or sheet form. An on-line stabilization-paper processor is provided in each Videocomp photocopy unit to provide immediate proof output.

Technical Concepts

The basic technical concepts embodied in the 70/822 Videocomp are:

1) *Off-line character dissection*—Characters are dissected off-line and converted into digitally coded representations of the vertical strokes and other parameters comprising the character. Fonts are stored digitally in computer magnetic tape or disc and in Videocomp high-speed memory. These fonts are obtained by off-line scanning and digitizing under a precise system of quality control.
   Once approved by the Art Director and Typeface Committee, a typeface is released into the master library as a set of digital information. Since no physical analog of the font characters are used in the equipment, time, dust, dirt and the environment can have no degrading effect on the character shape and appearance.
2) *Digital font storage*—Digital storage of fonts provides twin advantages of flexibility and steadily decreasing costs

as the computer industry continues its search for higher speed memories at lower costs.

3) *CRT character generation by vertical stroking*—Electronic *X*-motion under precise control of horizontal CRT deflection is used to position characters along a line. The CRT beam is maintained within a narrow, vertical aperture, so as to minimize effects of CRT geometric distortion. *Y*-motion or leading (spacing) is obtained by mechanical motion (transport) of the film or paper.

4) *Electronic magnification over limited size range*—To minimize the digital memory required for font storage, electronic magnification is used over a 2:1 size range. A single stored font is used for 8-point sizes within a size range. In addition, extended, condensed, or slanted versions of a typeface can be readily produced.

THE COMPOSITION LANGUAGE

The goal of the 70/9300 programming system is to produce complete pages with properly apportioned text and spaces for the insertion of graphics. It has been demonstrated in the past that a computer program could be written to generate a page of a *specific* format. When the desired page format changes, the computer program is changed. This can be costly and slow, depending upon the complexity of changes from one type of page to another. To achieve the goal of the 70/9300 programming system, the RCA 70/9300 composition language was developed. This language is a problem-oriented computer language based on the work of Dr. Michael P. Barnett at the RCA Laboratories. It is used to instruct the computer how to position text characters for electronic composition. The user of the 70/9300 composition language writes statements which described the desired format of the finished copy. A program in the computer translates these statements into codes which are then executed, generating the output format. The results of this process are retained in the computer memory until enough text has been internally composed. Then, the Videocomp output subsystem is directed to produce either paper proofs or film, ready for plate making. The input to the computer composition system is the manuscript to be set (data) and the 70/9300 composition language format statements which tell the computer how to set the text.

The approach used in this language is to permit varied page formats by providing a means of describing a page as the sum of its parts; e.g. heads, body text, secondary text, footnotes, run-arounds. Each of these parts is specified by a series of format statements in the 70/9300 composition language. The computer *builds* a page from a collection of typographical parts. Any part of the page may be changed independently to create an entirely new page.

The classical problem of automatic pagination is the determination of the layout of a page, based on the contents of that page. Since the page breaks are unknown when preparing manuscripts, the composition language permits the user to state rules for all alternative composition requirements. The computer selects the proper alternative format, in conjunction with its own results at that point in composition. For example, if a run-around is called for after a figure reference, the statements that specify the run-around automatically check the space remaining on the page, and determine whether the run-around should be included on that page or its facing page.

The RCA 70/9300 composition language contains the following elements which are listed and described below:

1) Control words
2) Control word qualifiers or parameters
    a) Absolute magnitude
    b) General variable
3) Control strings
4) Format statements
5) Job Specification

The user of any language should be aware of the vocabulary (words) grammatical rules for punctuation (e.g. using commas, semicolons, colons, and periods), and rules of constructing sentences (strings of words) for that language. These three topics are also included as they apply to the 70/9300 composition language.

Control Words

The vocabulary of the composition language is much smaller than that of a natural language. There are a number of control words in the composition language, so named because each one has a unique and positive meaning which causes the computer to execute a particular function. For example, the words "new line" will cause the computer to terminate setting in the current line and begin setting in the next line without justifying the current line. New line is

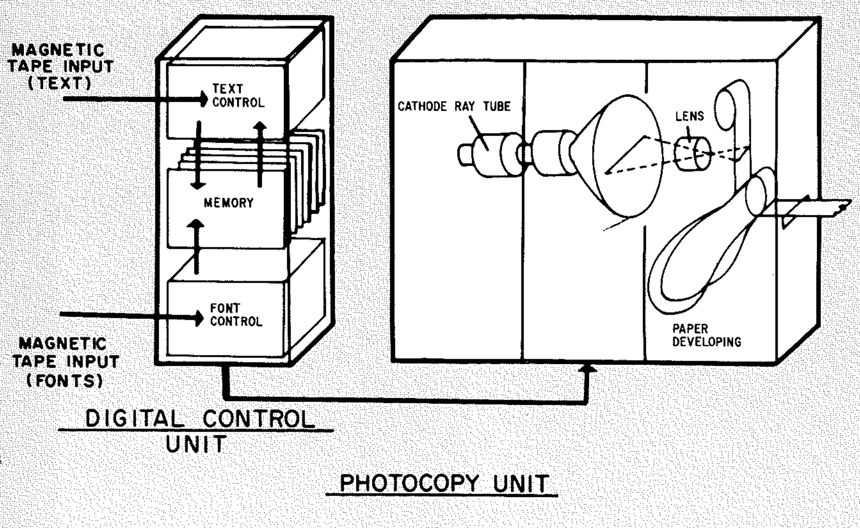


Fig. 4—70/822 Videocomp output subsystem.

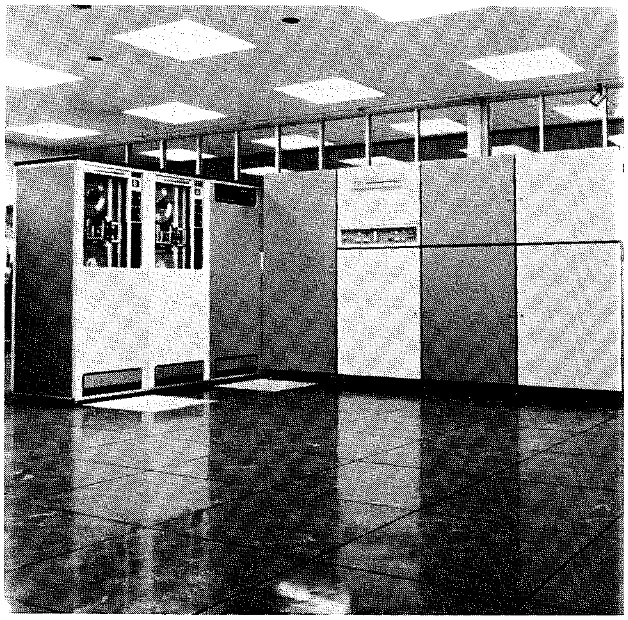


Fig. 5—70/822 Videocomp output system.

spelled *nl* in the composition language. All words in the language are spelled by a unique combination of two letters. A few examples are listed below:

Page number	*pn*
Paragraph	*pr*
Point size	*ps*
Typeface	*tf*
Tab set	*ts*

Qualifiers or Parameters

Many control words require a qualifier, or a *parameter*, to completely define their function. For example, the control word *ps* specifies point size for the text. However, until the exact point size is stated, the computer does not have sufficient information to perform its function. Therefore, a user may write *ps, 10.* The computer then can set type in 10 point until further instructed. The number *10* is the parameter of the control word *ps;* it may vary each time the control word is used. In this case, the parameter is simply a number or constant. For reasons that are explained later, the user may wish to write a control word, but may not wish to specify the value of the parameter at the moment. To do this, a variable (rather than a constant) is used as the parameter.

A variable in the composition language is the name of a location in the computer where the parameter is stored. There are 200 variables available at any one time: *gv 1* through *gv 200.* As an example, to use a variable rather than a constant to specify point size, the user writes *ps, gv 5.* In order to make the general variable number five *(gv 5)* equal to the proper point size (e.g. 10 point) the user also writes *gv 5, 10.* When the computer executes the control word *ps,* it notices that the parameter is a variable, seeks the specified value in location *gv5,* and sets the text in 10 point. The advantage in the use of variables is the elimination of re-keyboarding of instructions which are repetitive.

Punctuation

The first rule of punctuation in this language states that a *control word is always separated from its parameter or variable by a comma.* If a control word has more than one parameter, each is separated by commas. The second rule of punctuation states that a *control word and its parameter(s) are separated from the text to be set by delimiters.* Since the control word is spelled with letters from the same alphabet as used for text, the delimiters indicate which characters are data and which are control words to the translation program in the computer. The bracket symbol is generally used as a delimiter.

Control Strings

An arbitrary number of control words may be strung together. For example, [*ps, 10*] [*bl, 12*] [*tf, 6*]. To reduce keystrokes, the composition language has made a semicolor equivalent to a double delimiter. Thus, the above string could be written as [*ps, 10; bl, 12; tf 6*]. This example represents the method for building strings of words (sentences) in the composition language. Unlike most other languages, it is possible to build meaningful strings of words which are independent of their order. For example, the user obtains the same results whether he writes [*ps, 10; bl, 12*] or [*bl, 12; ps, 10*]. A similar example in the English language would either produce nonsense, or a legitimate sentence with a different meaning. In the composition language it can be said that *generally the string of instructions (control words, parameters, and delimiters) is legitimate if each indi-*

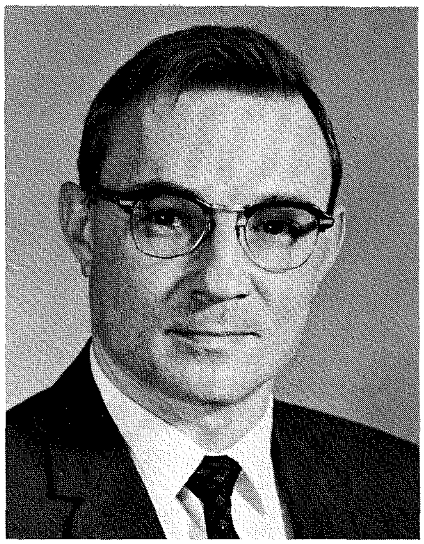
AARON H. COLEMAN received the BSEE in 1939 from the City College of New York and was awarded a MSEE from the Polytechnic Institute of Brooklyn in 1949. From 1939 to 1953 he was engaged in the research and development of early warning radar and integrated air defense systems at the U.S. Army Electronic Laboratories in Ft. Monmouth, N. J. From 1954 to 1960 he held engineering and project management positions with various computer manufacturers in the design and development of military and commercial digital computer systems. Since joining RCA in 1960, Mr. Coleman has been engaged in computer engineering, management, and data communications systems engineering. He transfered to the Graphic Systems Division in 1965 where he assumed responsibilities for the Product and Programming Planning activities. Mr. Coleman is a member of the IEEE, AOA, TAGA professional societies.

ROBERT F. DAY received the BSEE from Fournier Institute of Technology in 1952. From 1952 to 1954, he was a development engineer at Bendix Radio Corporation, engaged in the development of precision CRT displays and controls for a ground-controlled approach radar system. From 1954 to 1956, he served at Picatinny Arsenal. Mr. Day joined RCA in 1956 and until mid-1965 he held various engineering and supervisory positions with responsibilities in the development of military digital computers and control systems. In early 1965, he joined the group which formed the Graphic Systems Division, where, as administrator of Product Planning, he has been responsible for the systems planning and specifications of new products.

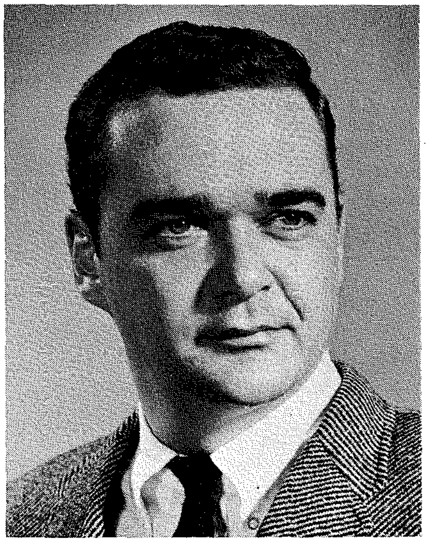
DONALD G. GERLICH received the BS in General Science from St. Peter's College in 1960. After serving two years in the Army Transportation Research and Engineering Group, Mr. Gerlich worked for the Volt Technical Corporation until 1963 where he was engaged in automating the generation of parts catalogs. From 1963 to 1965 he was active in the Bell Telephone Laboratories doing programming design for on-line computer graphic terminals. Joining the RCA Graphic Systems Division in 1966, Mr. Gerlich was assigned to the task of designing and analyzing computerized typesetting for newspapers. His present position as administrator of Programming Planning gives him the added responsibility for programming planning systems.

A. H. Coleman

R. F. Day



D. G. Gerlich



vidual control code is legitimate. There are exceptions where certain codes must follow in a sequence. Each string has a specific meaning which results in a unique typographical event, such as a line of certain type set on a certain measure or a space of certain dimensions located on a printed page. For this reason, sentences which are written in the composition language are called formats.

Formats

Many formats are repetitive, that is, they are used with different sets of copy. In that case, the user enters the format into the computer only once, and thereafter refers to it each time it applies. Rather than keyboard it every time he wishes to "say the same thing," the composition language provides the facility of referring to a format by a "defined name" which consists of one letter followed by one digit, such as *C8*. Using the 26 letters of the alphabet and 9 digits, there are 234 unique names available for formats.

To use this technique for a repetitive format, a mark-up man may follow a three-step procedure:

1) Define the output format desired by writing a string of control words—[*ps, gv 1; bl, gv 2; tf, gv 3*];
2) Assign a *name* to this string—*F2;* and
3) Instruct the computer to store the format and its name—[*F2*] = [*ps, gv 1; bl, gv 2; tf, gv 3*].

The format is stored by the system using a non-composition or system-update program. It is available for use with any composition job. To use this format a mark-up man or copy editor simply writes the name [*F2*] delimited by brackets, at each point in the copy that he wishes the equivalent string of copies to be executed. This format would be available without re-keyboarding for every job that is composed on the computer.

Job specification

Each job may require different parameter values. For this reason the use of variables is required in the format statement. The mark-up man specifies the value of each variable by writing a *job specification.* This is a list of general variables and synonyms and their corresponding value entered into the computer at the first "take" of a job. A synonym is a format used exclusively by a single job and is entered with the job itself during composition input. A synonym may also be a string of repetitive text, such as a chapter title to be used as a running head.

THE 70/9300 PROGRAMMING SYSTEM

As shown in Fig. 6, the 70/9300 programming system which exercises the composition language is divided into two cycles that are overlapped in time: system input and composition.

System Input

Data prepared on paper tape is read and stored in a random-access buffer. This data may represent a number of independent composition jobs, such as titles or stories. Each item, or take, is identified by a job number and a sequence number. As the data is buffered, the program maintains a directory of all inputs by identification number. This allows data preparation and system input to be scheduled independently of the composition-processing cycle.

Composition

The second and main cycle, composition, is divided into three phases. The cycle is initiated when the operator enters the identification of the next job to be composed. The phase-1 program then selects all the inputs for that job from the input buffer and places them in order of sequence number. It merges alterations by line with the existing master file for that job. It then performs language analysis, that is, the format names are replaced by their equivalent strings of control codes. The results of the phase-1 program are stored in an intermediate file, called the preliminary master file.

The phase-2 program is automatically initiated at the conclusion of phase 1. This program executes each composition language control that appears in the data and justifies each line through word-spacing and hyphenation techniques. The result of phase 2 is an updated master file which is automatically passed on to phase 3 and also saved for subsequent processing of that job.

At this time the master file is in the order that data was inserted. This may not correspond to the required order of the final page. The phase-3 program reads the master file and sorts the lines to correspond to the required Videocomp output. That is, heads, footnotes, multi-column text, etc. are properly apportioned. Vertical justification is performed by the phase-3 program. Finally, all composition controls are translated into Videocomp machine code. The results are stored on the magnetic tape output file. The output file contains character codes, machine commands, and digital font data, in a form suitable to drive the Videocomp and produce pages on either photographic paper or film.

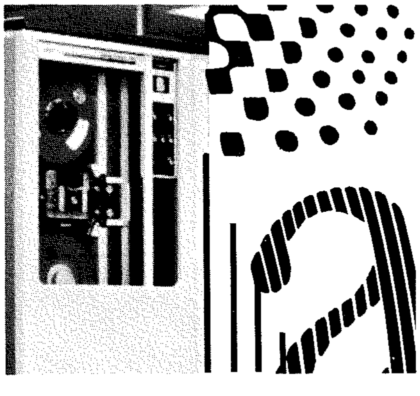
FUTURE DEVELOPMENTS

It seems reasonable to assume that future electronic composition systems, such as the 70/9300 Videocomp electronic composition system will move in two major directions: lower overall system cost and increased performance capability and versatility. Lower system costs probably will be achieved by more thorough-going system synthesis of the major subsystems of an electronic composition system and by the advent of substantially lower-cost, higher-speed, random-access memory systems. The latter, of course, is a goal which is being pursued by the entire computer industry. Recognition of this was a major influence in the RCA decision to employ digital font-file storage. Increased performance capability and versatility may be expected to result in increased printed-line widths—up to newspaper-broadsheet. The efficient, low-cost photocomposition of full pages, complete with alphanumeric text and graphics, may be anticipated as a major competitive element in the second or third generation of high-speed electronic photocomposition equipments.

Simultaneous with the photocomposition hardware developments will be parallel developments in composition programming systems and languages for use in the high-speed processing of many printed products from newspaper, magazines, and books to manuals, parts lists, directories and varied commercial printing products. Improved methods of entering text and control data into a computer system are inevitable as a direct by-product of similar activity in the entire computer industry.

CONCLUSIONS

By describing our first electronic composition products and systems, and predicting some future directions in this field, we have presented a picture of RCA Graphic System Division concepts and results in the field of electronic composition. We have emphasized the importance of the fruitful marriage between the graphic arts and associated technologies on one hand and the electronic computer, communications, and CRT display technologies on the other.



