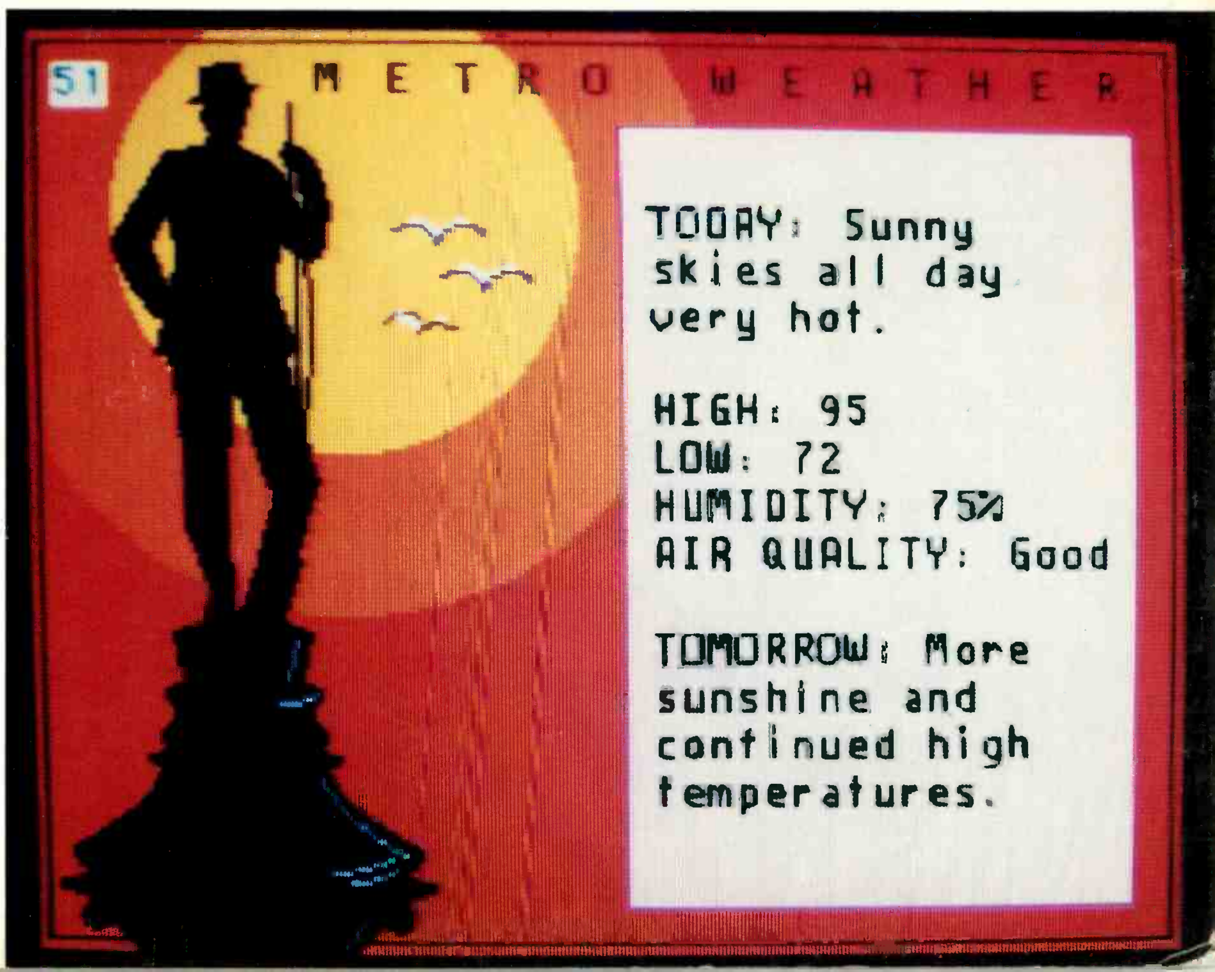
RCA Engineer

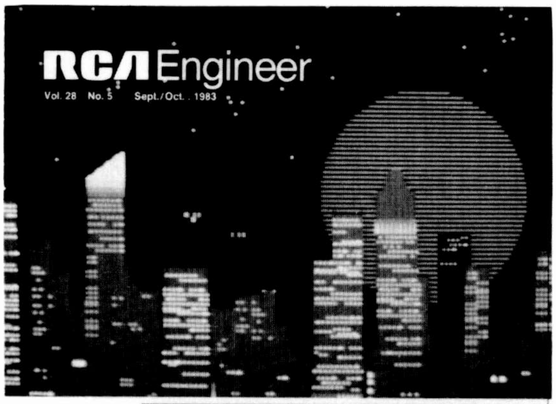
Vol. 28 No. 5 Sept./Oct. 1983

Digital Broadcast

NBC & NABTS Present Teletext

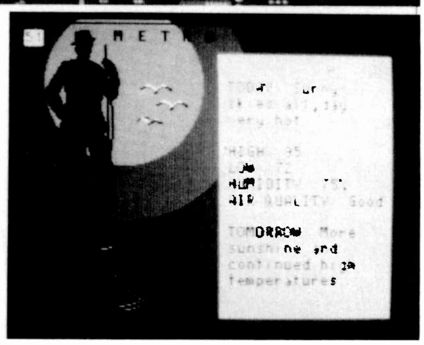


Front cover graphics produced by Laurence Merritt and James Kimac (Art director: Annette Geyer) of NBC Teletext



DIGITAL BROADCAST

NBC & NABTS PRESENT TELETEXT



NBC Teletext, based on exciting new digital broadcast technology, promises to be an entirely new medium for the exchange of information. Some have called it an "electronic magazine," but it could eventually offer much more. Graphics are one of the main concerns of teletext producers, and NBC—as our cover shows—is no exception. The front cover images were made at NBC with equipment and software from Videographic Systems of America. Thanks to Barbara Watson at NBC Teletext, New York, we can show them to you.

NBC transmits teletext "pages," over-the-air, in the vertical blanking interval of the standard TV picture. Today, few people own the decoders needed to see the images we've reproduced, but they are in development. The system operates according to the North American Broadcast Teletext Standard (NABTS) currently being refined by standards-setters at RCA Laboratories and elsewhere (see the article on page 15 by Brian Astle).

NABTS partisans point to two key advantages of the variable coding that their system uses—superior graphics, and software compatibility with videotex systems (videotex essentially operates as a two-way teletext transmitted over telephone and cable-TV lines). NABTS alpha-geometric graphics give reliable color and identifiable reproduction of company logos—a must for attracting advertiser support.

—MRS

RCA Engineer

A technical journal published by
RCA Technical Excellence Center
13 Roszel Road
P.O. Box 432
Princeton, NJ 08540
TACNET: 226-3090 (609-734-3090)

• 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.

K.H. Powers

The changing environment for technical standards

Imagine moving into your newly constructed home and finding that your electrical subcontractor has installed the latest in improved technology for the wiring, connectors, and control circuits. Very good so far, but suppose also that the voltage and frequency are different from those of your appliances and none of the old plugs will fit the new sockets.

This extreme case illustrates misplaced marketplace standards, and one finds it difficult to imagine that any responsible industry could permit such a chaotic situation by not setting specifications for compatibility across system interfaces. Yet, the broadcast industry is facing just such a dilemma today in the wake of landmark Federal Communications Commission (FCC) decisions on stereo AM, teletext, and, imminently, multi-channel television sound.

Many *de facto* standards serving us well today arose because a competitive shake-out in the market left a few products that, at the time of their introduction, either stood alone or did not require interfacing with other systems. The ¾-inch U-Matic videotape cassette is a good example. In the absence of a shake-out, the marketplace fails, leading to multiple standards that are often detrimental to all concerned, particularly when one standard has little to offer over another.

In response to the FCC's moves toward deregulation, the television industry is forming the new Advanced Television Systems Committee. The Committee will coordinate the development of voluntary U.S. national standards for the generation, distribution and reception of improved-quality television signals made possible through emerging new technologies. The intention of the Committee is to anticipate the technology and to set specifications for interfaces before new products create incompatibilities.

Whereas U.S. television standards organizations are desperately trying to head off a total collapse, the international environment for standards in some ways has been greatly improved in recent years. The international arena (especially in television) has long been dominated by nationalistic pride and political considerations. The international standards bodies such as the CCIR have had to be content with documentation of existing national standards as a thwart to the proliferation of unnecessary new ones. The historic event that occurred in 1982, when the CCIR Plenary Assembly adopted unanimously a single specification for the signal interface in the all-digital television studio, constituted a new high in international technical cooperation.

The euphoria of this unprecedented success will linger as groups of nations are now busily reaching agreements rather than hotly debating such new possible standards as analog component interfaces and extended-definition television for new transmission systems such as the Direct Broadcast Satellite.

RCA engineers have historically contributed to television standards development and are continuing to do so in the interests of RCA and the television industry. Although this issue of the *RCA Engineer* highlights the applications of digital technology in television, the thread of standardization issues permeates much of the work reported.

Kerns H. Powers
Staff Vice-President,
Communications Research
RCA Laboratories

RCA Engineer

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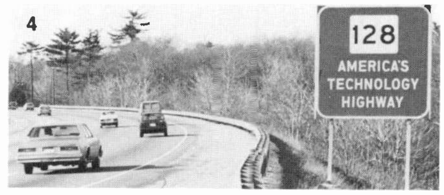
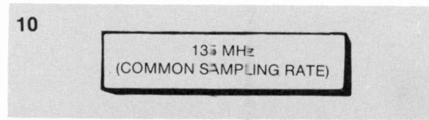
in this issue ...
digital broadcast

■ **Skavicus:** *"We have over 100 military contracts and will continue to expand our leadership role in all our systems areas."*



■ **Hurst/Powers:** *"The document produced by the CCIR (Comité Consultatif International des Radio Communications) . . . took a great step toward the establishment of a true international television exchange medium."*

■ **Astle:** *"I believe that the ability to choose timely and attractively presented information without apparent cost will make teletext a popular service . . . ."*



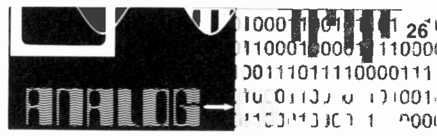
■ **Marlowe:** *"RCA engineers will not merely witness the change from analog to digital TV—we will create much of it."*

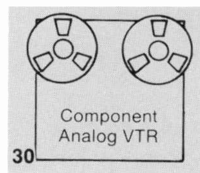
■ **Gurley/Haslett:** *"Recently, the concept of a component analog studio, centered on a component analog VTR, has received much attention . . . ."*

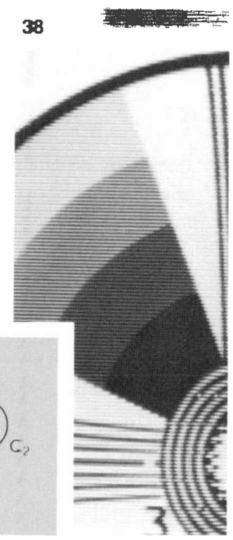
■ **Reitmeier:** *"The appropriate use of tape format to distribute dropout errors in the television raster allows the use of two-dimensional signal processing to conceal errors."*

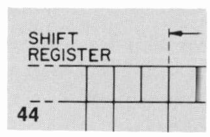
■ **Acampora:** *"The digital filters presented in this article have wider bandwidths than the analog filters currently used to extract vertical detail in pictures."*