Measurement of the RCA Basic Time Sharing System Performance

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Time Sharing Project
Information Systems Division, Cherry Hill, N. J.

This article describes the test procedures used and the test results obtained in attempting to measure the performance of the RCA BTSS (Basic Time Sharing System). For the purposes of this article, BTSS provides the following functional capabilities to a user at a remote terminal: 1) compile and debug a FORTRAN program, 2) execute a FORTRAN program, and 3) create and edit data files.

THE ORGANIZATION of the key elements of BTSS is shown in Fig. 1. The processor subsystem consists of the 70/45 Processor, a number of 70/564 Disc Storage Units, and a Communications Front End. The processor subsystem is connected to remote Model 33 or 35 Teletypes and RCA 70/752 Video Data Terminals through the dial telephone network. Within the processor subsystem, a time sharing software system, developed by N. Gordon's group of the Laboratories controls the system operation.

A user may request data processing which would require processor-time-to-complete ranging from a few milliseconds to many minutes. One of the system design objectives is to complete user tasks requiring a "short" amount of processor time as quickly as possible. Since all users who are currently active must share the processor time, preferential service is given to users with "short" tasks which in turn lengthens the time to complete "long tasks."

SCHEDULING ALGORITHM

Fig. 2 is a simplified illustration of the scheduling algorithm used in the system. To illustrate the operation, assume the time slice is set for ½ second and that the first task in the system has just been received from a terminal. The task is listed in the bottom of the Immediate Queue and given control of the processor. Assume that 100 milliseconds later, the task requires a page from random access. (It is assumed that program portions and data are transferred between main memory and random access storage devices in integer multiples of a page.) Processor control is taken from the task after this first execution period. In blocks 1 and 2 it is determined that neither the task nor the first time slice have been completed. The task is again listed at the bottom of the Immediate Queue. Since there is only one task in the system, the processor idles until the page is in main memory. Processor control is then again given to the task. Assume the task uses the remaining 400 milliseconds of the first time slice in the second execution period and is still not completed. Processor control is taken from the task and the task is listed at the bottom of the production queue. Since this is the only task in the system it will receive successive execution periods until completed.

SYSTEM OPERATION

Fig. 3 is a simplified illustration of system timing under three different conditions of operation. In the entire figure, the time slice is assumed to be set to ½ second. In Fig. 3a, a single user is active. Assume at time 0, point *A*, the user enters his first task which is compute bound (i.e. requires no data transfers to peripheral equipments) and requires ½ second of processor time to complete. The task is entered on the immediate queue and completed at *B*. In this case, the response time is the ½

Definitions

The terms **task**, **execution period**, **time slice**, **elapsed-time-to-complete**, **response time**, and **Page** have the following meanings in this paper:

Task is any user's job within the processor which requires additional processor time to complete.

Execution period is a single continuous time during which a task has control of the processor. This period includes all the system's overhead, the user program execution time and any idle time incurred while the task has control of the processor.

Time slice is the maximum amount of processor time any task may use before processor control is taken from the task. A time slice may be made up of one or more execution periods.

Elapsed-time-to-complete is the elapsed time between entering the last character of a task at a terminal and receiving at the terminal the first character of the final processor output at completion of that task.

Response Time is a short-hand notation for elapsed-time-to-complete when less than one time slice is needed to complete the task. Response time is a system performance criteria for tasks requiring less than one time slice. Response time, as herein defined, is not meaningful for multi-time-slice tasks.

Page is a fixed number of characters.

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MURRAY SPENCER received the BS in Applied Mathematics, Computer Sciences Option, from Clemson University in 1965. There he was a member of Phi Kappa Phi. He has taken graduate courses at Stevens Institute of Technology in Mathematics and programming. He has worked with small and large digital computers programming applications and as a systems programmer since 1962 at Clemson University, Bell Telephone Laboratories, and, since 1967, at RCA. He is now an EDP Product Planner, and is responsible for the technical aspect of running the RCA Corporate Time Sharing System.

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second period from *A* to *B*. Approximately 1½ seconds later, the second task is entered at *C*. The second task requires a page from the disc after 100 milliseconds of execution time. Therefore, at the end of execution period 1 the processor remains idle until *D*, when the page has been read into memory and the second execution period starts. The same procedure is repeated for execution periods 3 and 4. The task is completed at *G* and the response time in this case is the 0.7 second period between *C* and *G*. It should be noted that a total 0.4 seconds of processor time was used in the 4 execution periods, therefore, this task was completed on the immediate queue.

Fig. 3b illustrates a situation where a single user is active; his task is compute bound and requires three seconds of processor time to complete. The task starts at *A*; ½ second later after completion of the first execution period, the task is placed on the production queue. Since it is the only task in the system, it receives five successive ½-second execution periods completing the task at *B*. The elapsed time to complete for this task is the 3-second period between *A* and *B*.

Figure 3c illustrates the operation when three users are simultaneously active. User 1 enters three tasks, each of his tasks requires less than ½ second of processor time to complete, therefore, each task is completed on the immediate queue. Users 2 and 3 have long compute bound tasks in the system. Assume that at time zero, user 1 enters his first task which requires ½ second of processor time to complete. Further, assume that he gains control of the processor at point *A*. One half second later, at *B*, the task is completed and the second execution period of user 2 is started. At *C*, user 1 enters his second task, immediately after user 3's fourth execution period starts. At *D*, when user 3 completes his fourth execution period, user 1 who is on the immediate queue gains control of the processor completing his second task at *E*. User 1 had to wait from *C* to *D*, one time-slice period, before starting his task. In this simple model, the response time for a single user on the immediate queue may be expected to vary between the actual time required to finish his job and that time plus one time slice. At *E*, user 2's third execution period starts. At *F*, user 1 enters task 3 which is the same task he had entered between *C* and *G* in Fig. 3a. This time the task has to wait until time *G* to start executing. After 100 milliseconds, the task requires another page, and therefore, user 3 is given control of the processor to execute his fifth period. At *H*, user 1 again is given control of the processor he executes for 100 milliseconds, and he again loses control of the processor while the next page he requires is read from random access. The procedure continues through execution periods 3 and 4, the task being completed at *K*, 2.2 seconds after it was entered on the immediate queue at *F*. Assume for a moment that after time *K*, users 2 and 3 are the only users in the system and further, that each has a compute bound job active. These two users would share the processor time equally and each would require twice as much time to complete their tasks as when each is the only user in the system.

The ratio of *elapsed-time-to-complete a task in the actual environment being considered/elapsed-time-to-complete when this is the only task in the system* is defined as the Elapsed Time Multiplication Factor (ETMF). Theoretically, if all users had compute bound jobs, the ETMF would be equal to the number of simultaneously active users. Thus, if there were 8 users simultaneously active, each with a compute-bound job, the ETMF would be 8. Where the jobs are I/O bound (e.g. Fig. 3c task 3 of user 1) the relationship is not so simple. In this case, the time required was 0.7 seconds when the user was alone in the system, (task 2 of Fig. 3a) and 2.2 seconds (task 3 Fig. 3c) when the users were simultaneously active. In this case, the elapsed time multiplication factor is 2.2/0.7 = 3.1.

SYSTEM PERFORMANCE MEASUREMENTS

To check how well this simplified concept of the BTSS operation agreed with actual performance, a series of tests were run, the results of the first one are illustrated in Fig. 4.

A special program was devised by the Laboratories which would use exactly 50.5 seconds of processor time and then print out the reading of the elapsed time clock. Thus, the elapsed-time-to-complete a task could be determined by subtracting two successive time print outs. Timing tests were run with only one, two, three, four and eight such programs simultaneously active. The straight line on Fig. 4 is drawn through the computed average elapsed-time-to-complete for each test. The result is a straight line agreeing with the theoretically expected results. The average efficiency of the system can also be determined from the slope of the line. The slope of the line is approximately 102 seconds/task. Since the program per task required 50.5 seconds, the efficiency is 50/102 = approximately 50%.

Another performance characteristic in a time sharing system is the variation in response time as the number of users entering tasks requiring less than one time slice increases. Theoretically, if the time slice is ½ second, the system could handle two inputs/second, maximum. However, if each input only required 100 milliseconds to complete, the system could handle 10 inputs/second, maximum. If queuing is considered, the 10 inputs/second would be in the order

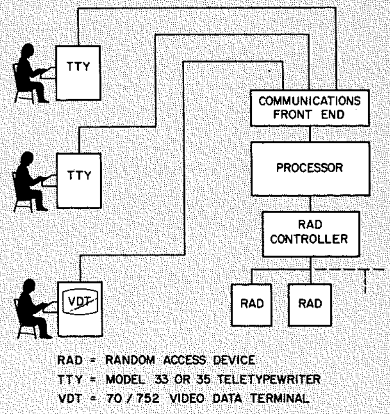


Fig. 1—Time sharing system configuration.

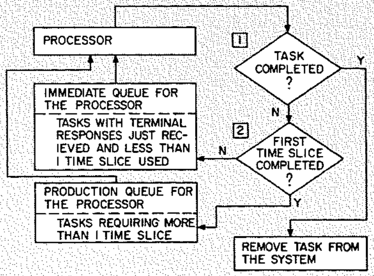


Fig. 2—Two-queue scheduling algorithm.

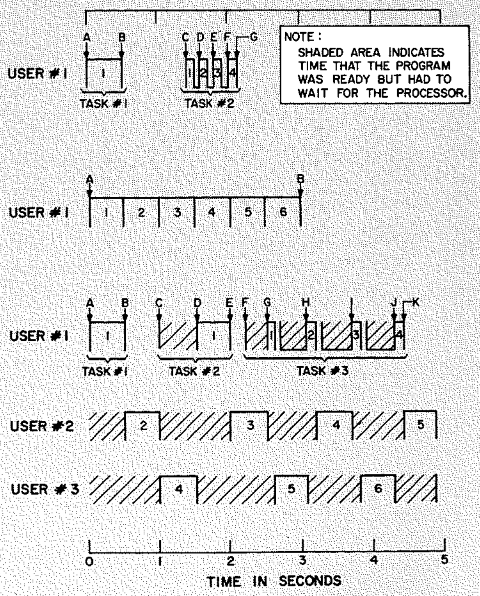


Fig. 3—Simplified system operation.

of 9. A test was set up in which a number of punched paper tapes were prepared, each having a repeated simple edit command requiring less than 100 milliseconds to complete. With such a series of tasks, the response time should remain fairly constant up to 8 or 9 inputs/second. Fig. 5 illustrates the results with up to approximately 3½ inputs/second. These were obtained with 7 terminals simultaneously active, each reading a simple edit command as quickly as it could from a punched paper tape. The one second response time is a minimum system response time and it will be noted that the response time remains constant, as expected, throughout test. Again, the measured performance follows the expected trend.

The usual way to test the performance of a time sharing system is in normal operation. Therefore, with the system in normal operation (many other terminals putting tasks into the system), a 206 record file was generated. The test task was for the Text Editor program to change successively a single character in each of a preset number of records.

This is a representative editing task. The elapsed time to complete the task was measured with a stop watch. Fig. 6 illustrates the results of editing 10, 50, 100, and 206 records during a 1 hour period of normal corporate time sharing operation on December 19, 1967. The elapsed time to complete the editing of 206 records varied from 4.1 seconds to 29 seconds—a variation of more than 7 to 1. With the range of variation shown, one would be hard pressed to derive any very meaningful system performance data—except, perhaps, that something is wrong.

ETMF IN PERFORMANCE MEASUREMENTS

There does seem to be a way of making sense out of the data using results obtained from tests under controlled conditions. Fig. 7 illustrates results obtained using the same edit program tasks when the number of compute-bound users was changed under controlled conditions. There were no other terminals using the system during this test. In light of later results, at least 5 readings should have been taken at each point to check repeatability.

Assuming the data in Fig. 7 correct, curves based on this data were drawn in Fig. 8 which terminate in the numbers 0, 1, 2, 3, 4, and 5 enclosed in squares. The other data for Fig. 8 was gathered in the following manner: the same edit programs tasks used to obtain Fig. 7 were run during a normal day (December 19, 1967 as described above in connection with Fig. 6) while BTSS was running for Corporate Time Sharing users who are running tasks of unknown and varying amounts of execution and I/O. During the running of the edit program tasks, the test program used to obtain the data in Fig. 4 was run from another terminal. The elapsed time required for each edit task was recorded with the elapsed-time-to-complete readings obtained from the compute-bound

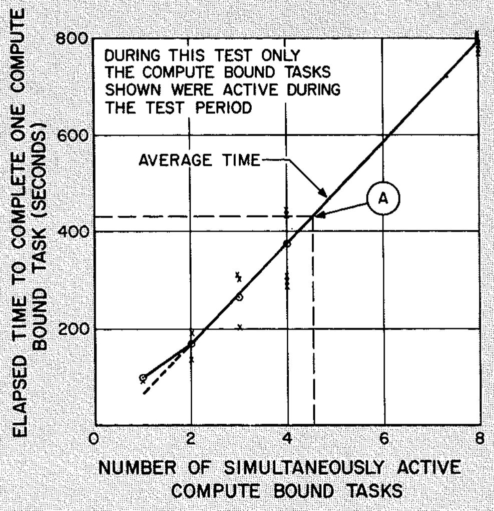


Fig. 4—Measured performance.

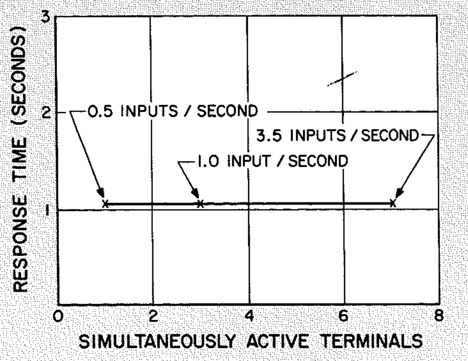


Fig. 5—Response time characteristic for short tasks.

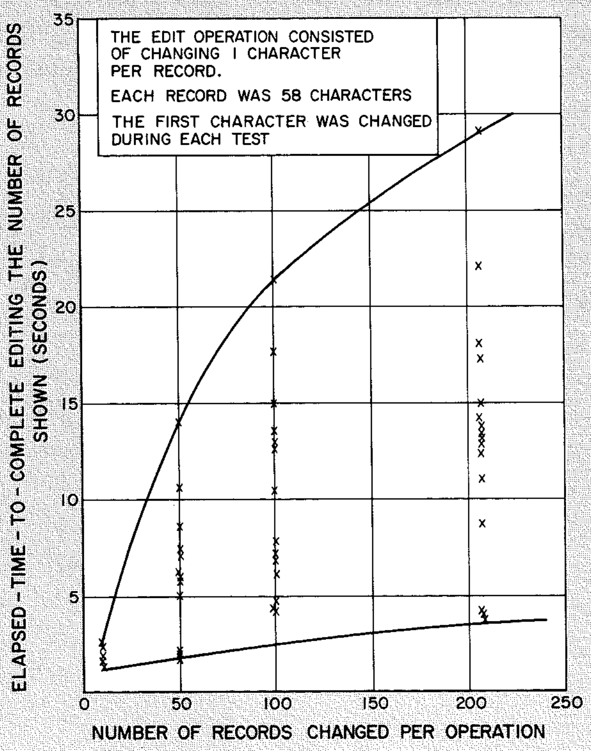


Fig. 6—Elapsed-time-to-complete data measured when the system was operating.

program. The points plotted in Fig. 8 are the edit program task times. Using the measured elapsed-time-to-complete of the compute-bound program together with Fig. 4, the average Elapsed Time Multiplication Factor was determined. This data is shown within the circles on Fig. 8.

The upper heavy line, was taken with a measured ETMF between 4 and 5. There were between 12 and 14 users simultaneously active (obtained from normal operator console statistics printout. The ETMF of 4.3 at point *A* is the result of a measured 430 seconds elapsed-time-to-complete the compute-bound program. The 430 seconds on Fig. 4, point *A*, yields an ETMF of 4.3. The approximately 25 second elapsed-time-to-complete data point *A* falls only a short distance from where compute-bound user curve *No. 4* predicts it should be. The circled 1.5 ETMF, point *B*, on the lower heavy curve was calculated using the test program. This falls between the 1 and 2 curves, as it should. It should be remembered that any of the 14 users starting or stopping a FORTRAN execution usually adds or subtracts one entry on the production queue. The square enclosed points, enclosed by line *C*, were obtained with no test program active. From the results, one could conclude that on the average between 0 and 2 tasks were on the production queue during this series of tests.

At 206 records edited per task of the edit program test, the elapsed-time-to-complete may vary from 4 to 33 seconds, depending upon how many compute-bound users are active at the time of the test. The cluster of triangular points was taken with the calculated compute-bound users varying between 2.2 and 2.6. These cluster quite well around the 1 to 3 simultaneous user curves. The actual ETMF during a test may be quite different from the average obtained with the ETMF measuring program. For example, at point *B*, the edit test was completed in 8 seconds. The measured ETMF was averaged over 150 seconds. (At an ETMF of 1.5, the elapsed-time-to-complete the ETMF test program is 150 seconds.) During this 150 seconds, the number of active compute-bound programs when 12 to 14 users are active may easily vary between 0 and 2 making it difficult to obtain an accurate ETMF during the 8-second edit test period. Using the results of Fig. 4 and 7 and running a control program during the edit timing test, the apparently senseless data of Fig. 6 starts to make some sense.

SUMMARY

A most important goal of this article is to indicate the difficulty of measuring the performance of even a relatively simple time sharing system. With sufficient insight into system operation and controlled test data, some of the test results obtained from a terminal during a live operation are explainable. Without insight and controlled test data, it is highly improbable that more than boundary-type measured performance is obtainable under live conditions.

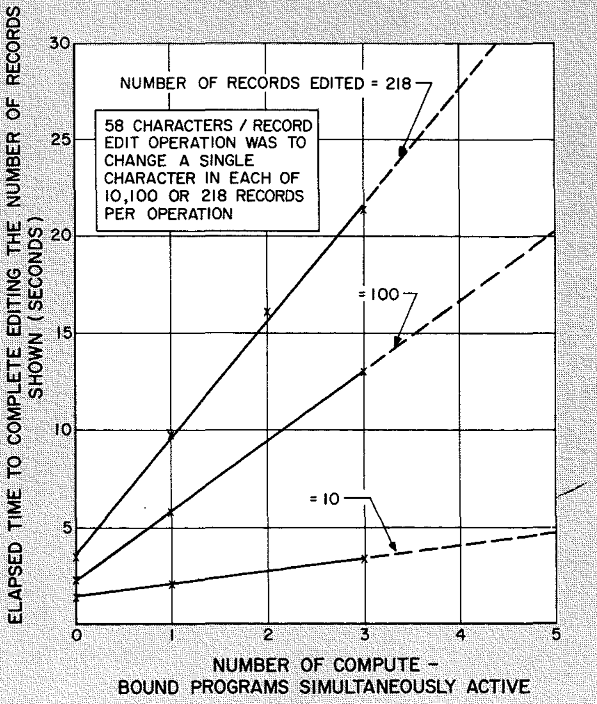


Fig. 7—Editing time as a function of compute-bound users active.

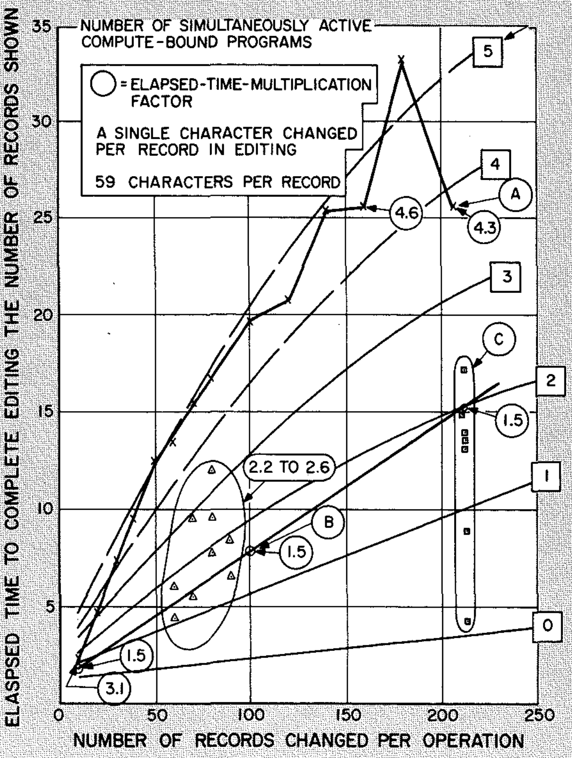
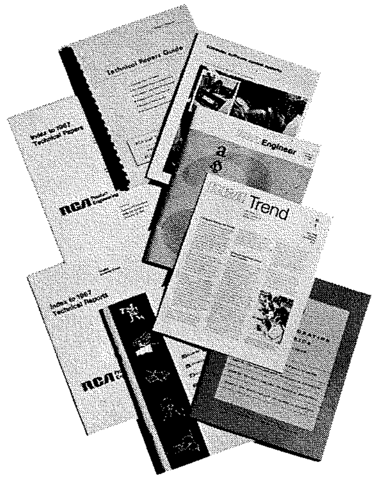


Fig. 8—Elapsed time to complete measurements with a "live" system.



Technical Publications—an RCA Product Engineering Staff Function

J. C. PHILLIPS, Administrator
Technical Publications
Product Engineering, Camden, N. J.

This paper describes the activities of Product Engineering Technical Publications—a service group for engineers and scientists throughout the corporation. This group publishes and distributes the RCA Engineer; publishes and distributes TREND; administers the technical papers program; and administers the technical reports program.

Technical Publications is dedicated to enhancing the professional stature of the RCA Technical Staff in the engineering community and to improving communications between engineers and scientists within RCA. This group works closely with the Technical Publications Administrators (TPAs) and Editorial Representatives (Ed Reps) in the various divisions and major operating units. These individuals (listed inside the back cover of every issue of the RCA Engineer) answer most inquiries regarding the services described in this paper; however, direct inquiries, suggestions, and ideas are always welcome.

RESPONSIBILITIES

The manager of Technical Publications, W. O. Hadlock, serves as Editor of the RCA Engineer, chairman of the Trend editorial board, and administers corporate policy relating to technical papers and reports. Reporting to Bill Hadlock, Mike Geverd and John Phillips have specific responsibilities in each of these areas: Mr. Geverd is the Editor of Trend and is responsible for expanding the use of RCA technical papers in outside publications; Mr. Phillips is the Assistant Editor of the RCA Engineer and is responsible for maintaining the RCA Engineer reprint service and for the publication and distribution of the *Annual Technical Reports Index* and the *Technical Papers Index.* Regardless of specific responsibility, any member of Technical Publications—including the two secretaries, Mary Daly and Judy Hare—will gladly help resolve any problems or questions pertaining to technical publications.

THE RCA ENGINEER

. . . enters its fourteenth year of publication with this issue. Established in 1955 as a journal "by and for the RCA engineer," its objectives (page one of every issue) have not changed since that first issue.[1,2] The Editors work closely with the Consulting Editors, Advisory Board, Editorial Representatives, and Technical Publications Administrators to ensure that the journal continues to be a useful and timely mode of communications for the entire engineering community within RCA. In addition, the Editors regularly solicit the opinions of the entire readership to determine how well the journal is meeting its objectives.[3]

Technical Publications staff; left to right are Mike Geverd, John Phillips, and Bill Hadlock.

From idea to article

The majority of articles are suggested through the Ed Reps and TPAs who, being close to the "engineering heartbeat," can most effectively reflect both current, important engineering work and reader interests. In other cases, the Editorial Staff, the Editorial Advisory Board, and the Consulting Editors may individually or collectively conceive article ideas and contact appropriate authors or Ed Reps.

Selection of articles

The page space available is limited by a strict budget, yet a basic objective is to represent as many engineering authors and associated activities as possible. With this in mind, selection of articles is based on the 1) wide interest value of the story, 2) importance of the work described, 3) timeliness of the story, and 4) quality of presentation.

REPRINTS OF RCA ENGINEER ARTICLES

A complete file of page negatives of the RCA Engineer is maintained to allow quick, economical reprinting. Many such reprints have been made for marketing, training, recruiting, and other purposes since the inception of the RCA Engineer.[4] During 1967, about sixty individual reprints were produced; of this quantity, forty were reprints of single articles; the remaining twenty were brochures containing collections of several articles with a special cover to suit the needs and desires of the division. Typical quantities are 100 to 500 copies for single-article reprints and 1000 to 5000 for brochure-type reprints. This total reprint activity embraces about 90% of all the technical articles published in the RCA Engineer. A working file of all reprints is maintained in the RCA Engineer office. Information sheets and in-

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Reprint RE-14-1-22/Final manuscript received June 10, 1968.

dexes of reprints are issued on a regular basis.

Complimentary Reprints

A new service was started with the Vol. 13, No. 6 issue of the RCA Engineer. A small quantity of complimentary reprints of each article is now being provided for the authors at the completion of each issue. The TPA for the author's division distributes copies to the author, local division files, and Editorial Representatives.

TREND

. . . The Research and Engineering News Digest is published monthly and distributed to more than 13,000 RCA managers, engineers, and scientists. Its major objectives are to keep readers abreast of the various activities within RCA and to make engineers and scientists aware that they are part of a dynamic, growing organization. To accomplish these goals, Trend contains timely news capsules on technological advances throughout the Corporation, changes in Corporate policy, contract awards and new business, business outlooks, and professional awards and activities.

TECHNICAL PAPERS

Annually the RCA corporate-wide review and approval system involves about 1300 actions that clear through the Technical Publications group. These consist of requests for the approval of presentations, publications, books, theses, technical notes and abstracts. This activity is carried out in conjunction with the TPA's of the various major operating units, and Technical Publications serves as liaison among TPAs when problems or questions arise.[6] This group periodically reviews, updates, and reissues Policy Instruction 10211 covering oral presentations and papers for publication.

Pen and Podium Indexes

On a regular basis, the Ed Reps (in cooperation with the TPAs) submit records of papers published and presented; these are categorized, indexed by subject and author, and published in the *pen and podium* column of the RCA Engineer.

Annual Index to Technical Papers

For the past four years indexes to RCA technical papers have been distributed to all recipients of the RCA Engineer. These indexes list over 1100 technical papers arranged in 85 convenient technical subject categories.

RCA Technical Papers Guide

This 100-page manual, published in 1962, provides answers regarding policy on papers, RCA journals, outside publications, and general technical writing. To supplement this service, individual writing aids produced in the divisions are distributed and shared corporate-wide as appropriate.

Placement of Papers

Technical Publications acts as a focal point for information exchange throughout the corporation; this group is in a unique position to work with the TPAs to encourage the writing of articles by engineers for publication in journals both inside and outside the corporation.[5]

TECHNICAL PROFESSIONAL SOCIETIES

Technical Publications acts as a clearing house for information on 20 to 30 key professional technical societies. Program information is redistributed to the TPAs who may have an interest in their divisions. A section in the RCA Engineer is devoted to *dates and deadlines* for papers for upcoming *meetings*. The information carries the name of the society, date of the meeting and also includes a separate list for *calls for papers*.

TECHNICAL REPORTS

Technical Publications serves as liaison with the report coordinators of the various divisions (in most cases these are the TPAs). Reports are written within the various engineering groups and distributed by their publication activities in accordance with divisional procedures usually administered by the TPAs. Such procedures are based on the RCA Policy Instruction which is administered by Technical Publications.[7]

Minimum Standard Distribution List (MSDL)

Product Engineering Technical Publications issues a "Minimum Standard Distribution List" to all TR and EM coordinators on a quarterly basis. This list includes key managers who receive copies of TR and EM title pages informing them of the availability of the report; also included on this list are the RCA technical libraries that receive complete copies of all TRs and EMs.

Technical Reports Guide

The *Technical Reports Guide* issued in 1962 is still being actively used by the various managers and report coordinators to assist them in the establishment of style, arrangement and format and will be updated as needed.

Index to RCA Technical Reports

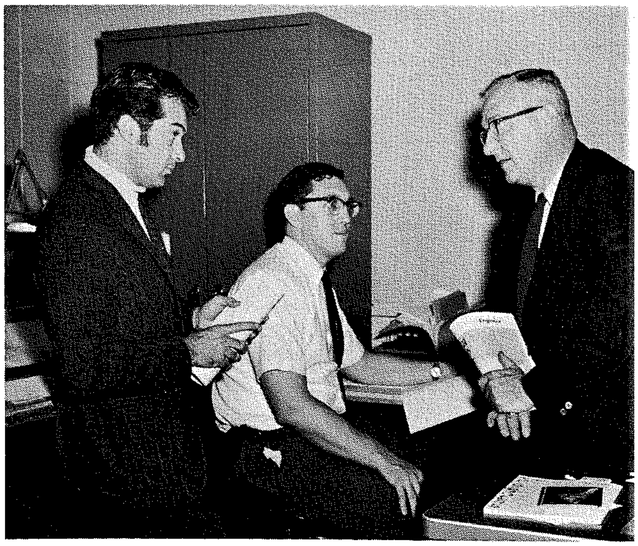
In early 1968, the third in a series of technical reports indexes (TR-6003) was issued and distributed. Reference copies of this report are available at all RCA technical libraries. This 52-page *company private* index lists over 1100 technical reports in approximately 85 major subject categories. The documents indexed include corporate TRs and EMs, Princeton PTRs and PEMs, Montreal Lab. reports, RCA-generated government contract reports and miscellaneous division level technical reports (where information was available).

CONCLUSION

The technical information outputs of RCA's engineering and research represent one of the company's most valuable assets. Thus, Technical Publications is interested in encouraging the effective publication, dissemination, and utilization of RCA's combined technical knowledge. RCA strongly encourages engineers to document information of value. Several manifestations of this encouragement are described in this paper. Technical Publications, through the TPAs and Ed Reps, will make every effort to help you publish your work—internally, externally or both.

REFERENCES

1. Hadlock, W. O., "The *RCA Engineer*—Its First Year," *RCA Engineer*, Vol. 2, No. 1 (Jun-Jul, 1956) pp 32-36.
2. Jennings, E. R., "The *RCA Engineer*—Its Management, Policies, and Operation," *RCA Engineer*, Vol. 6, No. 1 (Jun-Jul, 1960) pp. 36, 37.
3. Farbro, P. C., "Third *RCA Engineer* Readership Survey," this issue of the *RCA Engineer*, pp. 48, 49.
4. "Reprints of *RCA Engineer* Articles," *RCA Engineer*, Vol. 13, No. 5 (Feb.-Mar., 1968) p. 88.
5. Geverd, E. M., "The Engineer-Author and RCA," *RCA Engineer*, Vol. 13, No. 6 (Apr.-May, 1968) pp. 68, 69.
6. Hadlock, W. O., "RCA Technical Papers and Their Approval," *RCA Engineer*, Vol. 11, No. 1, (Jun-Jul, 1965) pp. 2-5.
7. Hadlock, W. O., "Technical Reports and Engineering Memoranda," *RCA Engineer*, Vol. 8, No. 6 (Apr.-May, 1963) pp. 2-5.



The cover art and layout of the *RCA Engineer* are under the direction of V. M. (Bart) Bartholomew. In the photo (left to right) Tony D'Alessandro, Ed Burke, and Bart Bartholomew discuss the layout of one of the articles.

Polymer-Film Belts for Power Transmission

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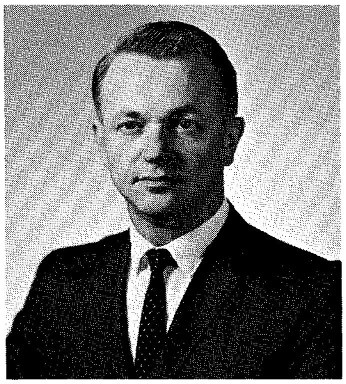
Polymer-film seamless belts can be fabricated to show remarkably stable characteristics for uniform, precise power transmission in the range below 3 horsepower. The detailed manufacturing process described was evolved with the goal of developing an optimum performance belt. This process evolved from a series of parametric tests programmed to determine the effects of initial raw material, dimension, processing technique, and final heat treatment. Methods of maintaining quality control are given. The results of static and dynamic creep, relaxation, and fatigue tests are discussed, showing the relative advantages of two polymers. Belt torque, friction, and pulley relationships are analyzed, and recommended design guides are established to facilitate the design of a typical drive system.



WALTER PAROBY received the BS from Lehigh University in 1948, and has taken graduate courses in Applied Mechanics at Stevens Institute of Technology and Columbia University. He is a specialist in stress and vibration analysis in the field of mechanical design engineering. From 1948 to 1953, Mr. Paroby worked on the design and analysis of reciprocating and turbojet aircraft engines at the Wright Aeronautical Corporation. From 1953 to 1957 he worked on auxiliary power units, compressors, and lubrication and pressurization systems at Walter Kidde and Company. In 1957, Mr. Paroby joined Reaction Motors as a senior engineer, engaged in the design of rocket engines, valves, and an internal combustion catapult powerplant. At the Astro-Electronics Division of RCA which he joined in 1959, he worked in the mechanical systems integration group on the mechanical and structural design considerations of astronautical components for space applications, and assisted in the preparation of technical proposals. Mr. Paroby is a member of the American Rocket Society.

THIN, POLYMER-FILM, SEAMLESS BELTS can be designed and fabricated to provide stable, efficient power transmission in belt and pulley systems used in precision electromechanical assemblies such as spacecraft tape recorders. A typical application is shown in Fig. 1. Large speed ratios, which would require several stages of fine-pitch instrument gears, are practical in a single-stage belt-driven pulley system. Drive systems using extremely small pulley diameters or high belt velocities (or both) are theoretically feasible, with efficiency losses being limited mainly by the bearing friction.

The belt materials tested are polymers known as "Mylar, Type A" and "Kapton," or H-Film, (both products of E. I. duPont de Nemours Company). For simplicity, they will hereafter be called Mylar and Kapton. Both polymers have tensile strengths and surface-hardness characteristics generally unattainable with conventional belt materials. They are essentially unaffected by the swing to temperature extremes and by the vacuum environment normally encountered in aerospace equipment. In the film-thickness range concerned (½ to 3 mils) the extremely small variation of the belt cross-sectional area and the homogeneous material make the use of tension idlers unnecessary. The thermal-expansion characteristics of the materials are close to those of aluminum and magnesium (the metals generally used for the drive-assembly housing). Thermal differential effects are small and so related that the belt tightens only slightly with increased temperatures and loosens slightly with decreased temperatures. Test results reveal that, in general, Kapton is superior to Mylar.

CHEMICAL AND PHYSICAL PROPERTIES

Mylar Type A is a polyester-film polymer formed by the condensation reaction between ethylene glycol and terephthalic acid. The molecular structure is shown in Fig. 2a. Kapton is a polyimide film formed by the condensation reaction between pyromellitic dianhydride and an aromatic diamine as shown in Fig. 2b. The physical properties of the two raw materials are quite similar, as may be seen from the listing in Table I. Kapton, however, maintains its satisfactory physical, electrical, and mechanical properties over a temperature range of −269° to 400°C, compared to −60° to 150°C for Mylar. Mylar is dull white and Kapton is light amber; both are transparent in thicknesses up to 3 mils.

After processing (as belts) both materials exhibit slight increases in ultimate tensile strength and 5 percent elongation strength over the values for unprocessed material. These changes are attributed to the polymer crystal reorientation that occurs during the stretching and heat-treating operations.

BELT FABRICATION

Seamless belts are formed from washers cut out of a sheet of the polymer and stretched until the inner radius becomes equal to the outer radius. The complete process involves four steps: 1) cutting the washer, 2) shaping the belt, 3) trimming the belt to proper width, and 4)

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Fig. 1—Spacecraft tape recorder.