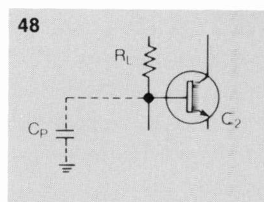
■ **Babcock/Rodda/Wedam:** *". . . . operation of the horizontal scanning system at double the normal scan rate presents major problems due to stresses imposed on the horizontal output transistor and damper."*



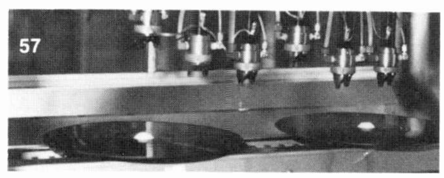








■ **Hakala:** *"An improved understanding of disc-surface physics and chemistry, and their relation to formulation and molding process conditions, will result in a more efficient surface treatment and lubrication."*



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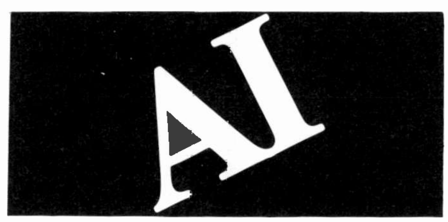
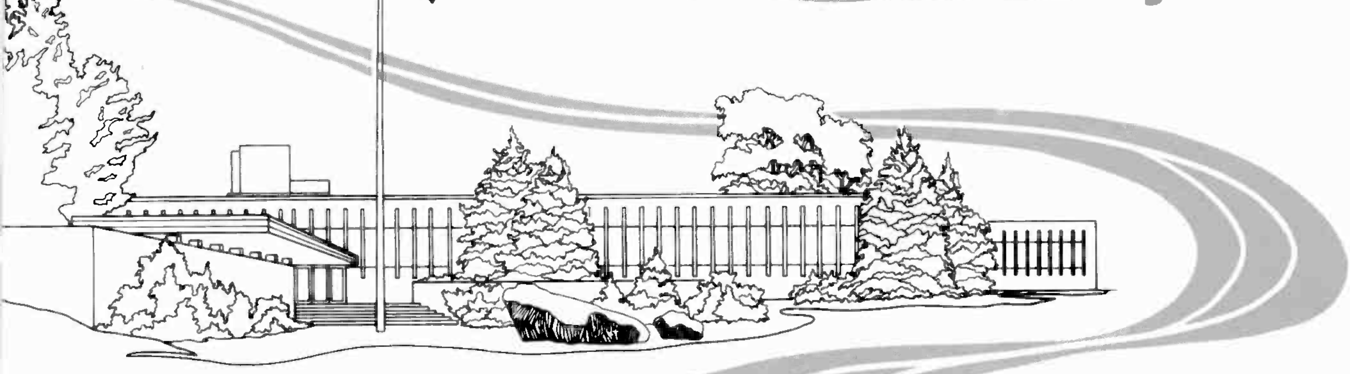
in future issues...
software,
manufacturing,
automating the engineer's workplace
technical excellence



RCA Automated Systems



Twenty-five Years on America's Technology Highway

By A.J. Skavicus

For over a quarter of a century, Automated Systems (AS) has been in the forefront of America's high-technology revolution. Route 128 (a beltway surrounding Boston, Massachusetts), was recently dedicated as America's Technology Highway because this area is recognized as the birthplace of high technology.

Like "Silicon Valley," the term "Electronics Row" is often used to describe the hundreds of companies involved in high-tech work in our area. Automated Systems, geographically located in the heart of "Electronics Row," started and continues to be in the fast lane of America's Technology Highway. High-quality, low-cost manufacturing capabilities have allowed our engineers and scientists to create superior systems and products. These have become our trademark in military circles. The axiom that "success breeds success" applies to Automated Systems. But, our success was no accident.

Careful corporate planning went into the formation of Automated Systems. Engineers were added in direct response to program needs, and they were selected based on their outstanding technical ability. The Burlington plant was constructed in 1958, and a complement of 450 technical and support people were moved into the new facility. This move marked the beginning of our first 25 years.

Our early involvement in certain technologies, which only today are catching the public's attention, is depicted in the technology chart shown to the right. This chart—presented in five-year increments—depicts some of the major technical advances, starting with the early space programs and leading to our current business areas.

Inertial guidance systems, one of the advanced technologies of the fifties, was also one of the first projects at AS. To support this growing technology, a unique analog computer was acquired. Archaic by present standards, it was sophisticated for that era. The combination of knowledgeable personnel and well-equipped facilities enabled us to bid and win the SAINT System program (Satellite Inspector). The successful effort on this program provided the basis for our early entry and long history of supporting subsequent space programs.

During our first five years in Burlington, many other advanced technologies were investigated and applied to military programs. Extensive effort was applied to electro-optics, lasers for ranging applications, miniature computer developments, as well as unique mechanical design techniques using weldplate design. At RCA, lasers and mini-computers were not a product of the seventies, but of the fifties!

Final manuscript received August 30, 1983.
Reprint RE-28-5-1

Technology Trend Chart

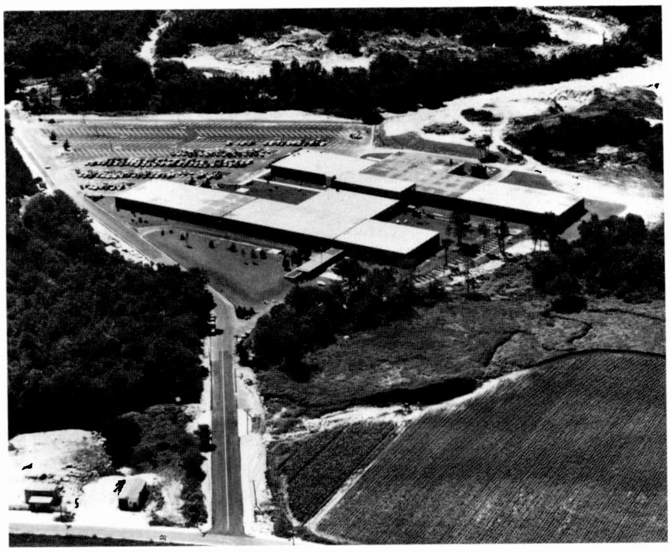
○ EARLY SPACE PROGRAMS
1 Interial Guidance System
2 SAINT
3 LEM (ATCA, DECA)
4 Rendezvous Radar

□ AUTOMATIC TEST SYSTEMS
1 Multi Purpose Test Equipment
2 DIMATE
3 APTE
4 LCSS
5 AMACS
6 AEGIS/ORTS
7 EQUATE
8 USM/410
9 HELLFIRE
10 AH-64
11 RPV
12 NARF
13 AN/GSM-285
14 PLSS
15 ATSS

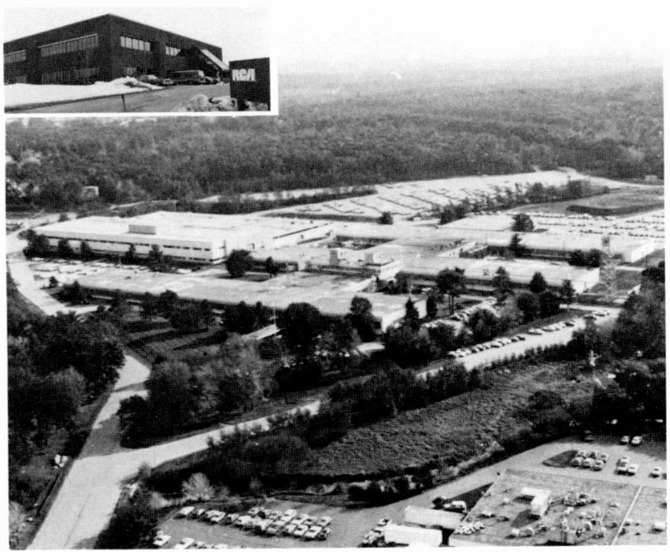
△ C^3I SYSTEMS
1 Infrared, LASERS, Mini-computer, Electro-optics Study Contracts
2 ADA
3 AN/TSW-7
4 TIPI
5 AN/GVS-5
6 REMBASS
7 TCAC
8 DFAS
9 EIFEL
10 A^3
11 Project E
12 USAFE Terminal
13 LASER TRANS Modules
14 Expendable Decoy
15 Schottky Barrier Camera

⬡ VEHICLE TEST SYSTEMS
1 BITE
2 ATSJEA
3 STE/ICE
4 STE-M1/FVS
5 STE-X
6 VMS
7 SPADE
8 Vetronics

	EARLY SPACE PROGRAMS	AUTOMATIC TEST SYSTEMS	C^3I SYSTEMS	VEHICLE TEST SYSTEMS
58–63	1, 2	1	1	
63–68	3, 4	1, 2, 3, 4	2, 3	
68–73	3, 4	3, 4, 5	1, 2, 3, 4	1
73–78		4, 6, 7, 8	1, 3, 5, 6, 4	2, 3
78–1983		6, 7, 9, 4, 10, 11, 12, 8, 13, 14, 15	1, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	3, 4, 5, 6, 7, 8



Automated Systems—1958.



Automated Systems—1983 (Inset: Avionics Test Facility).

Sixties

From 1963 to 1968, on America's Technology Highway, AS created and expanded new technologies used in such systems as automatic test equipment, infrared fiber optics, electro-optical signal processing, advanced airborne radar, and space systems. AS was awarded contracts on the Lunar Excursion Module (LEM). For that work, the David Sarnoff Award for Outstanding Technical Achievement was received in 1970. The LEM contracts helped us secure an honored position in the space program. With the development and production of the Rendezvous Radar, the ATCA (Attitude and Translation Control Assembly), and DECA (Descent Engine Control Assembly), we pulled into the passing lane. All 13 LEMs were outfitted with equipment that was designed, developed, and produced by AS.

During this time, AS also began developing one of its current major product lines—Automatic Test Systems. The initial contract for Multi-Purpose Test Equipment (MTE) was started in 1962 and completed in 1964. Follow-on work in this area for the U.S. Signal Corps resulted in the development and production of Depot Installed Multi-Purpose Automated Test Equipment (DIMATE) in the Tobyhanna Depot, Pennsylvania. This equipment performed in an exemplary fashion. It established AS as the recognized leader in automatic test equipment. Additional study contracts were completed, solidifying our position with the Missile Command of the U.S. Army, Huntsville, Alabama.

The technology developed by AS for the Army was also used, through technology transfer programs, in the development of equipment for the RCA Picture Tube Division. The Automatic Programmed Test Equipment (APTE) was developed to automatically test color kinescope tubes. A series of tests were programmed to evaluate these tubes on a "go, no-go" basis. The equipment was subsequently installed in the Marion, Indiana picture-tube plant. In 1968, the engineering team responsible for this project received the David Sarnoff Award for Outstanding Technical Achievement.

Seventies

As AS entered the seventies, it was still in the fast lane on America's Technology Highway. Automatic Test Equipment (ATE) was emerging as a very important product line. MICOM had contracted for the Land Combat Support System (LCSS), and 48 systems were fielded.

Again, the techniques developed for military applications were applied successfully to commercial ventures. Equipment was designed, developed, and built by AS for Walt Disney World, Florida. Overseeing the facilities, utilities, fire protection, security, and public health and safety is an integrated network of computers. These computers, interconnected in a multi-threaded manner, form the nucleus of an Automatic Monitoring and Control System (AM&CS) that keeps its fingers on the pulse of the entire Walt Disney World complex. The system was designed such that failure of critical elements results in a gracefully degraded mode of operation without loss of critical information.