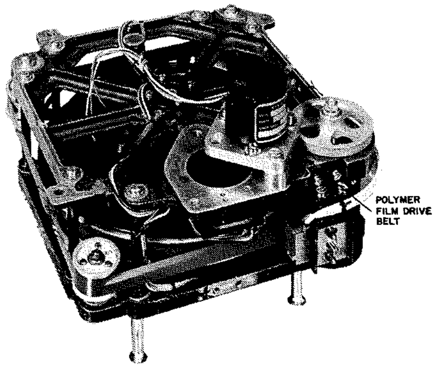
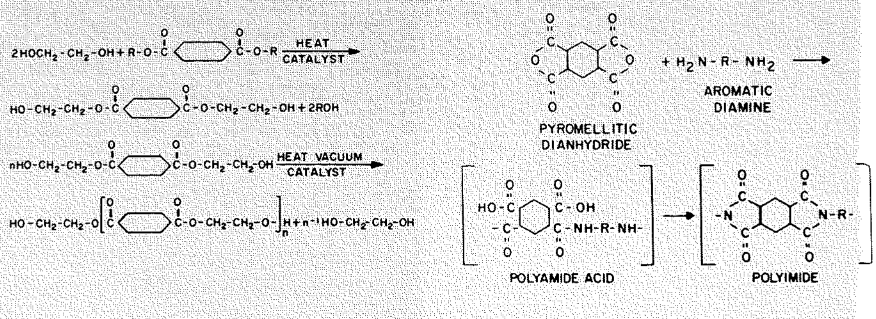


Fig. 2—Polymer film materials.



a. Polyethylene Terephthalate (Polyester).

b. Polypyromellitimide (Polyimide).

heat-treating the belt for stability. The Appendix contains specific details of physical characteristics of the belts.

The belt fabrication equipment is shown in Fig. 3. A film sheet of thickness equal to the final belt thickness is selected. A washer is cut with the outer diameter equal to 95 percent of the nominal belt diameter and the inner diameter such that a belt 20 percent wider than the final dimension will be formed. (Subsequently, the belt edges are trimmed to the designed width.) These dimensions result in stretching of the entire belt during shaping, and minimize the differential thickness in the trapezoidal cross-section inherent in the shaping geometry.

Shaping is performed on a set of rollers driven from a conventional lathe. The driven roller is a hollow cylinder; the idler spindle is a cylinder with a conical tip. The mechanism of shaping is shown in Fig. 4. The roller is driven at a speed between 1200 and 1500 r/min; a heating rod is inserted in the roller to raise its experimentally determined temperature (to 150°C for Mylar, 200°C for Kapton). The washer is placed over the roller and spindle tip, and these are moved apart so that the washer travels up the tapered spindle at the rate of one inch per minute, until the shaped belt is the desired size. A five-minute run-in at the high temperature and forming speed stabilizes the material at its new shape. The heater then is removed, allowing the belt to cool while rotating. The belt next is transferred to a drum where it is trimmed to the design width with a sharp blade.

For final heat treatment, the belt is mounted on the outer diameter of a tight-fitting aluminum disc (wider than the belt), which is placed on a hot-plate and heated to a temperature of 150°C (for Mylar) or 250°C (for Kapton). The disc diameter is chosen to provide the belt length required as well as to assure a positive radial pressure on the belt during the heat-treating process. After five minutes at the elevated temperature, the belt is allowed to cool on the disc to room temperature. The belt has been thermally stretched and restabilized, while cooling on the expanding disc, to its design configuration.

QUALITY CONTROL

Quality control is maintained by a polarized-light inspection and an operational test on each belt. Both Mylar and Kapton are birefringent materials and exhibit stress-strain patterns under polarized light. A properly processed belt shows nearly uniform fringe-pattern bands circumferentially, the fringe variation across the width being due to the difference in circumferential elongation of the original washer inner and outer diameters. Representative fringe patterns are shown in Fig. 5a and 5b. Improperly stretched portions result in patterns of which Fig. 5c is typical. A point of little or no stretch (a soft spot) shows up as a lack of fringe pattern, such as shown in Fig. 5c and 5d. Points of improper stretch generally show up diametrically opposite, and observations are usually made 90 degrees apart. The discovery of soft spots is cause for belt rejection.

The operational (or dynamic acceptance) test further ensures nearly equal circumferential strength. This test consists of running the belt in an acceptance-test rig for one hour at a speed equal to that of the actual application. To minimize the belt creep in actual equipment application, the initial tensile load during the acceptance test is made approximately 10% greater than that used in operational applications. However, the test driver and follower pulley diameters are equal to those for operational applications. An increase in belt length of 0.1 percent or more at the end of the test period is considered evidence of instability and such belts are rejected. After the test, the belt is cleaned with acetone and its new length is measured. Any limited material regressive or memory effect after the acceptance test would have a tightening rather than a loosening effect on the belt in final equipment installation. In normal operation, this is desirable within acceptable stress limits.

TEST EVALUATION

Post Heat-Treat Cooling

Air cooling and water quenching methods of cooling Mylar belts were investigated (Table II). Air-cooled belts were found to be more stable with respect to creep-rate. (0.072%) compared to 0.0262%) as shown in Fig. 6. There was no significant difference in tensile strength between the two cooling methods.

A statistical analysis of the test data established a 95% probability. The air-cooling method is now used in the post heat-treat cooling process for both Kapton and Mylar.

Static Creep

The increase in belt length under static loading (called "static creep") was measured after Mylar and Kapton belt runs of 21 and 19 days, respectively. From the collected data, shown in the zoned region of Fig. 7, it can be seen that both Mylar and Kapton exhibit stable creep characteristics at load levels normally recommended for initial belt tension. The data is indicative of the dimensional stability of both materials under static load conditions. Static creep of less than 0.14% is indicated in Fig. 7.

TABLE I—Typical Physical and Thermal Properties of Thin Polymer-Film Belts

(Measurements taken at room temperature)	Basic Raw Material[1]		Belt Processed Per Mfg. Proced.[2]	
	Mylar	Kapton	Mylar	Kapton
Ultimate Tensile Strength (psi)	25,000	25,000	25,000	26,000
5% Elongation Stress (psi)	15,000	13,000	16,000	13,000
Ultimate Elongation (%)	120	70	75	30
Modulus of Elasticity (psi)	550,000	430,000	420,000	310,000
Density (g/cc)	1.4	1.42	—	—
Coefficient of Friction (Kinetic-Film-to-Film)	0.45	0.42	—	—
Melting Point (°C)	250	Does not melt	—	—
Coefficient of Thermal Expansion (in./in./°C)	17x10^{-6}	20x10^{-6}	—	—
Coefficient of Thermal Conductivity (cal/cm^2/cm/sec./°C)	3.7x10^{-4}	3.7x10^{-4}	—	—

[1] Data Source: E. I. duPont de Nemours Company (Bulletins H-2 and M-2D)

[2] Data Source: Astro-Electronics Division of RCA (Manufacturing procedure No. 1, Rev. A)

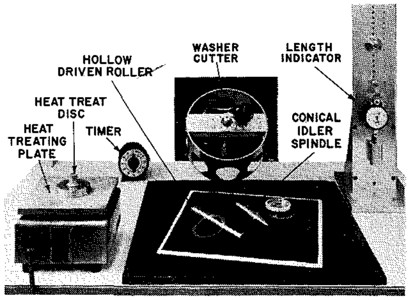


Fig. 3—Belt fabrication equipment.

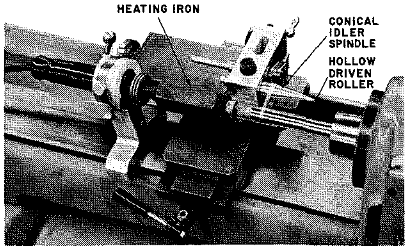


Fig. 4—Belt fabrication process.

TABLE II—Results of Air-Cooling and Water-Quenching Mylar Belts after Heat Treatment

Cooling Process	*Yield Load*	*Yield Stress*	*Elongation at Yield*	*Ultimate Load*	*Ultimate Stress*
Water-Quench	3.3 lbs	16,320 psi	6%	4.7 lbs	23,250 psi
Air-Cool	3.3 lbs	16,100 psi	5%	5.35 lbs	26,200 psi

Belt Relaxation

Mylar and Kapton belts were dynamically tested on a fixed-center, pulley-drive system for the equivalent of two years (38.999 × 10^6 cycles) of operating life of a spacecraft recorder to determine changes in belt tension. The Mylar test simulated actual spacecraft tape-recorder-installation load conditions. The resultant data is plotted in Fig. 8. For the Mylar belt, there is a gradual increase in tension between approximately 2.5 × 10^6 cycles and 5.5 × 10^6 cycles. After 18 × 10^6 cycles, the tension returned to a value near the original setting. At no time did the belt experience a decrease or relaxation in initial tension. The test demonstrated the stable load-retention capabilities of a polymer-film belt.

The Kapton belt was subjected to a more severe cyclical-bending stress. It also displayed relatively stable relaxation characteristics up to 27 × 10^6 cycles, where loss of load occurred due to excessive relaxation. Belt-fatigue failure occurred at 39.8 × 10^6 cycles. The test data of Fig. 9 indicates that a Mylar belt similarly loaded would fail at approximately 4.5 × 10^6 cycles.

Bending-Stress Fatigue

Heat-treated Mylar and Kapton belts were run at various bending-stress levels to compare their performance. From the data plotted in Fig. 9, it is evident that Kapton exhibits superior cyclic bending fatigue characteristics in comparison to Mylar. This is attributable to the more-flexible (lower modulus of elasticity) and higher-strength properties of the Kapton material in contrast to Mylar. Leveling off for the endurance limit occurs at approximately 5000 psi for both materials, which is the maximum recommended stress for heat-treated belts

ACKNOWLEDGMENT

The writer is grateful for the cooperation of the Materials and Manufacturing Departments of the Astro-Electronics Division, the E. I. duPont de Nemours Co., and Photolastic, Inc., of Malvern, Pa. in the preparation of this article.

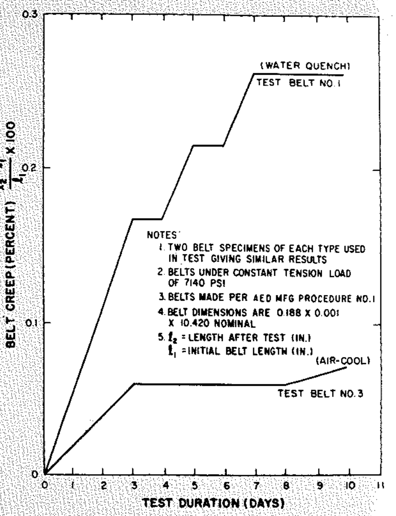


Fig. 6—Post-heat-treat cooling effect on mylar belt average static creep rate.

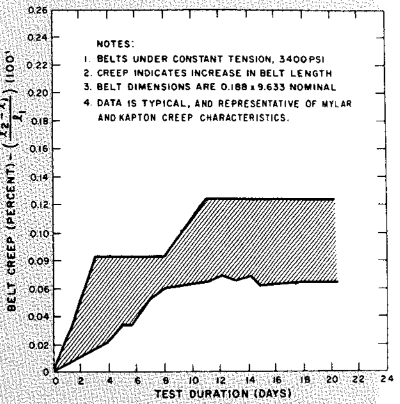


Fig. 7—Mylar and Kapton representative static creep rates.

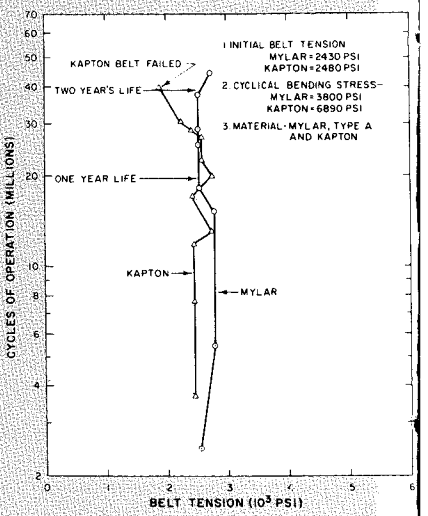


Fig. 8—Mylar Kapton belts; accelerated life test.

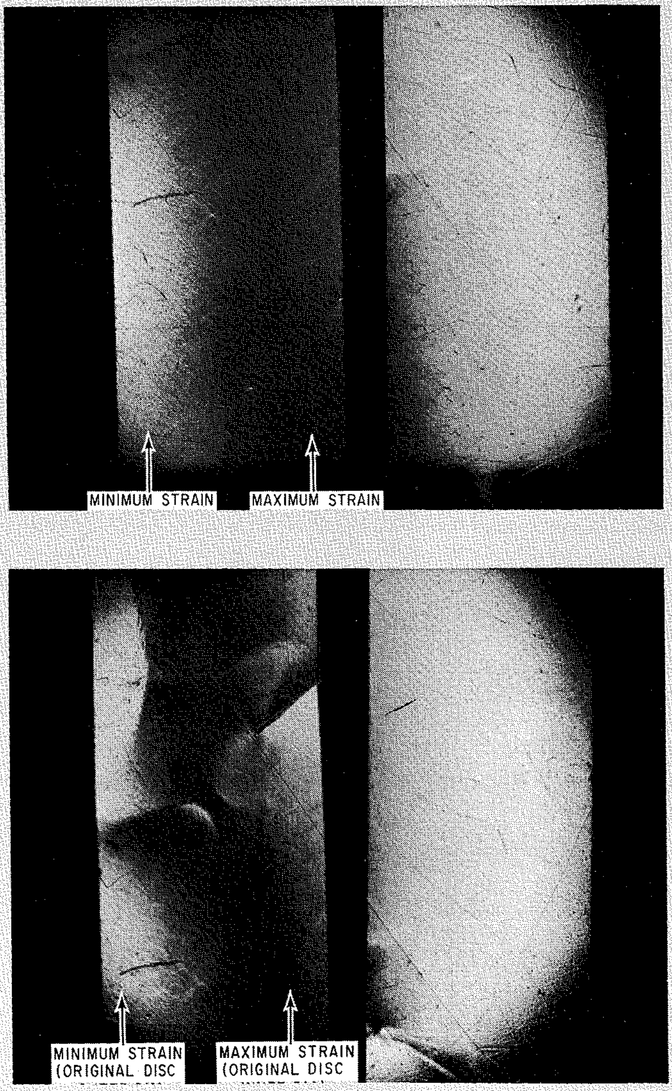
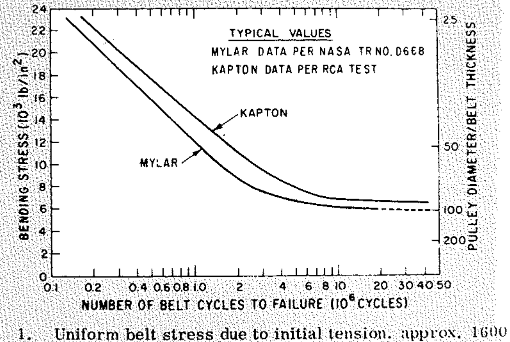


Fig. 5—Seamless polymer belt fringe patterns.

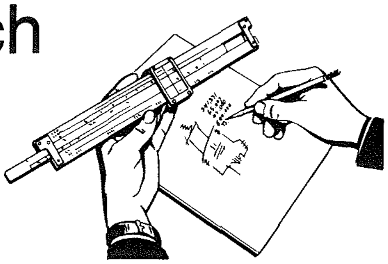


NOTES:
1. Uniform belt stress due to initial tension. approx. 1600 psi.
2. Kapton belts fabricated per RCA AED Mfg. Procedure No. 1 Rev. A (Air-cool, post heat-treat).

Fig. 9—Mylar and Kapton bending fatigue.

Engineering and Research Notes

Brief Technical Papers of Current Interest



Elastomeric Roofing Applied at Remote Alaskan Site

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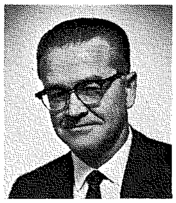


Reprint RE-14-1-23/Final manuscript received March 8, 1968.

When Robert Service wrote, "Talk of your cold! through the parka's fold it stabbed like a driven nail," he could well have been describing the winters at the Clear Missile Early Warning Station in Alaska, where elastomeric roofing systems now in use may be the answer to roofing problems which have plagued this sub-arctic installation since its construction in 1960.

This station, located approximately seventy miles southwest of Fairbanks, is a U.S. Air Force installation, operated and maintained by the Service Company as part of BMEWS. Winter temperatures of —50°F. are common with occasional —70°F. At these temperatures, rubber tires have been known to disintegrate and many building materials (e.g., felts and plastics) become extremely brittle and will shatter under very slight impact.

Several flat-roofed buildings house the electronic equipment and power distribution systems which are the heart and arteries of this gigantic radar system. These buildings were constructed using conventional built-up roofing installed over either concrete, foamglass, or fiberboard insulation and then covered with a mixture of asphalt and gravel approximately three inches thick. The roofs were flat resulting in a considerable amount of ponding.

During the first year of operation, these roofs began to leak. The electronic and electrical equipment had to be protected and many man-hours were expended draping the equipment with plastic sheets and mopping up water. The leakage occurred during spring breakup when the snow and ice on the roofs melted and would continue through the rainy summer season, stopping only when the extreme cold of the following winter froze the water trapped in the roofing materials.

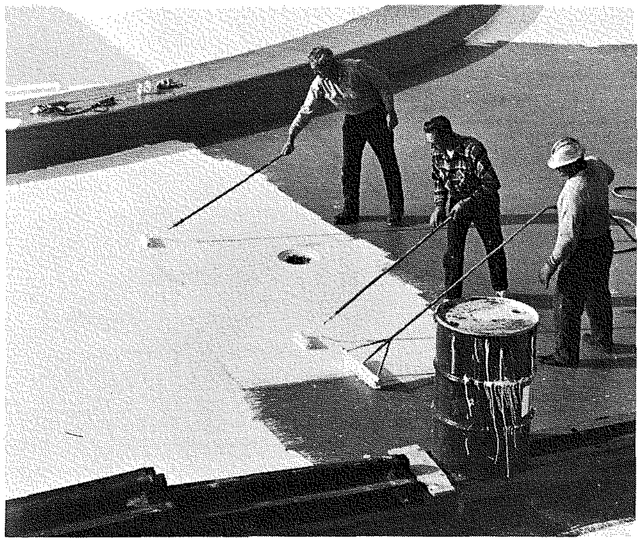
The failure of the original roofs is attributed to thermal stresses induced by the extremes of temperature (+90°F to —70°F). These stresses cause shrinkage cracks which permit migrating melted snow and rain to infiltrate the roof covering where it undergoes successive freezing-thawing cycles. Several conventional roofing materials and designs were considered by the Service Company's engineering staff but many of them required extensive reconstruction of the roofs or afforded no guarantee for performance in the arctic. Elastomeric material was selected because laboratory results indicated its ability to withstand extreme temperatures, and in this case, it could be applied to existing surfaces without completely reconstructing the roof. The roofs could be repaired without impairing the BMEWS mission and work could be accomplished during the short summer normally experienced at Clear. The project was approved by the Civil Engineer of the 9ADD (9th Aerospace Defense Division) of ADC (Aerospace Defense Command) and work commenced in July 1966.

Elastomeric roofing systems in general consist of several coatings of Neoprene and Hypalon rubber in liquid form placed on a prepared substrate. Each coat is allowed to dry to a tack-free state before applying subsequent coats. When all coats are dry, a continuous rubber membrane covers the substrate and is firmly bonded to it. The Neoprene, which is applied first, forms the body of the membrane. The Hypalon coatings protect the Neoprene from the atmosphere and rays of the sun.

This system was applied to two roof areas, one of 26,000 square feet and the other of 4,000 square feet, which have now performed satisfactorily through one full year. Several other roofs with areas of from 15,000 to 18,000 square feet were completed this past summer and give every indication that their performance will also be satisfactory.

The roofs were prepared for applying the elastomeric system by removing the asphalt and gravel covering to expose the felt where a foamglass or fiberboard substrate existed, and removing the felt where there was a concrete substrate. Additional roof drains were installed and a new concrete slab was placed which sloped to the drains. In one case, over a foamglass substrate, a concrete slab was not used and drainage was obtained by tapering foamglass boards and installing them over the existing materials. This was difficult to accomplish as the foamglass was too easily broken when it had been tapered to one inch or less in thickness. Subsequently, all roofs, regardless of the type of existing substrate, received a concrete slab which was sloped to the drains.

After the concrete slabs had cured and dried, the elastomeric coatings were applied. These consisted of one prime coat, two applications of Neoprene and two of Hypalon, formulated to retain elasticity at —70°F. Flashings and expansion joints were constructed using one-eighth inch thick Neoprene sheet attached with adhesive to the surfaces to be covered. The full elastomeric system was extended over these sheets. The roof drains were flashed by



Applying first coat of Hypalon over Neoprene.

View of completed roof.

applying fiberglass fabric as reinforcement in the coatings, and using a Neoprene rubber sheet cut to form a gasket under the hold-down ring.

The Neoprene and Hypalon were applied by means of a pressure roller. The materials were pumped from barrel containers in a truck at ground level to the pressure roller on the roof. Plain rollers followed the pressure roller to distribute the liquid in a uniform film. The finished membrane consisted of Neoprene with a minimum dry-film thickness of 14 mils and Hypalon with a minimum dry-film thickness of 6 mils.

The system which was applied over foamglass insulation has been through one full year without difficulty. However, it is obvious that the concrete provides a better base for the system.

The elastomeric roofing system has several features which makes it particularly attractive, especially for use in the Alaskan area. The high degree of elasticity of the material plus its ability to retain this elasticity at extremely low temperatures precludes its shrinking and breaking as other more conventional materials do. If cracking occurs in the substrate, the membrane will bridge the smaller cracks. If failure does occur, the area which has failed can easily be located. Patching of the membrane is easy. Simply clean the area that has failed, apply fabric reinforcement and recoat.

The cost of an elastomeric roofing system at this location is competitive with a conventional 5-ply built-up roof. In addition, three-year guarantees can be obtained from both the manufacturer of the material and the applier. On conventional built-up roofing, a one-year guarantee can be obtained from the roofing contractor but nothing from the manufacturer and bonds are not obtainable at all.

The roofs having the elastomeric system have not been in service long enough for definite conclusions to be reached as to their life and reliability so it is not claimed that this is the only answer to the problem. The experience gained so far, however, indicates that the system will provide satisfactory roofing for extremely cold climates and if current expectations are fulfilled, it will result in the best arctic roof since the igloo.

Integral Equations and Parseval's Theorem

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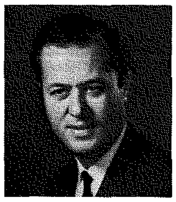

A. A. Clark

R. F. Barry

Reprint RE-14-1-23/Final manuscript received April 3, 1968.

Singular integral equations are used extensively in the analysis of general linear physical systems.[1] This note shows that through the application of the LaPlace transform and Parseval's theorem,[2] it is possible to write the singular linear integral equation as an integral equation evaluated over a contour in the complex plane. This new equation has the same general form as the original time domain equation. Solving this equation directly yields the LaPlace transform of the time domain solution.

The integral equation in the time domain is

$$\phi(t) - \lambda \int_0^\infty K(t,x)\phi(x)\,dx = f(t) \tag{1}$$

where $K\ (t,x)$ is the system weighting function, with $f(t)$ and $\phi(t)$ denoting system forcing and response functions. The LaPlace transform of Eq. 1 gives

$$\varnothing(s) - \lambda \int_0^\infty g(s,x)\varnothing(x)\,dx = F(s) \tag{2}$$

where $\varnothing(s) = L\ \varnothing(t)$, $F(s) = L\ f(t)$, $g(s,x) = L\ K(t,x)$ and the integral in Eq. 2 is assumed to exist. By Parseval's theorem Eq. 2 can be written as

$$\varnothing(s) - \lambda\frac{1}{2\pi j}\int_{Br}\varnothing(\xi)G(s,-\xi)\,d\xi = F(s) \tag{3}$$

where

$$G(s,\xi) = \int_0^\infty g(s,x)\,e^{-\xi x}\,dx \tag{4}$$

and Br is the Wagner-Bromwich contour in the ξ plane, and is placed where $Re\xi > \sigma_\phi$ absicissa of convergence of $\varnothing\ (x)$. Eq. 3 has the same general form as Eq. 1, and its solution gives $\varnothing(s)$ directly. In general, the contour (Br) can be closed on the right. For a physically realizable system, the function $\varnothing(\xi)$ is analytic in the open right half plane $(\sigma_\phi \geq 0)$, hence only the poles of $G(s,-\xi)$ that lie in the right half plane need to be considered. For lumped parameter systems, the resulting equation can be easily evaluated as the sum of residues as

$$\varnothing(s) + \lambda \Sigma\, Res\, G(s,-\xi)\ \varnothing(\xi) = F(s) \tag{5}$$

Two examples of the use of this procedure are provided:

Example 1:

Let $K(t,x) = e^{at}e^{bx}$ for $a, b < o$; $a \neq b$; and let $f(t) = e^{at}$. In this case, $F(s) = 1/(s-a)$ and

$$g(s,x) = \int_0^\infty e^{bx}e^{(a-s)t}dt = \frac{e^{bx}}{s-a}$$

$$G(s,\xi) = \int_0^\infty g(s,x)\,e^{-x}dx = 1/(s-a)(\xi-b)$$

Eq. 5 becomes

$$\varnothing(s) - \lambda \Sigma\, Res\, \frac{1/(s-a)}{\xi+b}\,\varnothing(\xi) = \frac{1}{s-a}$$

from which

$$\varnothing(s) = \lambda\frac{1}{s-a}\varnothing(-b) + \frac{1}{s-a} = \frac{A}{s-a}$$

and the constant A is therefore determined to be

$$A = \frac{a+b}{a+b+\lambda}$$

This result can be verified by substituting the inverse transform of $\varnothing(s)$ into Eq. 1 and integrating.

Example 2: simple RC *filter circuit:*

Specialize Eq. 3 to the form (let $\lambda = -1$ and drop the $\varnothing(s)$ term)

$$F(s) = \frac{1}{2\pi j}\int_{Br}\varnothing(\xi)\ G(s,-\xi)\,d\xi$$

The system weighting function for the filter circuit is

$$K(t,x) = \frac{1}{RC}e^{(t-x)/RC}$$

Thus,

$$g(s,x) = \left[\frac{(1/RC)}{S+1/RC}\right]e^{x/RC}$$

and

$$G(s,\xi) = \frac{1}{RC}\,\frac{1}{(S+1/RC)(\xi-1/RC)}$$

Let $\phi(t)$ be the forcing function and consider it to be an impulse. Thus $\varnothing(s) = 1$, and the system response $F(s)$ is computed to be

$$F(s) = +\Sigma\, Res\left[\left(\frac{1}{RC}\,\frac{1}{S+1/RC}\right)\frac{1}{\xi+1/RC}\right]$$

which is the correct impulse response for the RC filter circuit.

The above general procedure for directly obtaining the LaPlace transform of a response function, as given by Eq. 3, has wide application in system analysis problems. For lumped parameter systems, the response $\emptyset(s)$ is obtained as in Eq. 5 by a simple computation and the specialization to $\emptyset(j\omega)$ gives the frequency response function. The form of Eq. 3 lends itself to an iterative procedure for obtaining $\emptyset(s)$, where proper restrictions on the quantities involved yield a sequence of functions $\emptyset_0(s)$, $\emptyset_1(s)$, • • • which converges to the desired function $\emptyset(s)$. This iterative technique is similar to the usual Picard method, and lends itself to machine computation for rapid evaluation of $\emptyset(s)$. This procedure is somewhat lengthy for presentation in this note and is to be discussed in a future paper. The extension of this technique to non-linear system analysis, through the use of a Volterra kernel approach is also a possibility.

References:

1. Seifert, W. W., and Steeg, Jr., C. W., *Control Systems Engineering* (McGraw-Hill, N.Y., 1960) pp. 338-404.
2. Wolf, A. A., and Dietz, J. H., "A Statistical Theory for Parameter Identification in Physical Systems", *J. of the Franklin Institute*, V. 274, No. 5, (Nov. 1962) pp. 374.

An AGC Speech Amplifier

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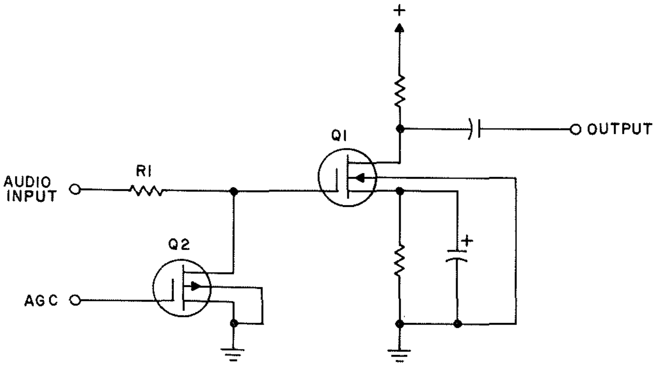
Transistor amplifiers lacking the remote cutoff characteristics of tubes present some difficult problems in the application of AGC. Some rather complex and ponderous circuits have evolved using pulse circuitry, variable light-intensity sources, and light-dependent resistors. The in-line amplifier shown in the Fig. 1 takes advantage of the characteristics peculiar to field-effect transistors. The circuit offers impedance transformation and net gain. The high input impedance and good linearity for wide dynamic range make it compatible to pre-amplifier stage inputs. The output impedance is of normal character for driving subsequent transistor stages. The AGC input requires no power and allows complete freedom in the design of the AGC network time constants and levels. With the selection of the enhancement-type FET for Q2, the polarity is correct. Increasing AGC strength causes a decrease in drain-to-source resistance and a net reduction in gain through the dynamic attenuator (R1 and Q2). The circuit has many possible applications (e.g., a program amplifier for tape and turntable inputs and for phone and microphone speech amplifiers).



Q1 - IGFET DEPLETION TYPE
Q2 - IGFET ENHANCEMENT TYPE

Fig. 1—AGC in-line amplifier.

A Compact Self-Contained Linear-Motion Transducer

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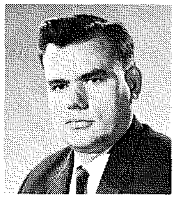


Reprint RE-14-1-23/Final manuscript received March 29, 1968.

This unique linear-motion transducer design has many applications where space is at a premium. The simple TO-5 integrated circuit oscillator and the small plastic bridge rectifier could enable the entire transducer to be packaged in less that $0.75\ \text{in.}^3$ The output is a DC voltage that varies with the longitudinal movement of the sensing rod. There is no friction in the sensing rod because it simply moves a coil slug inside a transformer coil. The only external connection is a 9 volt DC supply voltage.

The circuit uses a power oscillator with the transformer primary as an integral part of the oscillator (Fig. 1). The two secondary windings of the transformer drive a bridge rectifier which converts the oscillator AC signal into a DC voltage. The two windings are connected to buck or oppose each other so that by moving the slug the output will go through two equal maximum levels and one minimum or null.

The power oscillator is a push-pull type and the CA3020 can deliver up to 0.55 watts of AC power to the transformer load. With perfect coupling and no losses a 4-to-1 step-up could supply 37 volts DC across a 2.5 kilohm load. In the test circuit with an "air core" transformer and with the slug in a maximum coupling position, the DC voltage was 14 volts.

If the static position of the sensor rod is known, the transformer slug should be set so that the output is in mid-range (i.e. between a maximum output and the null). Which slope is used will determine the error polarity.

The physical construction of the transformer will determine the sensitivity of the transducer. The core length should be as short as practical for maximum sensitivity. The primary was made of 125 turns of #30 wire with a center tap. It was checked at 0.260 mH. The secondary had two windings of 500 turns of #38 wire. Each winding checked at 5 mH. These windings are positioned along the core and are connected to oppose each other. The CA3020 should be loaded with 125 ohms for maximum power efficiency. The 1500 $\mu\mu$f capacitor helps to stabilize the impedance seen by the transformer.

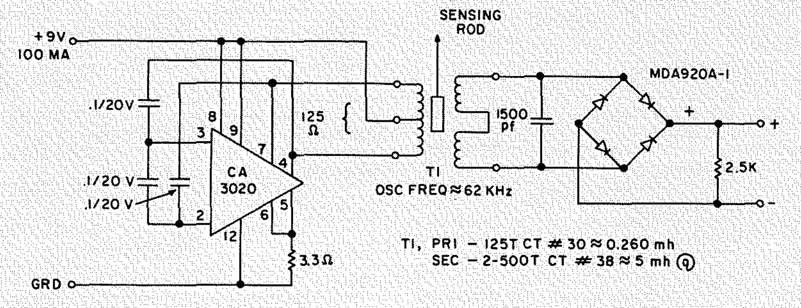
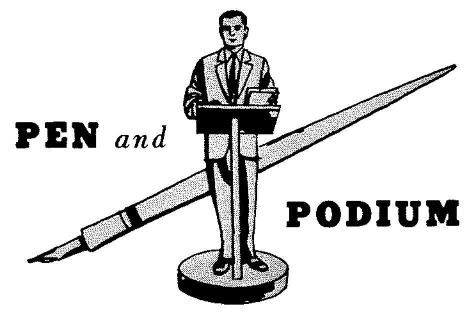


Fig. 1—Linear-motion transducer.



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QUARTER-WAVE MONOPOLE IN AN ISOTROPIC PLASMA, Experimental Impedance of a—D. L. Jassby (RCA Victor Co., Ltd., Montreal); *IEEE Trans. Antennas and Propagation*, V. 16, No. 2; 3/68

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ATE CHECKOUT—MTE and DIMATE—R. Turkington (ASD, Burl); DOD Seminar, Laboratories, Princeton, N.J.; 6/65

AUTOMATIC CHECKOUT TECHNOLOGY—O. T. Carver (ASD, Burl); *Space/Aeronautics R&D Handbook*; Fall, 1965

LCSS: Electronic and Electrooptical Automatic Test Equipment for Field Army Use—E. Stockton, D. Douglas (ASD, Burl); 6th Reliability and Maintainability Conf., Cocoa Beach, Fla.; 7/17-19/67; *Conf. Record*

SELECTION AND USE OF ELECTRICAL CONNECTORS, Practical Hints on—J. S. Korda, R. G. Lubelsky (RCA Victor Co., Ltd., Montreal); *Canadian Electronic Engineering*, V. 12, No. 4; 5/68

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MICROWAVE INTEGRATED CIRCUITS, Lumped Elements in—D. A. Daly, S. P. Knight, M. Caulton, R. Ekholdt (Labs., Pr); *IEEE Trans. on Microwave Theory and Techniques*, V. MIT-15, No. 12; 12/67

COMMUNICATIONS COMPONENTS (equipment subsystems)

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COMMUNICATION SERVICES—E. J. Tomko (DCSD, Cam); AMA Seminar, N.Y., N.Y.; 4/25/68

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PROGRAMMING LANGUAGES for ATE, Moderated Session on—P. M. Toscano (ASD, Burl); IEEE Automatic Support Systems Symp., St. Louis; 11/67

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MNS FIELD EFFECT TRANSISTORS, Memory Action in—J. Scott, T. Wallmark (Labs., Pr); Silicon Interface Specialists Conf., Las Vegas, Nev.; 3/4-6/68

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LINE-OF-SIGHT WAVE PROPAGATION, Effects of Turbulence Upon—D. A. de Wolf (Labs., Pr); P.I. & B. International Symp. on Turbulence of Fluids and Plasmas, New York City; 4/16-18/68

MAGNETIC SEMICONDUCTOR $Ag_xCd_{1-x}Cr_2Se_4$, Helicon-Spin Wave Interaction in the—B. Vural, E. E. Thomas (Labs., Pr); *Applied Physics Letters*, V. 12, No. 1; 1/68

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OPTICAL SYSTEM for the One Million Volt U.S. Steel Microscope Column—J. W. Coleman, J. H. Reisner (CESD, Cam); Electron Microscope Soc. of America, Chicago, Ill.; 8/28/67; *Proc.*; 1967