Also during the 1968-1972 years, AS became heavily involved in airborne programs, the precursors of our Command, Control, Communications/Intelligence (C^3I) business. The Post Attack Command and Control System—Airborne Data Automation (PACCS-ADA) was an automated system for the SAC Airborne Command Post facility that demonstrated the feasibility of automating functions presently performed by the airborne battle staff. The system was built around an RCA-developed Variable Instruction Computer (VIC). The most significant system-integration problems were in the selection of existing data-processing technology suitable for use in the airborne environment and the integration of PACCS-ADA into an existing aircraft. In the latter case, the system required compatibility with radiofrequency equipment operating over a 15-kHz to 10-GHz frequency spectrum. AS, now moving at top speed, won one of the Tactical Information Processing and Interpretation (TIPI) contracts.

The TIPI System, still operational, is a land-based system that is transported by mobilizer, truck, helicopter, aircraft or ship. The system is designed to increase the capability, improve the timeliness, and increase the accuracy of intelligence information by automating certain combat intelligence tasks. The Display Control/Storage and Retrieval (DC/SR) segment of TIPI consists of shelter-mounted equipment, computer software, intelligence data, and facilities. This segment, designed for use by the

USMC and the USAF, interfaces with other segments of the TIPI System and other existing field systems.

The Air Traffic Control Central (AN/TSW-7,7A), developed in the early 1970s under contracts with the U.S. Air Force and the U.S. Army, is a transportable, self-contained system that provides the communication facilities and meteorological data needed to control aircraft at or within the terminal area of a landing site. It can be deployed at an unprepared site to support tactical operations, and then be redeployed within a matter of hours. It can also be used at large bare-base tactical airfields. To date, 45 production-models and 4 development-models have been produced at AS.

From 1973 to 1978, AS added its skill in automatic test technology to the AEGIS program by joining the RCA Moorestown team. The data acquisition, control and display for the Navy's Operational Readiness Test System (ORTS) provides on-line, real-time monitoring of the status of the AEGIS Naval Weapon System. It was designed to determine operational readiness at system and equipment levels, to evaluate performance degradation and recommend reconfiguration, and to provide centralization of maintenance functions for display and control that can be operated with minimal personnel training. Specific goals to be achieved were fault-detection coverage of 90 to 95 percent with a false-alarm probability not greater than one percent.

The application of minicomputers started in 1968 when AS used a minicomputer for the APTE program. In 1974, the Wells Fargo building-management system was designed using many of the devices developed for APTE. The Wells Fargo system manages a major San Francisco skyscraper, two other local buildings and a building located forty miles away. In addition to providing security that set a new standard for the banking industry, the system optimized the mechanical systems operation in the conservation of energy. The minicomputers were configured with redundant peripherals to preclude interruption of system operation. The printed circuit boards required by this system used the Computer Automated Design System (Applicon) that was installed at AS in 1972 and augmented in subsequent years. This technology represented the early use of CAD/CAM and again kept us in the heavy traffic now found in the passing lane of the highway.

In the mid-seventies, Automated Systems became very active in the development of simplified test equipment for internal combustion engines (STE/ICE). However, simplicity of operation meant sophisticated hardware and software based on ingenious testing techniques. AS developed the concepts and rationale behind these techniques: performance testing while at engine idle speed, power testing, ignition-system analysis and starter-current waveform analysis.

The mid-seventies also marked the introduction of hybrid technology at AS. Size, weight, performance, and volume are traditional hybrid-microcircuit driving requirements. Each of these factors was important in developing circuits for the third-generation ATE, later to be called the AN/USM-410.

The introduction of hybrid technology represented a major advancement in our manufacturing capability. This technology put us ahead of the competition. Typical of our hybrid technology was the digital stimulus buffer hybrid, made up of 10 beam-lead diodes, 12 beam-lead transistors, 2 chip capacitors, and 18 thick-film resistors. The package had leads for edge-type connection of a printed circuit board. The conformally-coated circuit provided a heat sink to permit power dissipation of 2 W under maximum specified load conditions. In the test system, the digital stimulus/buffer was used to drive a Unit Under Test (UUT) with signals whose high and low voltage levels were programmable over a range of −20 V to +20 V. The pulse width and pulse-repetition rate were controllable from programmable switching signals.

Eighties

The eighties have brought rapid growth in our three major product lines—Automatic Test Systems, Vehicle Test Systems and C^3I Systems. The competition for military business has heated up and technology continues to push forward at an accelerating rate.

Some specific advanced technology areas of interest to AS in the eighties are high-density fail-safe microprocessors; bubble memories; user-friendly display and control devices; fiber-optics data buses; survivable external communications; ultra-rapid communications switching and reconstruction techniques; system-security methods; staring infrared imaging devices; image-pattern recognition; trackers; lighter-weight structures; extremely effective environmental protection techniques; and, most important of all, efficient software, including new developments such as common English languages and artificial intelligence techniques.

Our challenge in the eighties is to keep our ongoing products current and to evolve new products using the diverse advanced technologies to satisfy customer needs. In the following paragraphs, the current status of our three major product groups is discussed, along with some of the technical challenges we face in each group.

Automatic Test Systems

Our major Automatic Test System product, the AN/USM-410, is in peak production with 132 systems ordered and 71 delivered.

The AN/USM-410 is the Army's standard ATE for intermediate and depot levels. It is deployed worldwide in support of every major Army combat and combat-support system. For example, it supports the Abrams M1 battle tank, the AH-64A attack helicopter, the Sgt. York air defense gun, the Firefinder (a mortar-locating radar), and tactical field radios. Many of these systems are only now being introduced to the field, and they will be part of the Army's arsenal into the 21st century. RCA and the Army will make the current AN/USM-410 a platform for technology insertion by assuring test capability and ATE maintainability with the systems it supports.

In parallel with the AN/USM-410 production, work is proceeding on a new-generation system to match future customer needs in Test Program Sets, hardware architecture, and software.

Improvement in Test Program Set (TPS) generation is necessary. Test Program Sets are the software and interconnecting devices that make it possible for a computer-controlled automatic test system to evaluate and diagnose the condition of Units Under Test. Early TPS development, even for 1960s technology, was engineering-manpower intensive, costly, and time-consuming. Currently, test-set designs are written in the high-level, English-like ATLAS language. Compilers perform vocabulary and syntactical analysis of ATLAS programs, helping the designer debug his program before trying it on the ATE. To assist the engineer, an automated test library has been developed. Additionally, a family of automatic test generators is available for testing complex, high-density digital circuits.

There is a strong demand for more-flexible automatic test system architectures. Users must have the ability to meet changing requirements and support new technologies. This user demand is driving automatic-test-system design toward modular, reconfigurable architectures.

The reconfigurable architectures are being implemented through the use of distributed microprocessor networks. Each function contains a processor that controls its operation and data processing, with a central processor coordinating the system operation. Interconnecting the system through a bus network permits functions to be added, deleted, or relocated without disturbing system operation.

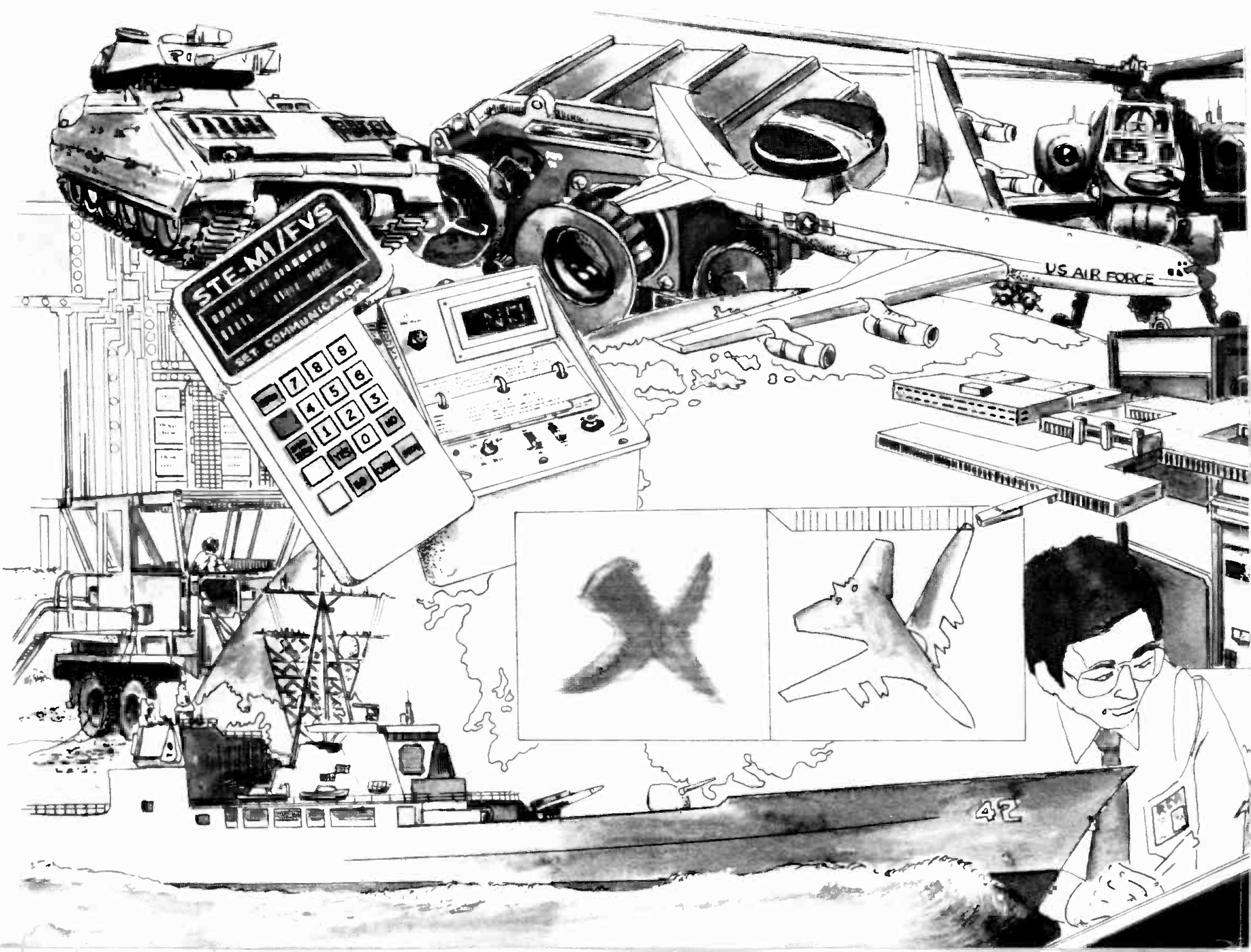
The software to control such a system is based on a modern, modularly structured operating system. Application software is written in the latest version of ATLAS and compiled on a newly developed syntax-driver compiler. ADA is used as the program-design language for all of the software being developed.

In addition to the development of a new generation of automatic test system products, work has also started on the evolution of Automated Systems Total Integrated Logistics Support concepts that will use most of the advanced technologies previously discussed.

Vehicle Test Systems

To date, almost 7,000 Simplified Test Equipments (STE) have been ordered. The concept of simplified test equipment evolved from a military requirement to solve complex diagnostic problems as close to the front line as possible. The complexity of new and emerging equipment and their associated technical manuals, coupled with the complex diagnostics they required, were major problems. AS has developed four test sets: STE/ICE (STE for Internal Combustion Engines), STE-M1 (STE for the M1 Abrams Tank), STE-M1/FVS (STE for the M1 Abrams Tank and M2/M3 Bradley Fighting Vehicle Systems), and STE-X (STE that is expandable to new and existing combat vehicle systems and engines). STE-M1/FVS tests the whole vehicle, that is, all of its mechanical and electronic subsystems. In 1980 the David Sarnoff Award for Outstanding Technical Achievement was presented to the AS team for work on STE/ICE in recognition of this fact. As pioneers of this state-of-the-art technology, we have earned a worldwide reputation for leadership in Vehicle Test Systems.

Using the vehicle experience gained from our STE programs, we have begun the evolution of significant concepts in the field of VETRONICS (Vehicle Electronics). The VETRONICS concepts involve the requirements for integrated operation of vehicles, with minimal or no crews, in a variety of missions. Conceivably, VETRONICS will involve every advanced technology area discussed earlier.



C^{3}I Systems

Our C^{3}I Systems involve diverse products, such as sophisticated surveillance and target-acquisition sensors, communications, distributed data-processing subsystems, and effective man-machine interface subsystems. Three of our current C^{3}I Systems programs are TCAC, REMBASS and AN/GVS-5.

Our largest C^{3}I program is the Technical Control and Analysis Center (TCAC) (AN/TSQ-130V). The system satisfies the primary mission of providing Army division and corps commanders with Signals Intelligence processing/reporting and electronic warfare management support. A three-shelter configuration can be deployed to support the Tactical Operations Center (TOC). The shelter hardware, software, and communications architectures necessary to fulfill the TCAC mission also provide a flexibility that allows a single shelter or a group of shelters to satisfy the military requirements either for a mobile communications or analysis facility. Major components of each shelter are the following: a Militarized Super Minicomputer, three dual-screen operator workstations, a line printer, radios, crypto gear, a magnetic tape unit, and a disk drive. This configuration provides considerable system flexibility. TCAC systems are operating successfully with the U.S. Army in Europe.

The REMBASS program is an Army program started in the mid-seventies to provide a detection system for use on the battlefield. The REMBASS system consists of three main subsystems—the sensors, repeaters, and monitoring equipment. Information picked up by the various sensors is transmitted over a VHF data link to manned monitoring sets, either directly or via repeaters that can be on the ground or in aircraft.

The system can be deployed with only one or more sensors. The number is limited only by the available frequencies and the operator's capability to integrate the information. REMBASS is a passive system. It uses magnetic, infrared, seismic/acoustic, analog, and strain-cable sensing devices. Transmissions are in short bursts that provide a low electromagnetic profile, and make detection difficult. Once emplaced, the sensors are unattended for long periods of time.

Repeaters are required to overcome range limitations and line-of-sight obstacles between sensors and monitor; single or multiple repeaters can be deployed to extend the range. The REMBASS program has completed its development phase and is about to go into limited production.

The AN/GVS-5 is a hand-held laser rangefinder that was developed for the Army by AS. It is a lightweight (2.3 kg), inexpensive device that determines the range to a distant object. The rangefinder has an emission wavelength of 1.06 microns, a range of 200 to 9990 meters, and a range error of ± 10 meters. It features built-in self-checking and is a highly reliable rangefinder with greater than 30,000 mean rangings between failures. Since 1974, almost 7,000 rangefinders have been ordered and over 5,200 have been produced. The David Sarnoff Award was received for work on this project in 1978.

Building on our experience gained through programs like TCAC, REMBASS and AN/GVS-5, work has begun on system concepts to support all Tactical C^{3}I missions and selected Strategic C^{3}I missions. The scope of these C^{3}I concepts involves all of the advanced technology areas discussed earlier.

Automated Systems has been and continues to be in the forefront of the high-tech field. Our accomplishments in the early space program, Automatic Test Systems, Vehicle Test Systems, and C^{3}I Systems, along with our long history of producing high-quality, low-cost products for the military, has resulted in the explosive growth we are experiencing today.

We have over 100 military contracts and will continue to expand our leadership role in all of our systems areas. Our seasoned professionals are blending their expertise with that of talented new people to assure an expansion of our technological expertise that will keep us in the fast lane of America's Technology Highway.

Albert J. Skavicus graduated *Summa Cum Laude* from the Catholic University of America, Washington, D.C., in 1943 where he received a BSEE degree. After Navy service, he joined RCA as an engineering trainee in 1946. He was promoted to Design Leader in 1952 and Design Manager in 1955. From 1955 to 1969 Mr. Skavicus had management responsibility on numerous ATE programs. Currently, Mr. Skavicus is Manager of Engineering Services at Automated Systems.
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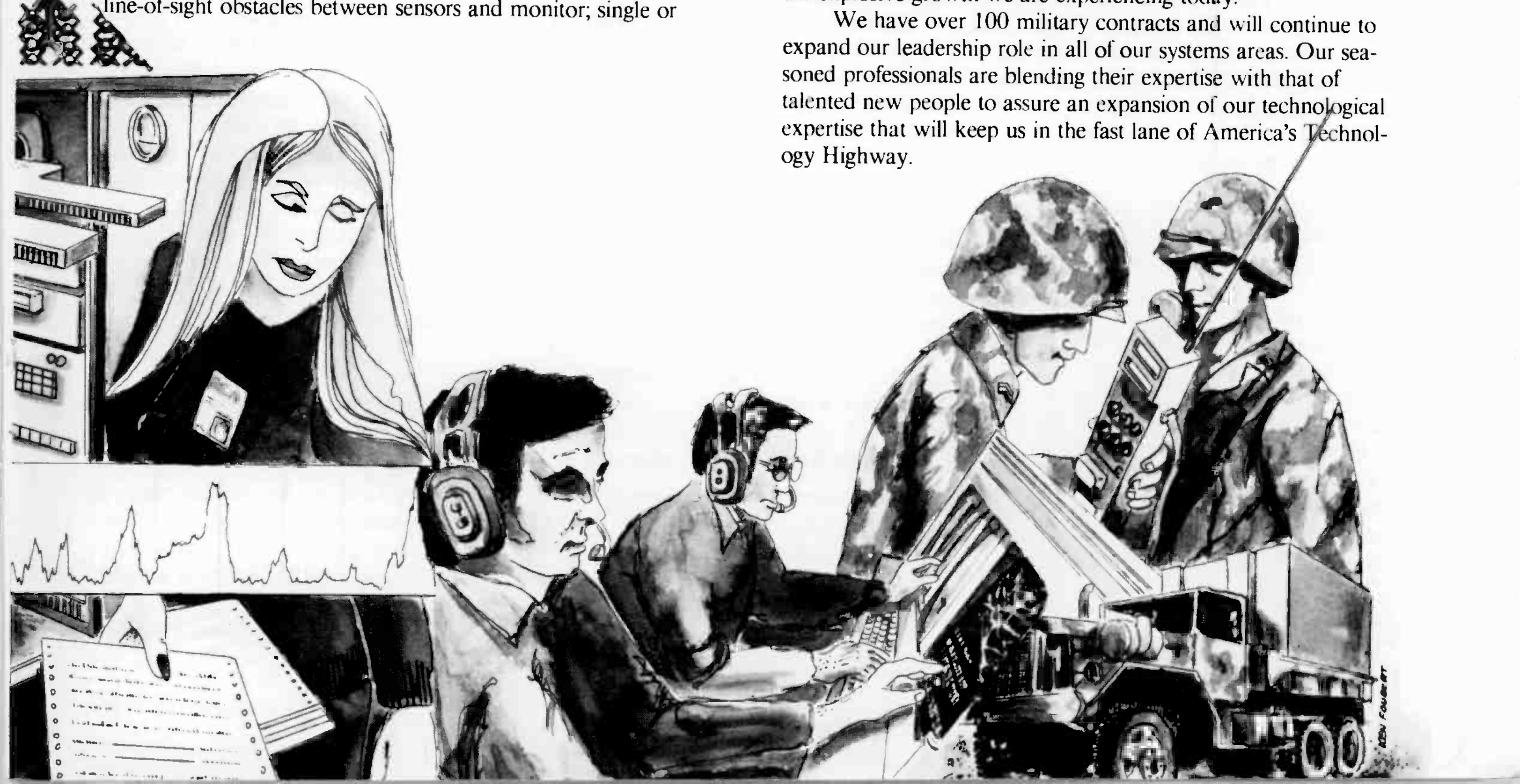

R.N. Hurst | K.H. Powers

The development of international television standards

Thanks to a serendipitous shift in the American color-subcarrier frequency 30 years ago, a composite digital sampling frequency relating the American and European television standards has been found today.

Television is a surprisingly ancient technology. Although many people firmly believe that TV began in the 1950s era of Kukla, Fran, and Ollie, the fundamental development of the technology actually took place in the nineteenth century. In fact, one of the more significant milestones—the invention of live scanning of a picture—was conceived and patented by Paul Nipkow nearly 100 years ago, in 1884.

Nipkow's elegantly simple invention—a rotating disc, filled with holes set in a spiral, that caused a flying spot of light to probe the object to be televised—was the key to practical television, and formed the basis for the first actual transmission of pictures nearly 45 years later. However, to reconstruct the pictures scanned by this method, the receiver needed to have an exactly matched disc with exactly the same number of holes, spinning at exactly the same speed. This need for identical scanning at transmitter and receiver created a "lock-and-key" arrangement; a receiver not constructed to be identical to the transmitter would be "blind" to the transmitted images. And, although television technology quickly moved from mechanical scanning with a disc to modern all-electronic scanning, the "lock-and-key" situation remained characteristic of television.

Abstract: *The authors briefly review the history of television standards as background for their history of digital television standards on both sides of the Atlantic Ocean. Component encoding's advantages over composite encoding are explained. The authors describe the efforts of the European Broadcasting Union, the Society of Motion Picture and Television Engineers, and most recently, the Comité Consultatif International des Radiocommunications, now on the road to a true international digital transmission standard.*

Final manuscript received July 25, 1983.
Reprint RE-28-5-2

Unfortunately, television's development was not coordinated among the various countries during the industry's formative years, and the "locks" and their corresponding "keys" were different in the various countries. At first, this was not thought to be a serious problem, since everyone thought that both distances and language barriers would preclude the exchange of programs among nations, anyway. But videotape recording and satellite transmission demonstrated that the inability to exchange video signals among nations was indeed a serious problem and was one destined to get worse, not better.

Television transmission standards

For several decades, the television industry has tolerated the existence of three major standards of picture transmission—the 525-line, 30-picture-per-second standard developed in the United States (called NTSC, for National Television System Committee); the 625-line, 25-picture-per-second standard originated in Europe (known as PAL, for Phase-Alternate Line); and the French-conceived 625-line system known as SECAM, from the French acronym describing its unique method of transmitting color signals. As satellite interconnections proliferated, and as the exchange of tapes among nations became commonplace, the industry developed large converter racks that could translate between standards, but these were very expensive and more than a little inconvenient to use.

Furthermore, the manufacturers of television equipment, most of whom addressed the worldwide market, found themselves burdened with the expense of producing three different versions of their basic designs, which raised the cost of all three versions.

This sorry state of affairs seemed to be doomed to permanence, since the public's billions of dollars worth of receivers could not be made obsolete by abruptly and arbitrarily changing to a common standard. That would be unreasonable.

History of digital transmission

However, the seeds of an opportunity for change had been sown in 1949 at Bell Telephone Laboratories. In that year, a researcher named W.M. Goodall transmitted television pictures using digital techniques, and reported his results in a paper delivered at the National Convention of the Institute of Radio Engineers (IRE) in

New York City, in March. The advantages of the system were clearly demonstrated, but the high cost of digital transmission did not, in 1949, justify the advantages gained. Mr. Goodall's work was published in the *Bell System Technical Journal* in January of 1951 (Vol. 30; p. 33), and the work was then quietly forgotten for nearly thirty years.