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QUARTER-WAVE MONOPOLE IN AN ISOTROPIC PLASMA, Experimental Impedance of a—D. L. Jassby (RCA Victor Co., Ltd., Montreal); *IEEE Trans. Antennas and Propagation,* V. 16, No. 2; 3/68

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CRITICAL STATES, On Tisza's Thermodynamic Description of—W. Czaja (Labs., Pr); Spring Mtg. of the Swiss Physical Soc. Mtg., Berne, Switzerland; 4/19-20/68

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ELECTRON BOMBARDMENT DAMAGE in Melt-Grown, Semi-insulating GaAs by Thermally Stimulated Conductivity, Studies of—H. Schade, H. Kressel, D. Herrick (Labs., Pr); American Physical Soc. Mtg., Berkeley, Cal.; 3/18-21/68

GaAs:GaP 50% ALLOY, Impact Ionization and Charge Transport in—R. Williams (Labs., Pr); *J. of Applied Physics,* V. 39, No. 1; 1/68

HALL MOBILITY of the Small Polaron. II—T. Holstein, L. Friedman (Labs., Pr); *Physical Review,* V. 165, No. 3; 1/15/68

HELICONS IN POTASSIUM, Surface Impedance Near the Cyclotron Edge for—R. C. Alig (Labs., Pr); Physical Review, V. 165, No. 3; 1/15/68

HOT ELECTRONS, The Acoustoelectric Effects and the Energy Losses by—Part III—A. Rose (Labs., Pr); *RCA Review,* V. XXVIII, No. 4; 12/67

n-InSb MOS STRUCTURE, Non-Reciprocal Surface Charge Wave in—M. Toda (Labs., Pr); Annual Mtg. of the Physical Soc. of Japan, Osaka, Japan; 4/1-6/68

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YTTRIUM-IRON-GARNET, The Critical Point Behavior of—K. Miyatani, K. Obayashi (Labs., Pr); Annual Mtg. of the Physical Soc. of Japan, Osaka, Japan; 4/1-6/68

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CLOSE-SPACED GROWTH of Degenerate P-Type GaAs, GaP, and Ga(As,P) by $ZnCl_2$ Transport—P. A. Hoss, L. A. Murray, J. J. Rivera (EC, Som); *J. of the Electrochemical Soc.;* 5/68

CRYSTAL GROWTH of $CuCr_2X_3Y$ ($X = S, Se, Te; Y = Cl, Br, I$)—I—F. Okamoto, Y. Wada, K. Miyatani (Labs., Pr); Annual Mtg. of the Physical Soc. of Japan, Osaka, Japan; 4/1-6/68

CRYSTAL GROWTH of $CuCr_2X_3Y$ ($X = S, Se, Te; Y = Cl, Br, I$)—II—Y. Wada, F. Okamoto (Labs., Pr); Annual Mtg. of the Physical Soc. of Japan, Osaka, Japan; 4/1-6/68

FERROMAGNETIC SEMICONDUCTOR $CdCr_2Se_4$, Growth and Properties of Single Crystals of the—H. von Philipsborn (Labs., Pr); Helvetica Physica Acta, V. 40; 1967

GdIG CRYSTALS Near the Compensation Temperature, Switching Speed of—T. J. Nelson (Labs., Pr); INTERMAG Conf., Wash., D.C.; 4/3-5/68

SINGLE CRYSTAL CHALCOGENIDE SPINELS, $CuCr_2X_3Y$ ($X = S, Se, Te; Y = Cl, Cr, I$), Magnetic Properties of—K. Miyatani, F. Okamoto, Y. Wada (Labs., Pr); Annual Mtg. of the Physical Soc. of Japan, Osaka, Japan; 4/1-6/68

SPIN-LATTICE RELAXATION RATE of Tm^{2+} in CaF_2, SrF_2 and BaF_2—E. S. Sabisky, C. H. Anderson (Labs., Pr); American Physical Soc. Mtg., Wash., D.C.; 4/22-25/68

TRANSITION METAL NIOBATES, Transport Reactions and Crystal Growth of—F. Emmenegger, A. Petermann (Labs., Pr); *J. of Crystal Growth;* 1968

VAPOR PHASE GROWN $GaAs_{1-x}P_x$, Imperfections in—M. S. Abrahams (Labs., Pr); Colloquium, Columbia U., N.Y.; 3/20/68

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MINORITY CARRIER LIFETIME in Silicon, On the Determination of—F. P. Heiman (Labs., Pr); Semiconductor Interface Specialists Conf., Las Vegas, Nev.; 3/4/68

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SURFACE NUCLEATION FIELD H_{c3} of Pure Lead—G. Fischer (Labs., Pr); *Physical Review Letters,* V. 20, No. 6; 2/5/68

THIN-FILM TRANSISTOR, An Adaptive—S. S. Perlman, K. H. Ludewig (Labs., Pr); *IEEE Trans. on Electron Devices;* 12/67

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HALL EFFECT of Ferromagnetic $CdCr_2Se_4$—H. W. Lehmann (Labs., Pr); *J. of Applied Physics,* V. 39, No. 2; 2/1/68

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NEW FERROMAGNETIC SPINELS, The Magnetism, Semiconducting, and Optical Properties of—P. K. Baltzer (Labs., Pr); Annual Mtg. of the Physical Soc. of Japan, Osaka, Japan; 4/1-6/68

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MAGNETIC FIELD DEPENDENCE of ^{53}Cr NMR in $HgCr_2S_4$—S. B. Berger (Labs., Pr); American Physical Soc. Mtg., Berkeley, Cal.; 3/18-21/68

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OPTICAL REFLECTIVITY TECHNIQUES Applied to Semimetals and Low Gap Semiconductors—D. L. Greenaway (Labs., Pr); Conf. on Semimetals and Narrow Gap Semiconductors, Durham, England; 4/68

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SOLID-STATE INFRARED IMAGE SENSOR, Development of a—D. Williams, N. Mills, W. Witt (ASD, Burl); Infrared Information Symp., Ft. Monmouth, N.J.; 5/7-9/68; *Proc.;* 1968

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ROCKETSONDE TRANSMITTER, A New Low-Cost Fundamental-Frequency—R. R. Lorentzen (EC, Hr); Electronic Communicator; Mar-Apr 1968

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Fairbanks, J. R. mechanical devices
Libbey, R. L. control systems
Lund, N. C. electromagnets
Mahland, E. W. communications systems
Reisner, J. H. electro-optics
Reisner, J. H. optics
Reisner, J. H. vacuum
Schuler, J. J. optics
Shapiro, S. W. vacuum
Shaver, K. C. education
Shaver, K. C. television equipment
Taylor, E. D. communications systems

CENTRAL ENGINEERING

Clanton, J. A. reliability

DEFENSE COMMUNICATIONS SYSTEMS DIVISION

Barton, H. R. reliability
Breen, J. N. environmental engineering
Bura, P. amplification
Bura, P. circuits, integrated
Canale, S. reliability
Crossan, E. F. management
Doughty, J. management
Frankle, J. T. communications components
Guenther, R. space communication
Hartshorne, F. A. spacecraft
Jacobowitz, H. computers, programming
Jacobowitz, H. logic theory
Kell, F. W. recording, image
Kell, F. W. spacecraft instrumentation
Magasiny, I. P. communications components
Paris, A. A. communications systems
Rittenhouse, J. D. recording

Rittenhouse, J. D. spacecraft instrumentation
Susskind, I. communications systems
Thomas, W. W. management
Tiger, B. reliability
Tomko, E. J. communications systems
Weir, K. reliability
Westcott, E. J. reliability

ELECTRONIC COMPONENTS

Baugher, D. M. reliability
Becke, H. W. lasers
Damon, G. F. optics
Hanchett, G. D. solid-state devices
Hartz, R. S. amplification
Hartz, R. S. solid-state devices
Hoss, P. A. laboratory techniques
Hoss, P. A. properties, molecular
Kamp, F. S. amplification
Kamp, F. S. solid-state devices
Lorentzen, R. R. space navigation
Martin, J. S. properties, chemical
Mendelson, R. M. circuits, integrated
Murray, L. A. laboratory techniques
Murray, L. A. properties, molecular
Rivera, J. J. laboratory techniques
Rivera, J. J. properties, molecular
Royce, M. R. properties, chemical
Schade, O. H. television receivers
Schilling, W. A. transmission lines
Siekanowicz, W. W. transmission lines
Smith, A. L. properties, chemical
Stanavage, J. P. properties, chemical
Turner, C. R. solid-state devices
Trond, S. S. properties, chemical
Turner, C. R. solid-state devices

GRAPHIC SYSTEMS DIVISION

Crooks, H. N. graphic arts
Coleman, A. H. graphic arts

LABORATORIES

Abrahams, M. S. properties, molecular
Afromowitz, M. A. properties, chemical
Alig, R. C. properties, atomic
Alig, R. C. properties, surface
Amarel, S. mathematics
Anderson, C. H. acoustics
Anderson, C. H. laboratory techniques
Anderson, C. H. properties, atomic
Anderson, C. H. properties, molecular
Baltzer, P. K. properties, electrical
Baltzer, P. K. properties, magnetic
Baltzer, P. K. properties, optical
Berger, S. B. properties, magnetic
Blanc, J. lasers
Blanc, J. properties, chemical
Blatter, H. geophysics
Bordogna, J. communications systems
Bordogna, J. lasers
Bortfeld, D. P. properties, optical
Bosomworth, D. R. properties, optical
Bostwick, D. I. properties, optical
Briggs, G. R. computer storage
Caulton, M. circuits, integrated
Coutts, M. D. laboratory techniques
Crandall, R. properties, electrical
Czaja, W. properties, atomic
Czaja, W. properties, optical
Czaja, W. properties, thermal
Daly, D. A. circuits, integrated
Dean, R. communications components
Dennehy, W. J. solid-state devices
de Wolf, D. A. electromagnetic waves
Dienst, J. F. communications components
Dreeben, A. properties, chemical
Dworsky, L. N. properties, surface
Emmenegger, F. properties, molecular
Enstrom, R. communications components
Ekholdt, R. circuits, integrated
Fatuzzo, E. properties, electrical
Friedman, L. properties, atomic
Fischer, G. properties, surface
Fischer, G. properties, magnetic
Freeman, S. properties, magnetic
Freeman, S. properties, optical
Friedman, L. R. properties, acoustic
Gahwiller, C. properties, optical
Gannon, J. J. properties, chemical
Gerritsen, H. J. properties, optical
Gittleman, J. I. properties, electrical
Glicksman, M. education
Gorog, I. lasers
Grabowski, J. T. computer storage
Greenaway, D. L. properties, optical
Greenberg, J. S. radar
Greenberg, J. S. space navigation
Gwozdz, P. properties, electrical
Hannan, W. J. communications systems
Hannan, W. J. lasers
Harbeke, G. properties, optical
Hattori, T. properties, magnetic
Hawrylo, F. Z. properties, electrical
Hawrylo, F. Z. properties, optical
Hegyi, I. J. lasers
Heiman, F. P. properties, surface
Herrick, D. properties, atomic
Hershenov, B. circuits, integrated
Hirsch, C. J. television broadcasting
Hoffstein, V. properties, surface
Hoffstein, V. superconductivity
Holmes-Siedle, A. G. solid-state devices
Holstein, T. properties, atomic
Karlsons, D. communications systems
Karlsons, D. lasers
Klein, R. properties, magnetic
Kleinknecht, H. P. properties, optical
Knight, S. P. circuits, integrated
Kokkas, A. communications components
Krausbauer, L. properties, optical
Kressel, H. lasers
Kressel, H. properties, atomic
Kressel, H. properties, electrical
Kressel, H. properties, optical
Larach, S. properties, electrical
Lehmann, H. W. properties, electrical
Leopold, W. solid-state devices
Levin, E. R. laboratory techniques
Li, K. computer storage
Ludewig, K. H. properties, surface
Maruska, H. P. lasers
Mason, P. R. properties, electrical
Mezrich, R. S. properties, optical
Miller, A. optics
Miyatani, K. properties, atomic
Miyatani, K. properties, molecular
Miyatani, K. properties, magnetic
Nelson, H. lasers
Nelson, T. J. properties, molecular
Nelson, T. J. properties, electrical
Nelson, T. J. properties, thermal
Nuese, C. J. properties, chemical
Obayashi, K. properties, atomic
Okamoto, F. properties, molecular
Okamoto, F. properties, magnetic
Olson, H. F. acoustics
Pankove, J. I. lasers
Perlman, S. S. properties, surface
Petermann, A. properties, molecular
Redfield, D. properties, chemical
Rehwald, W. properties, mechanical
Rose, A. properties, atomic
Rosenblum, B. properties, mechanical
Ross, D. L. lasers
Ross, D. L. properties, chemical
Ross, P. W. linguistics
Rothwarf, A. properties, mechanical
Rothwarf, A. superconductivity
Sabisky, E. S. acoustics
Sabisky, E. S. laboratory techniques
Sabisky, E. S. properties, atomic
Sabisky, E. S. properties, molecular
Sass, A. R. properties, surface
Sass, A. R. superconductivity
Schade, H. properties, atomic
Schein, L. B. properties, surface
Schein, L. B. superconductivity
Scott, J. computer storage
Shallcross, F. V. properties, surface
Simphony, M. properties, surface
Simphony, M. properties, electrical
Southgate, P. D. lasers
Spong, F. W. lasers
Steigmeier, E. F. properties, thermal
Stewart, W. C. properties, surface
Stewart, W. C. superconductivity
Taylor, B. N. properties, atomic
Thomas, E. E. electromagnetic waves
Tietjen, J. J. lasers
Toda, M. circuit analysis
Toda, M. solid-state devices
Toda, M. properties, atomic
Toda, M. properties, surface
Tuska, J. W. computer storage
Vieland, L. J. properties, thermal
Vilkomerson, D. H. R. properties, optical
von Philipsborn, H. properties, molecular
Vural, B. electromagnetic waves
Vural, B. properties, atomic
Wada, Y. properties, molecular
Wada, Y. properties, magnetic
Wallmark, T. computer storage
Waxman, A. properties, surface
Wicklund, A. K. properties, thermal
Williams, R. properties, atomic
Williams, R. properties, surface
Williams, R. properties, electrical
Willis, A. properties, surface
Willis, A. properties, electrical
Winder, R. O. logic theory
Wojtowicz, P. J. properties, magnetic
Woodward, J. G. laboratory techniques
Yocom, P. N. properties, chemical

MISSILE AND SURFACE RADAR DIVISION

Buder, S. H. radar
Mochan, J. space navigation
O'Brien, J. F. radar
Pavley, R. F. radar
Stephens, B. C. laboratory techniques
Stophel, R. A. space navigation
VanOlst, R. A. management

RCA COMMUNICATIONS, INC.

Acampora, A. communications components
Frankle, J. T. communications components
Klapper, J. communications components

RCA SERVICE COMPANY

Pinion, J. F. radar
Tokareff, P. radar

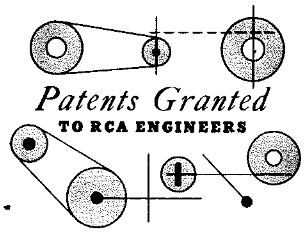
RCA VICTOR COMPANY, LTD.

Bachynski, M. P. antennas
Carswell, A. I. plasma physics
Ghosh, A. K. plasma physics
Jassby, D. L. antennas
Jassby, D. L. plasma physics
Johnston, T. W. plasma physics
Korda, J. S. checkout
Lubelsky, R. G. checkout
Richard, C. plasma physics
Shkarofsky, I. P. mathematics
Shkarofsky, I. P. plasma physics
Shkarofsky, I. P. spacecraft

RECORD DIVISION

Max, A. M. management
Max, A. M. recording

PATENTS GRANTED



As Reported By RCA Domestic Patents, Princeton

ADVANCED TECHNOLOGY

Control System for Helical Scan Recorder—F. E. Shashoua (AT, Cam), F. D. Kell (DCSD, Cam) U.S. Pat. 3,378,646, April 16, 1968

DEFENSE COMMUNICATIONS SYSTEMS DIVISION

Control System for Helical Scan Recorder—F. E. Shashoua (AT, Cam), F. D. Kell (DCSD, Cam) U.S. Pat. 3,378,646, April 16, 1968

Chalcogenide Thermoelectric Device Having a Braze Comprising Antimony Compounds and Method of Forming Said Device—L. Pessel (DCSD, Cam) U.S. Pat. 3,373,061, March 12, 1968

Bit Buffering System—R. H. G. Chan (DCSD, Cam) U.S. Pat. 3,373,418, March 12, 1968

Low Noise VHF Transistor Oscillator—A. W. Weinrich (DCSD, Cam) U.S. Pat. 3,375,467, March 26, 1968

CONSUMER ELECTRONIC DIVISION

Amplitude Limiting Signal Translating Circuit Utilizing a Voltage Dependent Resistor in the Output Circuit—L. P. Thomas (CED, Indpls) U.S. Pat. 3,377,426, April 9, 1968

Unitary Beam Convergence Magnet Structure and Control Apparatus—J. W. McLeod, Jr. (CED, Indpls) U.S. Pat. 3,377,512, April 9, 1968

Phonograph Pickup Device—D. E. Laux, J. M. White (CED, Indpls) U.S. Pat. 3,375,012, March 26, 1968

Regulated High Voltage D.C. Power Supply—B. E. Denton (CED, Indpls) U.S. Pat. 3,375,436, March 26, 1968

Clipping Circuit Utilizing an Insulated Gate Field Effect Transistor—L. P. Thomas (CED, Indpls) U.S. Pat. 3,374,312, March 19, 1968

Magnetic Recording and Playback—C. F. Rose (CED, Indpls) U.S. Pat. 3,371,881, March 5, 1968

UHF Tuner Mechanism—T. D. Smith (CED, Indpls) U.S. Pat. 3,365,962, January 30, 1968

Integrated Electrical Circuit—J. Avins (CED, Indpls) U.S. Pat. 3,366,889, January 30, 1968

INFORMATION SYSTEMS DIVISION

Light Responsive Circuit which Prevents Photosensitive Device Saturation—E. C. James (ISD, W. Palm Beach, Fla) U.S. Pat. 3,376,423, April 2, 1968