Then came the transistor, followed by the integrated circuit, followed in turn by large-scale integration, which gave rise to low-priced, high-capacity digital memories. Suddenly, the television industry realized that these new computer components would give low-cost ways to store and manipulate the video signal—if it were converted to digital form. The Bell Labs work of 1949 was dusted off, and the move to digital television was on.

Initially, the conversion of a TV picture to digits was done in a very straightforward manner: the "composite" signal—so named because it carried, on one wire, all the luminance and color components of the signal—was fed into a high-speed digitizer, which converted the composite signal to an 8-bit parallel digital signal. Since the TV signal (in the United States) has a bandwidth of 4.2 MHz, the well-known Nyquist criterion required that the conversion be done at an 8.4-MHz rate, or faster. In fact, it was discovered very early that the conversion rate should be a multiple of the color subcarrier frequency, which is embedded in the normal TV signal to carry the color signals. In the United States, this frequency is 3.579545 MHz, so the conversion rate of these early digital systems was pegged at three times this frequency, or 10.738635 MHz.

Most, if not all, of these early systems were "black boxes." They were self-contained digital systems that received a normal analog TV signal at their inputs, did all the conversion, manipulation, and reconversion internally, and delivered a standard analog signal at their outputs. The most common manipulation was time-base correction, whereby a system receives a "nervous," jittering signal from a videotape recorder, stores it temporarily in a digital memory, and reclocks it from the memory as a stabilized, nonjittering signal. Later, black boxes using more digital memory managed to eliminate the picture "roll" seen on switching from, say, a studio signal, to a signal from a sports stadium. Still later developments of these systems permitted a whole new class of special effects, with picture-size changes ("electronic zoom"), left-or-right "slide-offs," and picture rotations being the most-easily described.

Rise of digital standards

As television engineers continued to pursue this area, better and higher-speed digitizers soon made it possible to do conversion at four times the color subcarrier rate, and new "black boxes" were built that could spew out 14.31818 megasamples per second. These systems had many worthwhile advantages, and standardizing committees began writing tentative draft standards based on four-times-subcarrier digital sampling systems.

Also, several groups began discussing the "all-digital television studio," forecasting how these "black boxes" could all be interconnected digitally to form a completely digital television station. Other groups were exploring the requirements of digital videotape recorders for the all-digital studio, while yet other organizations were discussing the behavior of microwave transmission links for the new digital television signals.

The European solution

In the midst of all this activity, a few disquieting thoughts arose, chiefly from Europe. First, the Europeans noted that, although the four-times subcarrier was indeed technically very nice, four times *their* subcarrier (which was 4.43 MHz, not 3.58 MHz as in the U.S.) was a very large number. The resulting torrent of digitized television data might prove difficult to process, and most certainly would be a burden to the data-storage capabilities of a future digital videotape recorder. In addition, the microwave and satellite links would be hard-pressed to handle the flood of data representing a television picture sampled at this awesome rate. And the idea that an all-digital television studio could be developed by simply expanding the boundaries of all the black boxes till they touched, struck many as being uneconomical.

Also, Europe viewed the advent of digital television as an opportunity to rectify the difficulties of program exchange between France and neighboring countries. Although the basic 625-line scanning system is used throughout Europe, the method of transmitting color is not the same, with the SECAM system being used in France, Russia, and the Eastern Bloc nations, and the PAL system being used elsewhere. Program exchange among these nations would be facilitated, argued several Europeans, if the new digital television systems did *not* sample and digitize the signals *after* they were in some national format, but instead did the digitization while the signal was still a basic set of color signals—a form that is common to all national standards.

All national standards generate three signals within the camera—a luminance signal, which conveys the monochrome detail of the picture, and two color signals, which provide the color information. These three signals are the basic components of the television signal. The national differences arise only when these components are encoded for transmission to receivers. The encoding process places these three components together into a composite signal; the exact make-up depends on the standards of the country where the signal is to be transmitted.

All the earlier "black boxes" had digitized the composite signal; the question being asked from Europe was, "Shouldn't we, instead, digitize the basic components, so international exchange is possible?"

In addition, the Europeans pointed out, the quality of the pictures resulting from component encoding was basically superior to that from composite encoding. The national standards-setters had years ago made some compromises, in order to squeeze color service into existing monochrome channels. Slavish adherence to composite digital coding carried all these compromises with it; component coding neatly stepped around all these problems.

The move to worldwide standards: Component coding

Thus, in early 1979, the major European standardizing group (the Technical Committee of the European Broadcasting Union, or EBU) and the major U.S. standardizing group (the Society of Motion Picture and Television Engineers, or SMPTE) found themselves considering whether or not there might be a way to extend this concept of component digitizing not only to accomplish European program exchange, but also to facilitate worldwide program exchange.

The general technique used in component coding is simple. The three components to be transmitted are Y, the wideband luminance signal, and R-Y and B-Y, the two narrowband color signals. Under the Nyquist criterion, the sampling rates for each of these three components can be adjusted to account for their differing bandwidths. Since most European systems have a 5.5-MHz luminance bandwidth, any sampling rate above 11 MHz is theoretically adequate for the Y signal, while the 1.3-MHz R-Y and B-Y signals can be sampled at any rate above 2.6 MHz. One of the earliest proposals to come from Europe suggested that the three signals be sampled at 12 MHz for Y and 3 MHz for the two color signals. This was called a 12:3:3 system, and the three numbers and their separating colons became the standard means for describing all the subsequent proposals as well.

In 1980, the SMPTE organized a Task Force on Digital Component Coding, to act as liaison with the EBU and other organizations searching for the best approach for digital television. Among the important tasks performed by this group was the issuance of a document on the basic parameters of component coding. This document became the U.S.'s submission to the CCIR (the Comité Consultatif International des Radiocommunications), which was another group, of world dimensions, actively interested in the direction being taken by developers of digital TV. In addition, the SMPTE Task Force organized a demonstration of picture quality as a function of various types of component coding; a well-attended demonstration that took place in San Francisco in February of 1981.

Competing approaches

By this time, there were many competing approaches to component coding. The key parameter of each proposal was the rate at which the Y (luminance) signal was sampled. In addition to the above 12:3:3 proposal, which sampled the luminance (Y) at 12 MHz, there were other proposals that sampled the Y signal at the old American four-times-subcarrier rate of 14.3 MHz. In addition, there was a variant of the 12:3:3 system that offered better color resolution by sampling the color signals at 4 MHz, making a 12:4:4 system.

The contenders quickly realized that there were two separable problems under discussion: (1) Should the Y sampling rate be the European-preferred 12-MHz rate or the USA-preferred 14.3-MHz rate—the latter being based on the color subcarrier frequency; and (2) What should the ratio of the luminance sampling rate to the color sampling rate(s) be?

To facilitate discussion on question (2), it was decided to express the ratio *as* a ratio, without regard for the actual luminance sampling rate, which could then be decided separately. For example, the 12:3:3 system would be referred to as a 4:1:1 system; the numbers would simply indicate that the luminance in the proposed system would be sampled at four times the sampling rate of the two color signals. An American-proposed system, which sampled at 14.3 MHz luminance and 7.16 MHz for the color signals, would be called a 4:2:2 system.

The adoption of a neutral ratio for expressing the luminance/color-sampling relationships aided in the determination of the need for a fairly high color-sampling rate for studio use, where special keying effects are used, for example, to "cut in" a background behind a newscaster. Good color resolution is needed for this special effect, or the fine detail of the foreground—the hairdo of the female anchor, for example—will vanish into the background. Tests such as the ones performed in San Francisco quickly established that 4:2:2 systems were absolutely required for good studio work, especially where chroma keying is used, while a 4:1:1 system might be perfectly acceptable for common carrier transmission or for field uses such as electronic newsgathering.

The San Francisco tests did little, however, to resolve question (1)—the choice between the European 12-MHz Y sampling and the U.S.-preferred 14.3 MHz. There was, predictably, a slight increase in picture quality whenever the sampling was raised from 12 to 14.3 MHz, but anyone could question whether or not the increased data rate and increased system cost really resulted in enough of a picture improvement to make it worthwhile.

At this point, it was entirely possible for the worldwide standardization attempts to founder, because the Europeans had no desire to burden their systems with the extra bytes from the American sampling rate, while the Americans had no wish to lose the added picture quality and at the same time move to a sampling rate not related to the subcarrier of the American standard. A compromise was needed, but the choice of compromise sampling frequency seemed doomed to be unrelated to either standard.

Agreement on a sampling frequency

It was then that serendipity came into play. In the early 1950s, while American color television standards were being developed, the color subcarrier, after several changes, had finally settled permanently (it was thought) at 3.583125 MHz. This number could be divided by appropriate numbers to derive the line rate of 15,750 Hz and the frame rate of 30 Hz; the numbers were such that all critical frequencies were interrelated. But, the field tests of the system showed that the color subcarrier and the sound carrier, at 4.5 MHz, could interact noncoherently to produce an annoying disturbance in the signal. Spectral analysis showed that the best way to cure the problem was to shift the sound carrier slightly, or to shift the color subcarrier slightly. Rather than risk tampering with the already-established sound carrier, the researchers opted to lower the color subcarrier to 3.579545 MHz. Since the scanning rates were tied to the subcarrier, this change lowered the line rate to 15,734.26 Hz, and dropped the frame rate to 29.97 Hz. All this was done in the early 1950s; no one could have possibly forecast what a fortunate and serendipitous effect it would have thirty years later.

In the 1980s, with Europe and America on the brink of losing a chance at international digital standardization, researchers seeking a compromise sampling frequency between 12.0 MHz and 14.3 MHz discovered that, thanks to the shift in color subcarrier frequency 30 years earlier, a compromise sampling frequency, precisely related to both European and American standards, existed at exactly 13.500000 MHz!

Figure 1 shows the beauty of this relationship. Starting with a frequency of 13.5 MHz, all the frequencies of both the U.S. color system and the European PAL system may be derived with simple integral factors. It is even possible to derive the recommended audio sampling rate for an accompanying digital audio system.

Tests showed that the 13.5-MHz system, realized as a 4:2:2 system (that means, of course, that the two color signals are sampled at a 6.75-MHz rate) offers all the quality needed for a studio system. In the fall of 1981, the system was presented to the world communications standardizing body, the CCIR, and after much debate and discussion, a document was issued affirming the CCIR's recommendation that this system form the basis for a worldwide digital television standard. The 158 nations of the ITU (International Telecommunications Union) unanimously adopted the 13.5-MHz standard in a recommendation at the CCIR Plenary Assembly at Geneva, in March of 1982.