Voltage Regulated Power Supply Including Ramp Voltage Starting Means and Over-Current Protective Means—A. S. Sheng, A. Y. Chen (ISD, Cam) U.S. Pat. 3,376,478, April 2, 1968

Feeder Apparatus—J. P. Watson, O. J. Shamblin (ISD, W. Palm Beach, Fla) U.S. Pat. 3,372,923, March 12, 1968

Punched Card Reader with Registration Indicating Means—E. A. Damerau (ISD, Cam) U.S. Pat. 3,373,264, March 12, 1968

Magnetic Tape Transport with Azimuth Adjustment—S. Baybick, J. B. Kelly, A. A. Sariti (ISD, Cam) U.S. Pat. 3,373,248, March 12, 1968

Scratch Pad Computer System—A. T. Ling (ISD, Cam) U.S. Pat. 3,373,407, March 12, 1968

Computer Capable of Switching between Programs without Storage and Retrieval of the Contents of Operation Registers—A. T. Ling (ISD, Cam) U.S. Pat. 3,373,408, March 12, 1968

Conversion from Gray Code to Binary Code—M. C. Wang (ISD, Cam) U.S. Pat. 3,373,421, March 12, 1968

Computer Peripheral Device Control—J. J. Schell, Jr. (ISD, Cam) U.S. Pat. 3,370,276, February 20, 1968

LABORATORIES

RC Circuit Means to Compensate for Defocusing of a Pulsed Image Intensifier—W. J. Hannan (Labs, Pr) U.S. Pat. 3,350,600, October 31, 1967 (Patent assigned to U.S. Government)

High Speed Scanning Slot Antenna Fed by Variable Delay Waveguide having Hinged Oscillated Vane—R. G. Shankweiler (Labs, Pr), R. J. Klensch (GSD, Dayton) U.S. Pat. 3,122,744, February 25, 1964 (Patent assigned to U.S. Government)

MEDICAL ELECTRONICS DIVISION

Intra-uterine Contraceptive Device—F. L. Hatke (MedElec, Trenton) U.S. Pat. 3,374,787, March 26, 1968

ELECTRONIC COMPONENTS

Adjustable Convergence Magnets—R. H. Hughes (EC, Lanc) U.S. Pat. 3,375,389, March 26, 1968

Method of Forming a PN Junction by Vaporization—N. Goldsmith (EC, Som) U.S. Pat. 3,374,125, March 19, 1968

Electron Tube Cathode with Nickel-Tungsten Alloy Base and Thin Nickel Coating—C. T. Lattimer (EC, Marion) U.S. Pat. 3,374,385, March 19, 1968

Field-Effect Transistor with Gate-Insulator Variations to Achieve Remote Cutoff Characteristic—J. A. Olmstead (EC, Som) U.S. Pat. 3,374,407, March 19, 1968

Heat Dissipator—D. B. Kaiser, R. Roth (EC, Lanc) U.S. Pat. 3,372,741, March 12, 1968

Method of Making a Multialkali Cathode—F. R. Hughes (EC, Lanc) U.S. Pat. 3,372,967, March 12, 1968

Vanadium-Containing Lithium—H. Lessoff, (EC, Needham) U.S. Pat. 3,372,122, March 5, 1968

Apparatus Responsive to Radio Frequency Noise for Non-Destructively Testing a Reversely Biased Transistor for Second Breakdown—P. Schiff (EC, Som) U.S. Pat. 3,371,276, February 27, 1968

Method of Making Passivated Semiconductor Devices—A. Mayer, E. F. Cave (EC, Som) U.S. Pat. 3,369,290, February 20, 1968

Method of Making Reed Switches—G. A. Shaffer, Jr., L. R. Campbell, H. L. Blust (EC, Hr) U.S. Pat. 3,369,291, February 20, 1968

Electrolysis-Resistant Electron Discharge Device—M S. Nachbar (EC, Woodbridge) U.S. Pat. 3,370,193, February 20, 1968

Composite Insulator-Semiconductor Wafer—E. F. Cave (EC, Som) U.S. Pat. 3,370,204, February 20, 1968

Self-Regulated Power Supply—G. D. Hanchett (EC, Som) U.S. Pat. 3,369,167, February 13, 1968

Method of Making Color-Kinescopes of the Line-Screen Sensing Variety—T. A. Saulnier (EC, Lanc) U.S. Pat. 3,367,790, February 6, 1968

Cascaded Thermionic Energy—W. B. Hall (EC, Lanc) U.S. Pat. 3,368,084, February 6, 1968

Four Identical Printed Coils for Horizontal and Vertical Deflection on Flexible Dielectric—G. E. Jannery (EC, Lanc) U.S. Pat. 3,368,095, February 6, 1968

Shadow Mask Welded to Frame at Twelve Points—R. C. Demmy (EC, Lanc) U.S. Pat. 3,368,098, February 6, 1968

Resistor Comprising Spaced Metal Coatings on a Resistive Layer and Traveling Wave Tube Utilizing the Same—E. S. Thall (EC, Scranton) U.S. Pat. 3,368,103, February 6, 1968

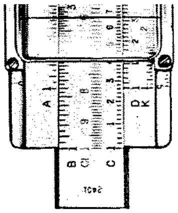
Semiconductor Devices—N. H. Ditrick (EC, Som) U.S. Pat. 3,368,124, February 6, 1968

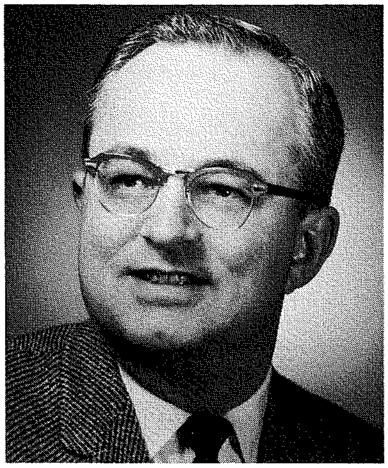
Cryoelectric Memory—R. W. Ahrons (EC, Som), D. A. Christiansen (EC, Needham) U.S. Pat. 3,372,384, March 5, 1968

AVIATION EQUIPMENT DEPARTMENT

Linear Logarithmic Amplifying Detector—T. D. Fujinami (DEP, W. LA) U.S. Pat. 3,373,294, March 12, 1968

Engineering NEWS *and* HIGHLIGHTS





BILL LIEDERBACH ELECTED A FELLOW OF THE AMERICAN CERAMIC SOCIETY

William H. Liederbach, Senior Engineer, Electronic Systems Development, Consumer Electronics Division, was recently elevated to a Fellow of the American Ceramic Society. Mr. Liederbach received the BS in Ceramic Engineering from Iowa State University in 1948 and began his career with the Electrochemical Division of the Dupont Company where he was concerned with the production and development of precious-metal compositions. From 1952 to 1956, he was a field engineer for the Dupont Company handling technical problems related to the use of materials in electronic applications. He was employed by the Centralab Division of the Globe-Union Company from 1956 to 1958 where he was in charge of a group responsible for the research and development on metalizing, printed circuits, capacitors, and metal-ceramic seals. In 1958, Mr. Liederbach joined RCA in the Microelectronics Department in Somerville, New Jersey, as a Senior Engineer. He has done an extensive amount of work in the areas of hermetic seals, metalizing, and associated production techniques for microelements. Mr. Liederbach was subsequently promoted to Engineering Leader in charge of the Development Laboratory in the Microelectronics Department. In 1962, he was named the Engineering Leader of the Ceramic Products Design Group. In 1963, he was assigned to an advanced development activity described as New Electronic Systems Development. The activity has as its objective the development of hybrid microcircuits for the manufacture of the next generation of consumer electronics products.

During the past ten years Mr. Liederbach has been Membership Chairman of the National Institute of Ceramic Engineers (1960); ASTM member on metal-ceramic seals (1958-1962); Chairman of ASTM Subcommittee VIII, C-25 Ceramics for Electronics (1962); Chairman of NEPCON Conference—Ultrasonic Cleaning of Microelectronic Assemblies (1962); First Chairman and co-founder of the Indiana Branch of The American Ceramic Society (1965) — *K. A. Chittick*

A. L. MALCARNEY DIES

Arthur L. Malcarney, Executive Vice President and a member of the Board of Directors of RCA died on May 28, 1968; he was 55. Mr. Malcarney, who had served as Executive Vice President, Manufacturing Services and Materials, previously had been Group Executive Vice President since May, 1962, with overall responsibility for the Defense Electronic Products activity, Electronic Data Processing Division, Graphic Systems Division and the Manufacturing Services Staff of the corporation. He had been a member of the RCA Board of Directors since December 1, 1961 and also served as a Director of RCA Defense Electronics Corp., a subsidiary. Mr. Malcarney was no stranger to the RCA ENGINEER readers: as Executive Vice President of DEP, he wrote of DEP's future planning in the December-January 1959 issue; more recently in the October-November 1967 issue, as Executive Vice President of Manufacturing Services and Materials, he wrote of the services provided under that function. On behalf of the Consulting Editors, Advisory Board, TPAs, and Ed Reps, the Editors offer their sincere condolences to his family.

ANNUAL T. E. WINNER AT M&SR

David Staiman was chosen as the 1967 annual technical excellence award winner. Mr. Staiman is cited for his outstanding performance during the year in conceiving and developing closely-spaced radiating elements for application in a planar array antenna. This unique concept, heretofore commonly believed to be impractical, affords an important avenue toward an all solid-state radar by permitting the free-space combination of power from a large number of moderate power devices.

Mr. Staiman's insight led to important modifications to the theory of such an antenna, and to well-planned experimental corroboration. To demonstrate this proprietary technique he conceived a 100-element transfer lens, 0.6 x 0.6 wavelength aperture, with each element equipped with a microstrip transistor amplifier circuit. The data obtained substantiated the validity of the approach and established conclusively the practicality of a full sized system. This model also corroborated the extension of the theory of radiating elements which was predicted by a computer program generated by Mr. Staiman. This technical achievement has won wide acclaim in the Engineering Community, becoming the subject of an RCA press release at WESCON 1967 and a paper at the International Solid State Circuit Conference in February 1968. A paper covering this work has also been requested by both *Spectrum* and the *IEEE Journal of Solid State Circuits.*

Paralleling this work was his activity on the Solid-State Radiating Transmitter Program. On this program he has extended the art in the design of a radiating element for a small broadside array, and his development of a 200-watt transistor UHF amplifier on ceramic substrate is the first to achieve this power level by paralleling transistor amplifiers in an integrated microwave circuit configuration.

LICENSED ENGINEERS

B. W. Siryj, DEP-AT, PE-13855-E, Pa.
J. E. Volkmann, Labs., Pr., PE-044193, N. Y.

ADVICE TO AUTHORS

If you've got a thought that's happy—
Boil it down.
Make it short and crisp and snappy—
Boil it down.
When your brain its coin has minted,
Down the page your pen has sprinted,
If you want your effort printed,
Boil it down.

Take out every surplus letter—
Boil it down.
Fewer syllables the better —
Boil it down.
Make your meaning plain—express it,
So we'll know—not merely guess it,
Then, my friend, ere you address it,
Boil it down.

Skim it well—then skim the skimmings—
Boil it down.
When you're sure 'twould be a sin to
Cut another sentence in two,
Send it in, and we'll begin to
Boil it down.

(Our thanks to Sid Weisberger who sent in this piece quoted from Canadian Public Health Journal, 1936)

TECHNICAL INFORMATION SYSTEMS ACTIVITY ESTABLISHED

Effective May 15, 1968, Product Engineering, Research and Engineering, established a new staff activity, Technical Information Systems (TIS). The TIS activity is responsible for the development and administration of RCA technical information storage and retrieval systems and a corporate-wide Technical Library Network (based on present RCA Technical Libraries) to provide information services for RCA engineering and research activities. **E. R. Jennings** was named as Manager, TIS, reporting to **G. A. Kiessling,** Manager, Product Engineering Professional Development.

A. DeStephen

A. DeStephen joined the TIS staff in May 1968 as Administrator, Technical Information Services. Mr. DeStephen received the BS in mathematics in 1958 and the MA in Library Science in 1964 both from Kent State University. From 1958 to 1962, he taught high school mathematics. From 1962 to 1965, he was Associate Librarian at the Goodyear Aerospace Corp. In 1965, he joined Harshaw Chemical Company as the Manager of Information Services. At Harshaw he was responsible for the supervision of the computerized technical information retrieval system, corporate microfilm system, and the Technical Library. Mr. DeStephen is a member of the American Society for Information Science, Special Libraries Association, and National Microfilm Association.

Dr. M. P. Barnett, a member of the staff of ISD Language Systems, has been serving as a consultant to the TIS activity on systems problems and programming approaches. **Robert Maier,** Senior Programmer, (on assignment to TIS from the Service Company) is heading up the programming effort and assisting in the systems analysis.

STAFF ANNOUNCEMENTS

Robert W. Sarnoff, President, announced that responsibility for the Medical Electronics activity has been assigned to **W. W. Watts,** Senior Executive Vice President, Defense and Commercial Systems. Mr. Watts has appointed **R. S. Holmes,** Division Vice President, Medical Electronics, who will report to **B. Kreuzer,** Division Vice President and General Manager, Commercial Electronic Systems Division.

Commercial Electronic Systems Division

A. M. Miller, Division Vice President, Instructional and Professional Electronic Systems Department, announced the organization of Instructional and Professional Electronic Systems Department as follows: **G. W. Bricker,** Manager, West Coast Operations; **M. M. Carpenter,** Manager, Training Programs and Instructional Systems Planning; **W. K. Charles,** Manager, Western Instructional and Professional Electronic Systems Sales; **R. R. Foley,** Manager, Audio-Visual Products Engineering; **A. J. Platt,** Manager, Audio-Visual Marketing; **A. W. Power,** Manager, Eastern Instructional and Professional Electronic Systems Sales; **R. A. Reynolds,** Manager, TV Relay and Instructional Product Support; and **N. R. Vander Dussen,** Manager, Scientific Instruments Engineering and Marketing.

A. L. Hammerschmidt, Division Vice President, Broadcast Engineering and Product Management, announced the organization of Broadcast Engineering and Product Management as follows: **J. H. Cassidy,** Manager, Sales Support and Services; **B. E. Fincher,** Manager, Radio Station Equipment Product Management; **T. M. Gluyas,** Manager, Broadcast Audio and Transmitter Engineering; **H. H. Klerx,** Manager, Electronic Recording Equipment Product Management; **H. N. Kozanowski,** Manager, TV Advanced Development; **A. H. Lind,** Manager, Studio Equipment Engineering; **A. C. Luther,** Manager, Electronic Recording Equipment Engineering; **R. L. Rocamora,** Manager, Antenna Engineering and Product Management; **W. B. Varnum,** Manager, Systems Engineering and Studio Equipment Product Management; **R. M. Williams,** Manager, TV Transmitter Product Management; and **H. S. Wilson,** Manager, Microwave Engineering and Administration.

R. L. Holtzheimer, Manager, Commercial Electronic Systems Manufacturing Operations, has announced the appointment of **Z. N. Trivelis,** Manager, Broadcast Studio Manufacturing.

Defense Electronic Products

I. K. Kessler, Division Vice President, Defense Electronic Products, announced the following appointments: **J. F. Burlingame,** Division Vice President and General Manager, Missile and Surface Radar Division; **J. H. Sidebottom,** Division Vice President, Defense Marketing.

M. N. Cinelli, Plant Manager, Moorestown Plant, Missile and Surface Radar Division, announced the organization of the Moorestown Plant as follows: **D. E. Dalgleish,** Manager, Manufacturing; **F. T. McGough,** Manager, Printed Circuit Manufacturing; **F. R. Freiman,** Manager, Cost and Production Analysis; **J. N. Hodge,** Manager, Security and General Services; **M. L. Ogden,** Manager, Plant Engineering; **D. L. Siegrist,** Manager, Program Planning and Control; **J. W. Thacher,** Administrator, Plant Budgets; and **M. N. Cinelli,** Acting Manager, Manufacturing Engineering.

Record Division

H. E. Jenkins, Division Vice President, Record Operations, has appointed **W. H. Dearborn,** Manager, Production and Engineering. W. H. Dearborn announced the organization of Production and Engineering as follows: **J. M. Eargle,** Manager, Quality; **H. L. Eitelabach,** Manager, Recording; **L. M. Goebel,** Manager, Manufacturing Planning and Services; **W. R. Isom,** Chief Engineer, Engineering; **R. O. Price,** Manager, Manufacturing Operations; **A. Stevens,** Manager, Facilities and Plant Engineering; **R. D. Summer,** Purchasing Agent.

Electronic Components

R. L. Klem, Manager, Sentinel Program, Solid State and Receiving Tube Division, announced the organization of the Sentinel Program as follows: **A. S. Rose,** Manager, Engineering; **S. Dansky,** Engineering Leader, Product Evaluation and Testing; **R. A. McFarlane,** Engineering Leader, Assembly and Header Preparation; **J. A. Schramm,** Engineering Leader, Wafer Processing; **C. D. Whelan,** Manager, Quality and Reliability Assurance.

T. E. Yingst, Manager, Power Devices Engineering, Industrial Tube Division has appointed **J. T. Mark,** Manager, Regular Power Devices Design Engineering. **W. W. Winters,** Manager, Marketing Planning—Conversion Tubes and Devices, Industrial Tube Division, has appointed **T. J. Grabowski,** Administrator, Market Planning—Photomultipliers. **R. T. Rihn,** Manager, Power Devices Manufacturing, Industrial Tube Division, has appointed **J. B. Pyle,** Manager, Production Engineering—Regular Power Devices.

Research and Engineering

G. H. Brown, Director, RCA Limited, and Executive Vice President, Research and Engineering, announced the appointment of **H. R. L. Lamont,** Director, European Technical Relations.

Management Information Systems

B. G. Curry, Director, Management Information Systems Programs, has appointed **T. Pearlman,** Manager, International Information Systems Projects.