The CCIR document and "Extensible Families"

This momentous document from the CCIR was issued under the unassuming title of

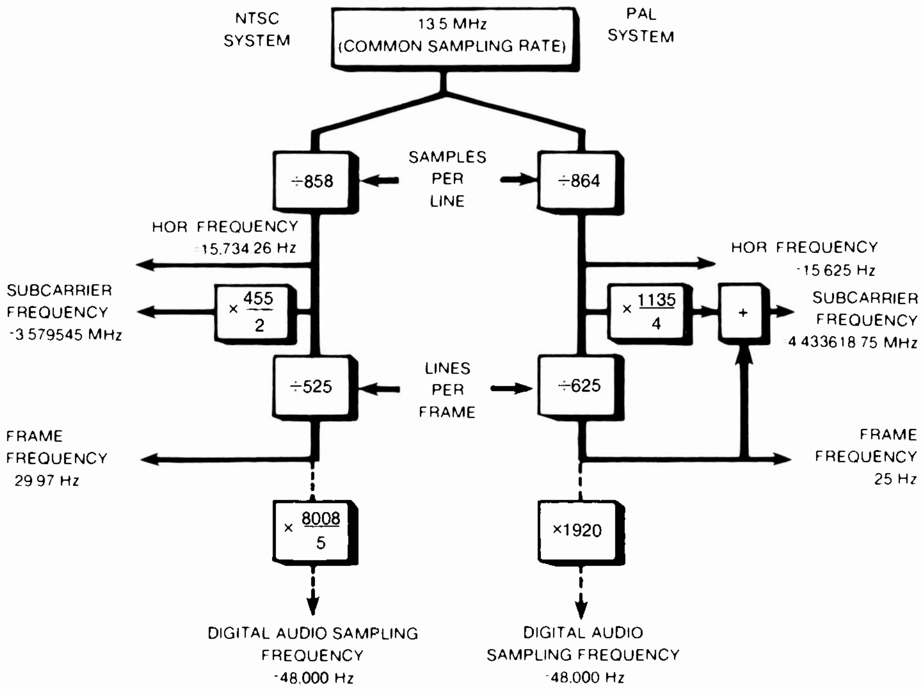

Fig. 1. *Thanks to the serendipitious choice of the American color subcarrier (in the 1950s), it was possible in the 1980s to choose a compromise digital sampling rate (13.5 MHz) that can be common to the critical frequencies of both NTSC (American) and PAL (European) TV systems.*

"Recommendation 601: Encoding Parameters of Digital Television for Studios." The body of the recommendation called for " . . . digital coding based on the use of one luminance and two color-difference signals . . . ," and also allowed, parenthetically, for the encoding of the basic red, green, and blue primary signals. It not only called out specifically the use of a 4:2:2 system for studio use, but also allowed for other systems. For example, a lower-quality, lighter-weight system for field use could conceivably sample the color-difference signals half as often, and would, therefore, be known as a 4:1:1 system. On the other hand, a system that encoded the primary signals directly would have to sample each color signal at the maximum rate, and would be a 4:4:4 system. Because of the simple relationship among the various sampling rates, the signals of one system could easily be converted to the signal format of one of the other systems. For example, a 4:1:1 signal recorded in the field could be transcoded to a 4:2:2 system when the field tape was brought to the studio for airing.

The groups of standards thus related were called "Extensible Families," and the CCIR document allowed for their " . . . establishment and evolution," further specifying that "It should be possible to interface simply between any two members of the family." International program exchange, the document went on to say, should be at the 4:2:2 level.

The frequency relationships between the sampling rates and the scanning rates were required by the CCIR document to be such that the sampling structure would not appear to move on the displayed picture. The authors of the document wrote that the " . . . Sampling structures should be spatially static." In addition, the sampling was required to be such that samples on successive scan lines should be one above the other—a structure called *orthogonal* in the document. One further requirement was laid on the sampling structure—the color samples and the luminance samples should fall on top of each other spatially; that is, they should occur at the same time. This arrangement is referred to as *spatial co-siting of samples.*

Solving the scan-time problem

All these provisions of the document established an excellent family of extensible coding standards at the component-sampling level. However, the recommendations described thus far do not actually produce an international standard. The times taken to scan one TV line, from left to right across a picture, are different in Europe and America. In Europe, the scan time is exactly 64 microseconds; in America, it is 63.5555555. . . microseconds. Since the sampling period of a 13.5-MHz sampling signal is 0.074074. . . microseconds, the European scan line will have exactly 864 samples per line; the American scan line, sampled at the same rate, will contain 858 samples—a difference of six samples.

This difference is shown in Fig. 2. But the figure also shows that a period of time is spent, during each line, in blanking the signal to allow for the transmission of synchronizing information. These blanking periods are sufficiently different, between the two standards, to permit the blanking periods to absorb *all* of the six-sample difference between the two standards' scan lines, thereby producing an identical number of samples during the active or picture-containing portions of the scan lines. Therefore, the CCIR Recommendation showed that each of the two systems should have exactly 720 samples during the active portions of the lines, with a 138-sample blanking interval for the American System, and a 144-sample blanking interval for the European System. Since most of the digital systems operate and process only the active picture interval, making the samples per *active* line identical effectively produces an international standard on a line-for-line basis.

Since the CCIR Recommendation is describing a digital signal, the quantizing aspect of the system is also described in the document. Basically, the document calls for an 8-bit system, which makes 256 levels available for signal transmission. Several of these levels must be reserved for "head-room," to avoid the rather abrupt clipping that takes place when a digital transmission system runs out of dynamic range. Therefore, the document specifies that only 220 of the possible 256 levels may be used, with level 16 corresponding to black, and level 235, to white.

In a 4:2:2 system, the two color signals would be sampled at half the luminance rate, which is 6.75 MHz. This arrangement produces 360 samples per line for each of the color signals, co-sited with the 720 luminance samples. Each color signal is also allocated 8 bits, but can use 224 of the 256 possible quantization levels, with the zero level of these bidirectional signals occurring at the 128th level.

Vertical rate

Although the document provides many of the needed provisions for a true international standard, it cannot and does not address one of the remaining problems—that of the vertical rate: the rate at which

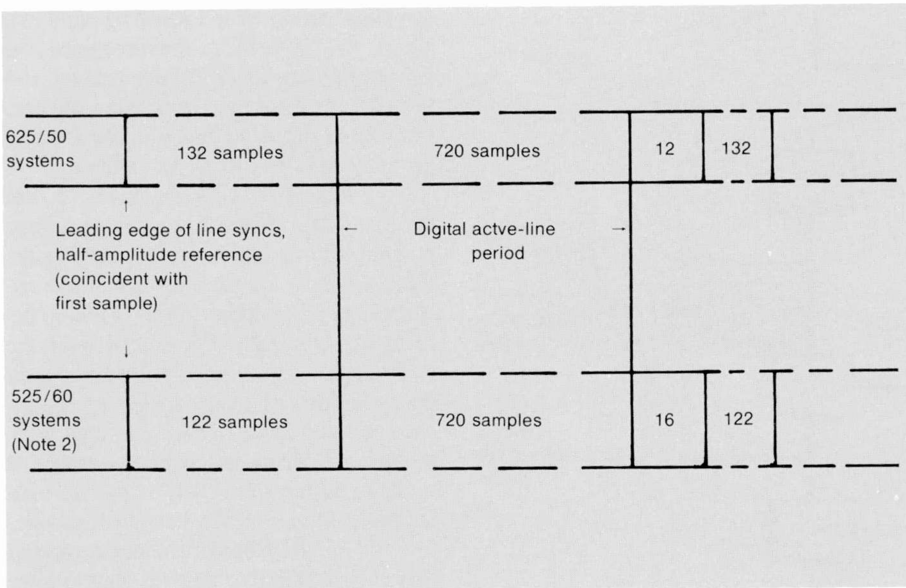

Fig. 2. *Relationship between the 720 digital active-line-luminance samples and the analogue sync. references for 625-line and 525-line systems. Although American and European TV lines are of different durations, the active (picture-containing) portions may both be expressed with 720 samples, and the six-sample difference between the two standards is absorbed in the blanking intervals.*

whole pictures are presented to the ultimate receiver in the home. In the U.S. and other NTSC countries (such as Mexico, Canada, Japan, and Chile), the whole-picture rate, or frame rate, is 30 pictures per second; in all other countries, where either SECAM or PAL is used, the rate is 25 pictures per second. These choices were made decades ago, and were originally based on the 60-Hz and 50-Hz power line frequencies of the various countries. The standard as written does not expunge this historical difficulty directly.

However, the tide of technology is definitely rolling in to wipe out this residual problem. Users of 25-Hz frame-rate systems have long been annoyed by the residual flicker on the screens of these systems. Just within the year, companies are experimentally using inexpensive whole-picture stores (frame stores) in home receivers, and displaying the received picture at a different rate, in order to eliminate the flicker. Eventually, the widespread use of these frame stores in all receivers will make frame rates a thing of the past; the receiver will not know or care about the rate at which the picture arrives. In fact, receivers of the future will receive data only as often as necessary, and will update the display only to show motion.

So the document produced by CCIR—made possible by a little serendipity in the 1950s—took a great step toward the establishment of a true international television exchange medium. Perhaps, through this medium, international understanding can be increased, and the squabbles that have plagued this planet can at least be diminished through the medium of international television.

Kerns Powers was appointed Staff Vice-President, Communications Research, for RCA Laboratories in Princeton, N.J., in May 1977. Dr. Powers is responsible for advanced systems research in the areas of television broadcasting, data transmission and satellite communications, and he is responsible for microwave technology development for commercial and government applications. Dr. Powers joined RCA Laboratories as a Member of the Technical Staff in 1951, to perform research in color television and on a high-resolution radar system. Dr. Powers received both B.S. and M.S. degrees in Electrical Engineering from the University of Texas in 1951 and his Sc.D. degree from Massachusetts Institute of Technology in 1956.

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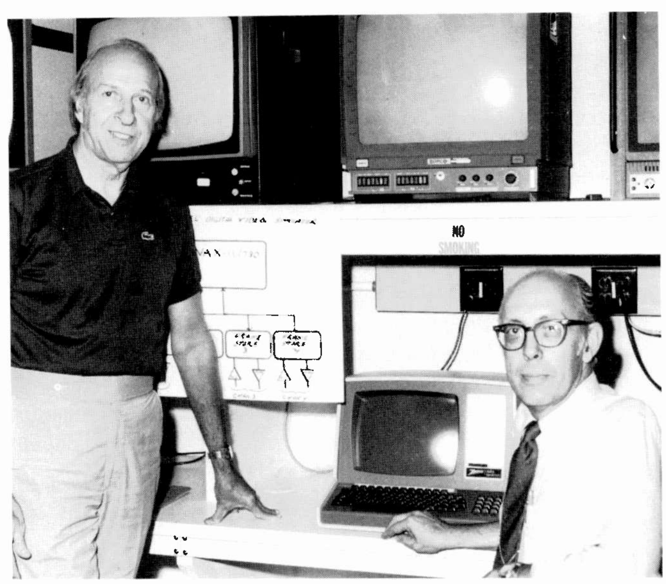
Bob Hurst received his B.E.E. degree from the University of Louisville in 1951. He joined RCA's Broadcast Engineering activity that same year, and participated in the development of color television equipment. From 1956 until 1972 he worked in the videotape recorder activity, designing the first transistorized subsystems used in these products. He was involved in the design of the TR-22, the first totally transistorized VTR, and also participated in the development of the TR-70 and the TCR-100 Cartridge Video Recorder.

Before joining the RCA Technical Training Activity in 1976, Mr. Hurst directed a group of engineers in pioneering digital television techniques. He has written and taught a transistor-design course, and has conducted courses in color television theory, semiconductor theory, videotape fundamentals, and digital television theory. He has written and presented numerous papers, and was a 1977 recipient of the Jesse H. Neal Award (the Business Press equivalent of the Pulitzer Prize) for a series of tutorial articles on digital television.



Authors Powers (left) and Hurst.

He holds 18 patents in the fields of color television, video recording, and digital television. Since 1967, Mr. Hurst has served on the SMPTE Video Recording Reproduction Committee, and is presently Chairman of that group's Nomenclature Committee.

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Teletext standards in North America

Even though receivers are not yet available, CBS and NBC have started broadcasting sophisticated teletext services in an effort to foster the growth of the new technology.

Teletext is a digital data system for transmission of textual, graphic and control information intended for display on screens of suitably equipped receivers. Teletext is a one-way service in which the receiver selects the desired information from a continuous flow of information. It is distinguished from videotex, which is a two-way service often transmitted over telephone lines.

In broadcast teletext, the information is transmitted within the horizontal lines of the TV signal. In Vertical Blanking Interval (VBI) teletext, the information is transmitted only during the vertical blanking interval, and is designed not to interfere with current TV receivers. In full-field teletext, all, or nearly all, of the lines in a TV field may contain teletext information. Transmission of VBI teletext has recently been permitted by the Federal Communications Commission (FCC),[1] and is currently being broadcast by the NBC and CBS television networks among others. Some examples of NBC teletext pages are shown in Fig. 1 (see color versions on back cover).

Abstract: *Teletext is a new broadcast service in which digitally encoded pages of text and graphics are broadcast in the vertical blanking interval of television signals and received by specially equipped receivers. This article surveys the standards for coding the information and discusses in some depth the North American Broadcast Teletext Specification.*

Final manuscript received July 27, 1983.
Reprint RE-28-5-3

In VBI teletext, the broadcasters will typically provide a few hundred pages including such items as news, weather, sports and entertainment information, together with TV-program-related material such as captioning. Fig. 1a shows the choices available on NBC teletext on July 7, 1983. The user will be able to select the pages of interest, and thus will have a wide choice of pages immediately available, as opposed to the sequential presentation of information in a normal TV program. It is expected that the service will be supported by advertising, and thus will be free to the viewer who owns a teletext receiver.

A simplified schematic diagram of a broadcast teletext system is shown on page 17 in Fig. 2.

The TV station may receive teletext from its network and from other services, and may generate some locally. These are put into a *teletext* page store. A *teletext inserter* adds additional control information and inserts the pages into the VBI of the baseband TV video signal. The composite signal is then filtered, modulated and transmitted.

The teletext receiver demodulates the signal to baseband. A *data processor* examines each line of the baseband signal and reassembles the data into pages. If the page is wanted by the *teletext controller,* then it is stored in the *page memory.* Upon command from the teletext controller, a *display processor* reads the stored code from the page memory, processes it, and feeds the result to a *mixer switch,* which overlays it on the TV video.

The user selects pages via an input to the teletext controller. This input may be by remote control or front-panel access. The teletext controller usually provides feedback to the user in the form of a row of text information outside the teletext display area.

Brief history of teletext

Teletext research was begun in 1970 in the United Kingdom (U.K.) by the British Broadcasting Corp. (BBC) and Independent Broadcasting Authority (IBA). The U.K. teletext standard was defined in 1974. It offered a basic text service together with low-resolution graphics. Trials were conducted in 1976 and regular broadcasts commenced in 1978. Those interested in further details of the early history of the U.K. system are referred to the article by K. M. McKee in an earlier issue of the *RCA Engineer.*[2]

The French designed a slightly improved but incompatible teletext service called Antiope, which was announced in 1978. The Antiope system used asynchronous transmission, unlike the U.K. system which used a fixed-format synchronous transmission in which each byte defined the character at a fixed display location. It overcame one minor limitation of the U.K. system and made it possible to change colors between characters without using a space. Although trials of Antiope were conducted it never became a regular service.

Telidon, a teletext system having significantly greater graphic capability than either

Fig. 1a. The main NBC index page. The primary character set was used to produce the small text and numbers. The larger "PLAYTIME" was constructed using the double-size control from the C0 control set. The different font in "NBC TELETEXT" was constructed using lines with a larger logical pel. The colored shapes underneath the title were constructed using filled polygons (see color versions on back cover). The text of the contents is presented on a light gray rectangle drawn with highlight turned on to produce the blue border. Additional blue lines were drawn to give the appearance of overlapping rectangles.

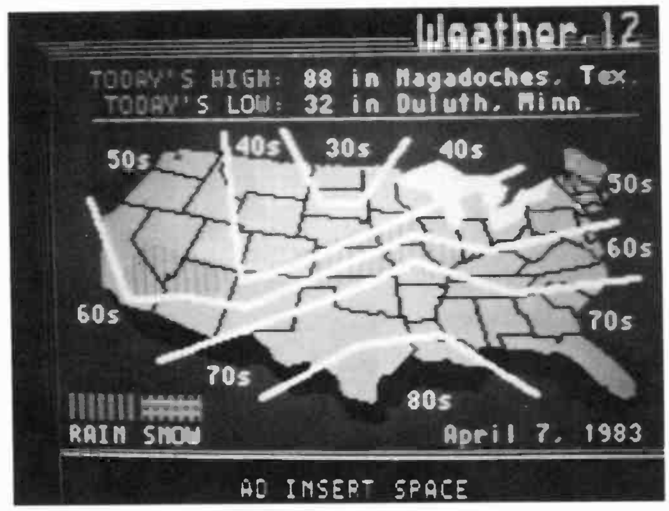

Fig. 1b. A national weather map. This map illustrates the intermixing of text and graphics. The outline of the United States was drawn using a filled polygon. The borders between the states were drawn with concatenated lines using a small logical pel, whereas the temperature contours were drawn with a larger logical pel to produce the thicker lines. The rain area was drawn on top of the map using a filled polygon with a vertical-hatch-texture pattern.

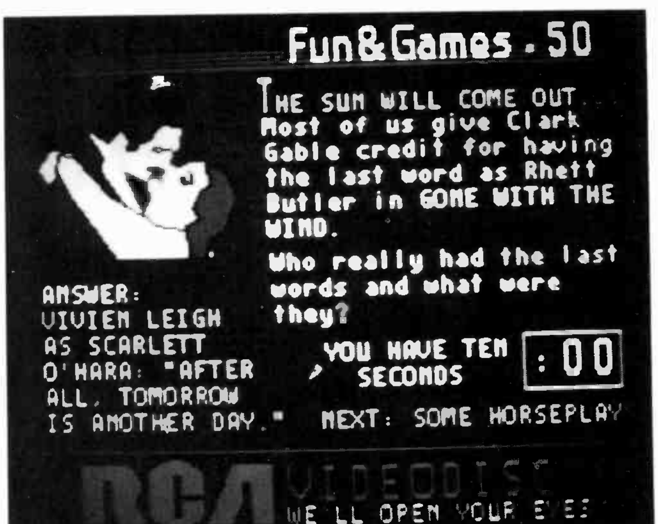

Fig. 1c. A page from the fun-and-games section. A series of one-second wait standards were used to produce a clock counting down from 10 to 0, at which point the answer was automatically shown.

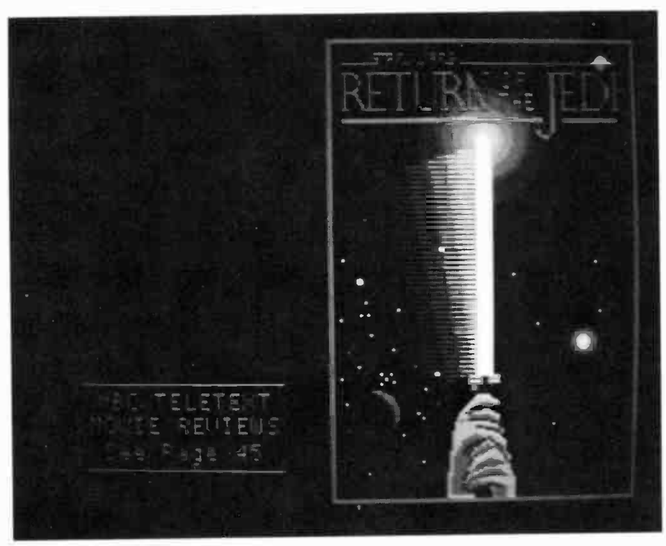

Fig. 1d. An elaborate rendition of a "Return of the Jedi" poster. It could be used to illustrate a movie reviews section. Several intensities of blue were used in the color map to produce the shading effect.

the U.K. or Antiope systems, was announced by Canada in 1978. Telidon introduced the concept of Picture Drawing Instructions (PDIs), which allowed cartoon-like geometric drawings to be transmitted with reasonable efficiency. It also had much greater color capability than the earlier systems.

In 1979 an Electronic Industries Association (EIA) committee was formed to evaluate the different teletext systems for use in the United States (U.S.). CBS conducted field trials of the U.K. and Antiope systems in 1979, and in 1980 petitioned the FCC to adopt an Antiope system for the U.S. Early in 1981 the U.K. petitioned the FCC to recognize an adaptation of their system for North America.[3] Field trials of Telidon were conducted in Canada.

In May of 1981, American Telephone and Telegraph (AT&T) announced the Presentation Level Protocol (PLP),[4] which combined the presentation levels of the U.K., Antiope, and Telidon systems. CBS added some Antiope-like communication protocols to the PLP and announced the result as the North American Broadcast Teletext Specification (NABTS) in June 1981.[5] In July of that year they petitioned the FCC to adopt the NABTS. In Canada

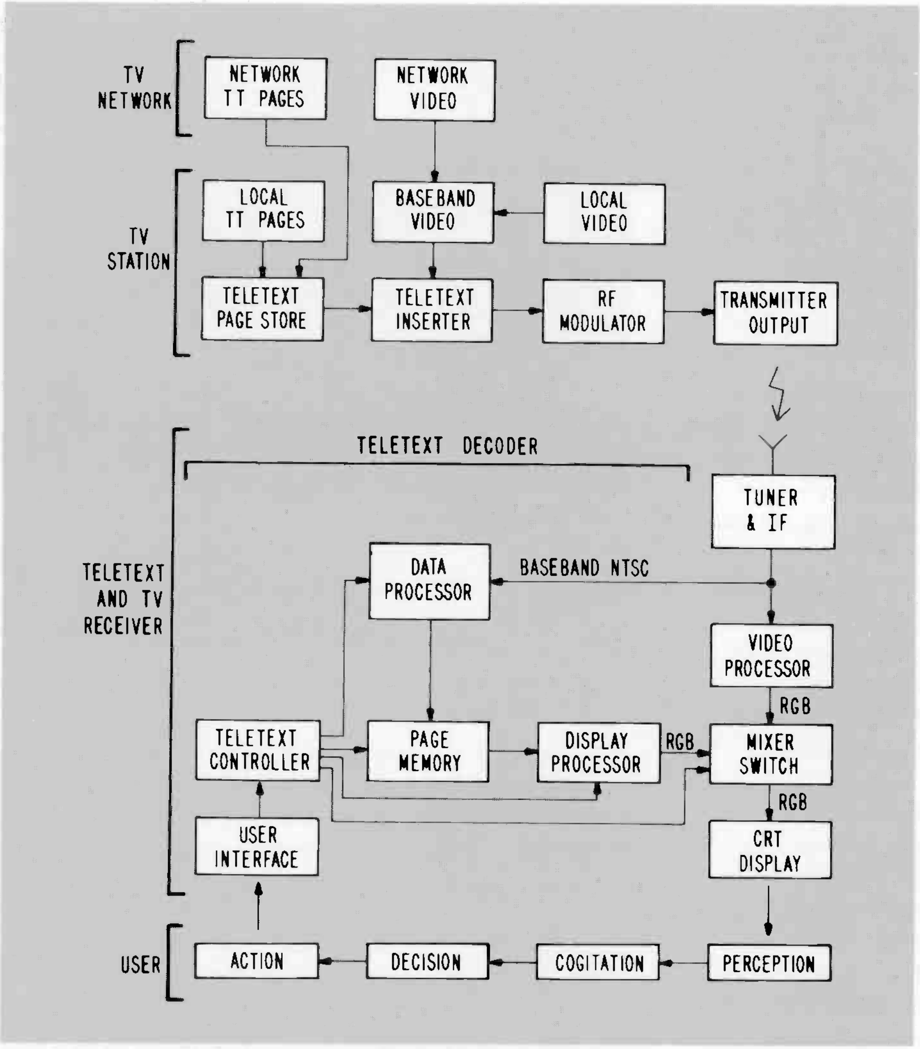

Fig. 2. Broadcast teletext system. Each television station may receive teletext pages from a TV network or other source, and may create or update some pages locally. These are transmitted to a teletext receiver. The teletext receiver shown here is a TV receiver with a built-in teletext decoder. An alternative teletext receiver would be a stand-alone unit that decodes the teletext pages and remodulates them to an NTSC signal as an input to a TV receiver.

the government officially adopted standard BS-14,[6] which defined a teletext service identical to that of the CBS NABTS.