RHODE ISLAND U. HONORS BROWN

Dr. George H. Brown, executive Vice President, Research and Engineering, was recently awarded the honorary degree of Doctor of Engineering by the University of Rhode Island. He was so honored at the University's dedication of the Kelley Hall Research Annex of the School of Electrical Engineering. Dr. Brown, who was the featured speaker, received the following citation during the conferring of degrees. . . . "As a pioneer in communications you have made possible many of the electronic devices which surround us and profoundly influence our lives. FM radio, color television and radar—all show the marks of your creative genius. One of the most prolific of inventors, you have developed some of the basic ideas upon which modern antennas are based. You conceived the Turnstile antenna now universally used in television broadcasting; and your inventions also make possible machines for bonding plastics and for dehydrating of penicillin. You are at home not only in the laboratory but in the business world, and your integrity, drive and insight as an executive vice president of a major industrial company have helped to put your inventions and those of your colleagues into production and use. You earned a doctoral degree when this was unusual for an engineer, and you have used your education and your creative abilities to bring benefit to mankind and great credit to the engineering profession. We welcome you to our engineering college and take pleasure in conferring upon you this honorary degree."

WCD GIVES IN-PLANT SYMPOSIA

As part of the DEP-wide program to establish a closer relationship between RCA and the universities, two engineering in-plant symposia were conducted at the West Coast Division. The first was attended by faculty and graduate students of California Institute of Technology and U. of California. The faculty of the U. of California at Los Angeles, U. of Southern California, and San Fernando Valley State College attended the second symposium.

DEGREES GRANTED

J. Amodei, Labs., Pr.	PhD., Electrical Engineering, Univ. of Penna., 8/68
J. R. Burns, Labs., Pr.	PhD., Electrical Engineering, Rutgers Univ., 5/68
J. P. McEvoy, Labs., Pr.	PhD., Physics., Univ. of London, Imperial College, 2/68
F. B. Micheletti, Labs., Pr.	PhD., Electrical Engineering, Princeton Univ., 6/68
T. J. Nelson, Labs., Pr.	PhD., Electrical Engineering, Princeton Univ., 5/68
A. G. Revesz, Labs., Pr.	PhD., Physical Chemistry, U. of Tech. Sciences, Budapest, 6/68
A. William Stephens, Labs., Pr.	PhD., Metallurgy, Univ. of Arizona, 5/68
D. Walters, Labs., Pr.	PhD., Electrical Engineering, Univ. of Penna., 5/68
L. J. Berton, Labs., Pr.	MS, Computer Science, Univ. of Penna., 8/68
E. Boleky, Labs., Pr.	MS, Electrical Engineering, Princeton Univ., 6/68
D. Flatley, Labs., Pr.	MS, Engineering Science, Newark College of Engineering, 6/68
R. S. Hopkins, Labs., Pr.	M.Phil., Electrical Engineering, Rutgers Univ., 5/68
M. Lippman, Labs., Pr.	MS, Electrical Engineering, New York Univ., 5/68
A. Varanelli, Labs., Pr.	MS, Management Science, Pace College, 6/68
I. Ashkenazy, Labs., Pr.	BS, Electrical Engineering, Polytechnic Inst. of Brooklyn, 6/68
V. Christiano, Labs., Pr.	BS, Electrical Engineering, Polytechnic Inst. of Brooklyn, 7/68
W. Homa, Labs., Pr.	BS, Electrical Engineering, Drexel Inst., 6/68
A. J. Kolpack, Labs., Pr.	BS, Commerce, Rider College, 6/68
R. Paglione, Labs., Pr.	BS, Electrical Engineering, Newark College of Engineering, 6/68
A. Smeraldi, Labs., Pr.	BS, Commerce, Rider College, 6/68
G. Weisbarth, Labs., Pr.	BS, Electrical Engineering, Polytechnic Inst. of Brooklyn, 7/68
E. Seybert, AT. Cam.	MS, Electrical Engineering, Drexel Inst., 6/86
F. E. Oliveto, DCSD Cam.	MS, Probability and Statistics, Villanova Univ., 5/68

PROFESSIONAL ACTIVITIES

Graphic Systems Division, Dayton, N. J.

R. Hensel, Product Planning, presented the photographic portion of the Graphic Arts Technical Foundation's Seminar on Process Quality Controls in Pittsburgh, Pa., 5/3/68. He also participated in the Graphic Arts Technical Foundation's Seminar on Halftone and Process Photography, 5/6-7-8/68—*Jack Gold*

Missile and Surface Radar Division

D. M. Cottler, Chief Engineer, was elected a member of Council of the Greater Philadelphia Section of AIAA. **T. G. Greene,** Technical Publications Administrator, was elected Vice-Chairman of the Greater Philadelphia Section AIAA. Mr. Greene also was recently appointed a member of the Advisory Committee on Engineering Science for Gloucester County College.

N. F. Pensiero, Defense Marketing, has been named Banquet Chairman and **J. G. Mullen,** Defense Marketing, will be responsible for Military Attendance Promotion for the forthcoming 5th Annual Meeting and Technical Display of the Philadelphia Civic Center, 10/21-25/68.—*T. G. Greene*

Aerospace Systems Division

J. W. VickRoy has been appointed Chairman of the Boston Chapter of IEEE Group on Engineering Management. **W. J. Gray** has been appointed Chairman of the Boston Chapter of IEEE Group on Reliability. **A. W. Sinkinson** served as Chairman of a Panel at the Electronics Components Conf., Wash., D. C. **Jay Prager,** Technical Staff, took first prize in the New York IEEE Student Prize Paper Contest, 4/27/68, for "A Wideband Balanced Modulator Using Field Effect Transistors." *D. B. Dobson*

Laboratories, Princeton, N. J.

Dr. J. S. Donal has been appointed Vice-Chairman of G-EWS of the IEEE *C. W. Sall*

Electronic Components, Lancaster, Pa.

O. J. Funke, Special Equipment Engineering, was elected for the fiscal year 1968-69 as the new Chairman of the Susquehanna Section of the IEEE. **C. W. Wieneke,** Industrial Tube Standardizing, was appointed to the ASTM Committee Fl on Materials for Electronics and Microelectronic Devices as Editorial Representative of Sub-Committee VII. **J. M. Forman,** Power Tube Operations and Operations Services, has been appointed Technical Advisor to the International Electrotechnical Commission (IEC) technical committee TC-50 "Committee on Environmental Testing." *J. M. Forman*

RCA Service Company, Florida

Dr. P. N. Somerville, Missile Test Project, Cocoa Beach, Fla., has been elected President of the Florida Chapter of the American Statistical Association. Dr. Somerville, Manager of Technical Evaluation for the RCA Missile Test Project, also serves as Head of the Department of Mathematics and Statistics at Florida Institute of Technology.

Astro-Electronics Division, Princeton, N. J.

M. Wolf was appointed a Member of the Energy Conversion Devices Sub-Committee of the 1968 EDM. **D. L. Paolini** was named President of the Mid-Atlantic Chapter of the Institute of Environmental Sciences. **R. Hartenbaum** is the local Chapter Director for the Mid-Atlantic Chapter of the Institute of Environmental Sciences. **G. Brucker, W. Dennehy, W. Poch, A. Holmes-Siedle** were recipients of NASA new Technology Award for developing an engineering prediction method for space radiation effects in transistors. **S. Teitelbaum** received an award from NASA for a "Unique Frequency-Shift-Keyed Demodulation System."—*S. Weisberger*

Medical Electronics, Trenton, N. J.

U. A. Frank has been elected Chairman of the Philadelphia Chapter of the IEEE Group on Parts, Materials, and Packaging. Mr. Frank has also been elected Secretary of the Philadelphia Chapter of the IEEE Group on Engineering in Medicine and Biology.—*L. Flory*

West Coast Division, Van Nuys, Cal.

R. H. Aires, Chief Engineer, has been elected Chairman of the IEEE San Fernando Valley Section for 1968. Mr. Aires, an active supporter of IEEE since his student days, was Vice Chairman of the section in 1967 at which time he served as Chairman, Engineer's Week Committee for the San Fernando Valley. He is presently also a Director of the San Fernando Valley Engineers' Council.—*B. A. Cook*

Advanced Technology, Camden, N. J.

R. Farquharson served as Chairman of a session on Interconnections at the Electronic Components Conf., Wash., D. C., 5/7-10/68. Mr. Farquharson also has been elected Secretary of the Philadelphia Chapter, IEEE Group on Parts, Materials, and Packaging. *G. Boose*

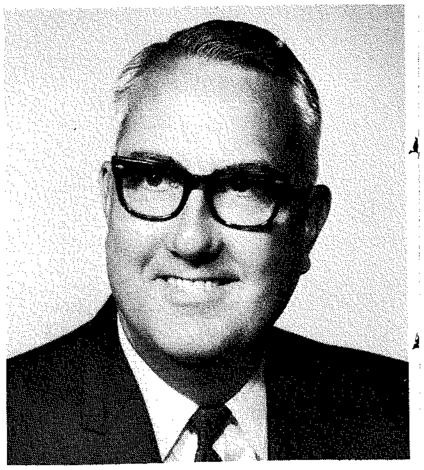
AWARDS

Missile and Surface Radar Division

The following M&SR engineers have been cited for their work during the Fourth Quarter of 1967: **H. M. Finn**—For advancing the state of the art of detection theory through application of basic Energy- and Resolution-Variant Sequential Detection techniques to multifunction airborne radar operation to overcome major problems of jamming and clutter. **B. R. Orzechowski**—For evolving the detailed design concepts required for an ultra-lightweight S-band antenna element to be utilized on advanced communications and surveillance satellites. **R. J. Renfrow**—For his outstanding accomplishment in demonstrating feasibility of an interrupted CW (ICW) mode for the TALOS replacement radar to provide greatly improved sub-clutter visibility. **P. T. Scully**—For outstanding mechanical design contributions to the Hard Tube Modulator for the Terrier System track transmitter. **G. E. Skorup**—For the evolution of unique designs of large-scale integrated arrays to provide the versatility and flexibility required for application to M&SR product lines. **R. L. Stegall**—For his outstanding accomplishments in digital systems engineering for the AN/FPS-95 program.

Astro-Electronics Division, Princeton, N. J.

Brian Stewart was recognized in March for the initiative, leadership, and technical competence which he displayed as an Engineering Leader in the Advanced Systems Activity. He spearheaded a series of skillfully prepared proposals and customer presentations which showed the operational advantages to be gained by incorporating a secondary propulsion system for orbit correction on TIROS-M type spacecraft.



MORTENSON TPA FOR INSTRUCTIONAL SYSTEMS

E. M. Mortenson has been appointed to serve as Technical Publications Administrator for the Instructional Systems Division, Palo Alto, California. In this function, he will administer the review and approval of technical papers and coordinate the technical reporting program. In addition, he will promote the preparation of papers for the RCA ENGINEER and other journals both internal and external. Ed Mortenson is presently a senior member of the engineering staff at Instructional Systems. He joined RCA in July 1967, to work with the Systems Integration Group. His duties include planning of computer sites, engineering support and documentation of field installations of student terminals, and general administrative support to engineering management. Mr. Mortenson came to RCA Instructional Systems from Stanford University where he was engaged from 1962 to 1967 in the design and construction of the Stanford two-mile linear electron accelerator. At the time, he was group leader in charge of the Electronic Systems Group in the Systems Engineering and Installation Department. Prior to joining Stanford, he was a Project Engineer with Western Union at their Electronics Research Laboratories in Water Mill, N. Y. and with the Transmission Research Division at 60 Hudson Street, New York. Projects there included a nationwide nuclear bomb alarm system for the U.S. Air Force and Telegraph Terminal AN/FGC-29 for the Signal Corps. He started his career with Western Union in 1940, while attending Brooklyn Polytechnic Institute, evening session, working toward an EE Degree He entered military service in 1942, as an Aviation Cadet and attended Pan American Airways navigation school at Coral Gables, Florida. After graduation served as navigator on Trans-Pacific routes of the ATC. He is a member of IEEE.

FLORY AND ZWORYKIN NAMED LIFE MEMBERS OF G-EMB

At its meeting on March 21, 1968, the Administrative Committee elected four Honorary Life Members of IEEE professional group on Engineering Medicine and Biology. They are: **Leslie E. Flory, John P. Hervey, Luke H. Montgomery,** and **Vladimir K. Zworykin.** These elections recognize the outstanding services which the new Honorary Life Members have rendered to engineering in medicine and biology and to the activities of GEMB. Mr. Flory is the Chief Scientist at Medical Electronics in Trenton, N. J., and Dr. Zworykin is an Honorary Vice President, Laboratories, Princeton, N. J.

The Editorial Representative in your group is the one you should contact in scheduling technical papers and announcements of your professional activities.

Defense Electronic Products		
Aerospace Systems Division	**D. B. DOBSON***	Engineering, Burlington, Mass.
West Coast Division	**R. J. ELLIS***	Engineering, Van Nuys, Calif.
Astro-Electronics Division	**H. M. GURIN***	Engineering, Princeton, N. J.
	I. M. SEIDEMAN	Advanced Development and Research, Princeton, N. J.
	S. WEISBERGER	Equipment Engineering, Princeton, N. J.
Missile & Surface Radar Division	**T. G. GREENE***	Engineering, Moorestown, N. J.
Communications Systems Division	**F. D. WHITMORE***	Engineering, Camden, N. J.
	C. W. FIELDS	Technical Communications, Camden, N. J.
	H. GOODMAN	Engineering, Camden, N. J.
	M. P. ROSENTHAL	Systems Labs., New York, N. Y.
Defense Engineering	**M. G. PIETZ***	Advanced Technology, Camden, N. J.
	I. FEINSTEIN	Defense Microelectronics, Somerville, N. J.
	H. EPSTEIN	Systems Engineering, Evaluation, and Research, Moorestown, N. J.
	J. E. FRIEDMAN	Advanced Technology, Camden, N. J.
	J. R. HENDRICKSON	Central Engineering, Camden, N. J.
Commercial Electronics Systems Division	**D. R. PRATT***	Chairman, Editorial Board, Camden, N. J.
	N. C. COLBY	Mobile Communications Engineering, Meadow Lands, Pa.
	C. E. HITTLE	Closed Circuit TV & Film Recording Dept., Burbank, Calif.
	R. N. HURST	Studio, Recording, & Scientific Equip. Engineering, Camden, N. J.
	K. C. SHAVER	Microwave Engineering, Camden, N. J.
	R. E. WINN	Broadcast Transmitter & Antenna Eng., Gibbsboro, N. J.
Medical Electronics	**L. FLORY***	Advanced Research and Development, Trenton, N. J.
Information Systems Division	**G. PAFF**	Palm Beach Engineering, West Palm Beach, Fla.
Graphic Systems Division	**J. GOLD***	Engineering, Dayton, N. J.
Laboratories	**C. W. SALL***	Research, Princeton, N.J.
Electronic Components	**C. A. MEYER***	Chairman, Editorial Board, Harrison, N. J.
Solid State and Receiving Tube Division	**M. B. ALEXANDER**	Solid State Power Device Engrg., Somerville, N. J.
	R. W. MAY	Commercial Receiving Tube and Semiconductor Engineering, Somerville, N. J.
	I. H. KALISH	Solid State Signal Device Engrg., Somerville, N. J.
	J. KOFF	Receiving Tube Operations, Woodbridge, N. J.
	K. LOOFBURROW	Semiconductor and Conversion Tube Operations, Mountaintop, Pa.
	R. J. MASON	Receiving Tube Operations, Cincinnati, Ohio
	J. D. YOUNG	Semiconductor Operations, Findlay, Ohio
Television Picture Tube Division	**J. H. LIPSCOMBE**	Television Picture Tube Operations, Marion, Ind.
	E. K. MADENFORD	Television Picture Tube Operations, Lancaster, Pa.
Industrial Tube Division	**J. M. FORMAN**	Power Tube Operations and Operations Svcs., Lancaster, Pa.
	R. L. KAUFFMAN	Conversion Tube Operations, Lancaster, Pa.
	H. J. WOLKSTEIN	Microwave Tube Operations, Harrison, N. J.
Memory Products Division	**G. R. KORNFELD**	Memory Products Dept., Needham, Mass.
Technical Programs	**D. H. WAMSLEY**	Engineering, Harrison, N. J.
Consumer Electronics Division	**K. A. CHITTICK***	Chairman, Editorial Board, Indianapolis, Ind.
	D. J. CARLSON	Advanced Devel., Indianapolis, Ind.
	R. C. GRAHAM	Radio "Victrola" Product Eng., Indianapolis, Ind.
	P. G. McCABE	TV Product Eng., Indianapolis, Ind.
	J. OSMAN	Electromech. Product Eng., Indianapolis, Ind.
	L. R. WOLTER	TV Product Eng., Indianapolis, Ind.
	R. F. SHELTON	Resident Eng., Bloomington, Ind.
Record Division	**M. L. WHITEHURST**	Record Eng., Indianapolis, Ind.
Services		
RCA Service Company	**B. AARONT**	EDP Service Dept., Cherry Hill, N. J.
	W. W. COOK	Consumer Products Service Dept., Cherry Hill, N. J.
	L. H. FETTER	Govt. Service Dept., Cherry Hill, N. J.
	M. G. GANDER*	Consumer Product Administration, Cherry Hill, N. J.
	K. HAYWOOD	Tech. Products, Adm. & Tech. Support, Cherry Hill, N. J.
	W. R. MACK	Missile Test Project, Cape Kennedy, Fla.
RCA Communications, Inc.	**M. L. HUTCHINS***	RCA Communications, Inc., New York, N. Y.
New Business Programs	**L. F. JONES**	Engineering, New Business Programs, Princeton, N. J.
National Broadcasting Company, Inc.	**W. A. HOWARD***	Staff Eng., New York, N. Y.
RCA International Division	**C. A. PASSAVANT***	Clark, N. J.
RCA Victor Company, Ltd.	**W. A. CHISHOLM***	Research & Eng., Montreal, Canada
Education		
Instructional Systems Division	**E. M. MORTENSON***	Instructional Systems Engineering, Palo Alto, Cal.

*** Technical Publication Administrators**