The FCC finally took action in November 1981 and released a Notice of Proposed Rule Making (NPRM) to consider authorizing TV stations to broadcast teletext services. The NPRM proposed, among other things, not to regulate the actual teletext coding scheme and thus to allow both the U.K. and NABTS teletext systems to be broadcast. The Commissioners argued that choosing one of the two contending systems would delay the introduction of a service for several years while the merits of each were debated, and that this would not be in the best public interest. It thus opened the way for a free-market competition between the two systems. A large number of comments were received by the FCC. RCA filed comments recommending that the FCC adopt a single system and, among single systems, supported the NABTS.

The proponents of the two systems hotly argued the merits of their systems in all available forums. The U.K.-system proponents argued that their system was cheaper, more resistant to transmission errors, and available immediately. The NABTS proponents argued that their system offered greater performance and that the cost differential would eventually be negligible.

The EIA, the logical forum for settling such debates, became completely deadlocked. But events were moving in favor of the NABTS on other fronts. AT&T submitted the PLP to the American National Standards Institute (ANSI) for standardization. ANSI set up a group that worked in conjunction with the Canadian Standards Association (CSA) to develop the PLP into the North American Presentation Level Protocol Syntax (NAPLPS). No similar U.S. standardization effort was being pushed for the U.K. system. In July of 1982 the U.S. State Department's Study Groups A & B unanimously approved the June draft of the NAPLPS as the official U.S. position to take before the International Telegraph and Telephone Consultative Committee (CCITT). In the same month the draft NAPLPS became a preliminary Canadian standard T500.[7]

The EIA established a Special Working Group to develop the NABTS as an EIA-recommended practice. This was done with the understanding that the NABTS might be one of several possible EIA-recommended practices, and that the purpose of the Group was not to make a decision between the contending systems. In reality this became the major EIA teletext activity, and EIA consideration of the U.K. system came to a virtual halt. In October of 1982, the EIA approved a subset of the NAPLPS selected by the Special Working Group as the display part of the the initial teletext service. The EIA Special Working Group joined the ANSI and CSA Working Groups and all reached unanimous agreement on a revised draft of the NAPLPS in June 1983.[8]

In May 1983, the FCC released a Report and Order[1] authorizing teletext transmissions by TV stations along the lines proposed in the NPRM. The delays that took place before this report was released worked inexorably in favor of NABTS since memory and processor costs continued their relentless decline, and the NABTS specification moved further towards finalization and approval. The FCC did not specify the coding scheme of the teletext service, and thus permitted an open-market approach to coding standards. Teletext signals were permitted on lines 14 through 18 and on line 20 immediately, and on lines 10 through 13 beginning in 1988. These lines are not reserved exclusively for teletext. Line 21 will be reserved for captioning until 1988, at which time the use of line 21 will be re-examined. The definition of teletext was broadened from the proposed definition in the NPRM to include data "intended to enhance the use of teletext information." The FCC requires that there be no out-of-band signals and no interference with present television signals. It specifies maximum amplitude. It requires precedence of emergency visual messages. It defines teletext as an ancillary service,

NBC offers teletext

NBC launched its Network Teletext service on May 16, 1983, at its Affiliate Meeting in Los Angeles, shortly after the FCC authorized the commercial broadcast of teletext on the vertical blanking interval (VBI). When it launched the service, NBC had in place the technology to support NABTS, the high-resolution standard that NBC believes is essential for a commercially viable teletext service. We are now broadcasting a 50-page magazine nationally on lines 15 and 16 of the network VBI.

NBC teletext is an over-the-air broadcast service, free to all viewers. Teletext will require that specially equipped TV sets receive the digital information carried on the broadcast signal and translate it into a video display in the form of graphics and text. Manufacturers are expected to provide set-top adapters as well as new TV sets with built-in decoders. The NBC service will be totally advertising-revenue supported.

Consumer decoders are not now available, although a number of manufacturers are planning product introductions. In the absence of consumer decoders, a basic question naturally arises: "Why are we broadcasting a service when no one is watching?" In the industry, this has been referred to as the "Chicken and Egg" problem and has occupied much print space in the past. The answer is fairly simple and has a parallel in the early days of television. The market will be service driven—consumers will "buy" teletext because it has an information and entertainment value for them. They won't buy equipment that will make teletext available to them unless they are aware of, and place value on, that service.

In the long-term, we expect teletext capability to be built into all television sets, and to have become an expected part of a household's daily life. We see teletext, in the future, as omnipresent as the TV set and the daily newspaper are today. The question facing NBC and the industry as a whole is how to develop this new marketplace.

Teletext fills a consumer need for timely, concise, and convenient information. It is more readily updated than any print media. It is punchy and to the point. And it's *there,* in the home. Teletext can also be viewed as a new and alternative distribution mechanism for current providers of information and entertainment. For many, it means the capability to

Artists generate NBC teletext graphics on terminals.

provide rapidly changing information at a low cost. For others, it simply means low-cost, paperless distribution. For marketers, it provides another, and lower cost, vehicle for presenting a message to the home viewer.

Teletext will succeed by providing a product that will meet consumers' needs and that will attract revenue. The packaging and promoting of teletext will be a major thrust for the industry over the next few years. Developing consumer awareness of teletext's potential will be essential both to create demand for decoders and to build the industry. Early purchasers are likely to be those attracted by new gadgetry and those who make heavy use of cable and print media.

Quite quickly, however, the market should achieve a broader base. Once the initial challenge of creating consumer awareness is met—generating demand for initial purchase—the challenge for NBC will shift to building usage.

During the next few years, NBC will be developing its product concept and promoting teletext in the public arena. While it builds the demand for decoders as well as new TV sets, it also will be developing a product that will hold and expand consumer interest.

—Barbara Watson
NBC Teletext
New York, New York

thus allowing cable companies to strip teletext signals, but this definition is being appealed.

In May of 1983, the NBC and CBS television networks began transmission of NABTS teletext services. In August the Special Working Group of EIA working with the Canadian Videotex Consultative Committee (CVCC) completed the draft NABTS.

Although this discussion has concentrated on the history of the standards activities within ANSI and EIA, there was, and is, considerable activity in other standards forums which affects teletext. The International Standards Organization (ISO) issued ISO 2022[9] on which the code-extension techniques of the NAPLPS are based, and is actively revising the standard to include the added functional requirements of the NAPLPS. For example, ISO 2022 permits only sets of 94 characters whereas the PDI character set in the NAPLPS requires 96 characters. ISO has also defined the basic layered model upon which the NABTS is based.[10] The International Radio Consultative Committee (CCIR) is developing teletext standards.[11,12] Further details on the historyof the PLPS can be found in Reference 13.

History of teletext at RCA

RCA explored the use of the VBI for analog transmission of information during the 1960s with a system called Homefax.[14] After that project ended, little work was done at RCA until a corporate Teletext Committee was established in the Fall of 1980. This committee reported in March 1981 recommending that teletext work be started and that an asynchronous system be supported for the U.S. It stated that, of the existing system proposals, the Antiope system came closest to meeting its criteria for an optimum system, but suggested that some high-resolution graphics be included in the initial decoders.

RCA Laboratories researchers started technical work in 1981, putting together simulation systems for evaluation and demonstration. They also evaluated hardware and software designs for teletext receivers in order to contribute to the cost-performance tradeoffs to be made in the development of standards.

At the end of 1981 RCA filed Comments to the FCC NPRM strongly recommending the adoption of a single standard, and favoring the NABTS as the basis for such a standard. RCA has also evaluated the ruggedness of the competing systems for the EIA.

In 1982 RCA became an active participant in, and a major contributor to, the development of the NAPLPS and NABTS standards, working through ANSI, EIA, and CCIR committees.

Present status

There are two major contending systems for the U.S. market: the U.K. system, recently renamed the World System, and the NABTS.

The NABTS is favored by the NBC and CBS broadcasting networks, some local stations, and several manufacturers including RCA. The NBC and CBS television networks are currently broadcasting NABTS teletext services. Norpak, Panasonic, RCA, Sony, and VSA (Videographic Systems of America) have shown prototype NABTS receivers or decoders. Time Inc. is currently conducting trials of an NABTS-compatible full-field teletext service on two cable systems. The U.K. system is favored by some local stations, Zenith Radio Corporation, and several cable systems. Taft in Cincinnati is currently broadcasting the U.K. system level 1 (see the next section), and compatible decoders manufactured by Zenith can be purchased for about $300.

The first three levels of the U.K. system are specified in Reference 11, together with an experimental version of level 4. Level 5 is not yet completely specified.

The NABTS service is defined by the "North American Broadcast Television Specification" from the Electronic Industries Association. The NABTS is in draft form and has been approved by the joint EIA/CVCC Special Working Group. Approval by the EIA as a recommended practice is expected to be completed in the fall of 1983. The presentation layer of the NABTS is defined by the NAPLPS.[8] The NAPLPS has completed its public comment period. It is expected that the ANSI technical approval process will also be completed in the fall of 1983. Some details of the U.K. and NABTS teletext systems are given in the following sections.

United Kingdom (U.K.) teletext system

The U.K. system, as modified for North America, is specified in CCIR Report 957.[11] It is divided into five levels. These correspond to performance levels, not to the Open System Interconnection (OSI) levels. These levels are upwards compatible with each other, a compatibility achieved at the expense of transmission efficiency.

Level 1 is primarily a text-transmission system with a primary character set plus two *mosaic* sets. Each mosaic set contains the 64 graphic shapes formed by dividing a character cell into an array of blocks, two horizontal by three vertical. In one set the blocks adjoin whereas in the other they are separated. A fixed text resolution of 23 rows of 40 characters plus a page header row is provided. Using mosiacs, graphic images of resolution 80 pixels horizontal by 69 pixels vertical may be obtained. A fixed palette of eight colors is provided.

Level 2 includes the addition of accents for showing languages other than English, smoothed mosaics for enhancing the appearance of mosaic graphics, and the inclusion of 16 pastel colors.

Level 3 includes the addition of a Dynamically Redefinable Character Set (DRCS) that allows other character shapes to be downloaded by the broadcaster and intermixed with the predefined characters. Level 4 includes alphageometric coding that allows geometric images consisting of lines, rectangles, polygons, circles and arcs to be drawn. Level 5, which is not yet completely specified, will include alphaphotographic coding to obtain high-resolution full-color images.

North American Broadcast Teletext Specification (NABTS)

The NABTS is specified by the EIA. It is primarily concerned with the interface between the broadcaster and the TV receiver. But NABTS also specifies some receiver processes, together with some features of the interface between the receiver and the user.

Although the teletext service is a one-way service, the NABTS contains functions to increase the interaction between the user and the broadcast teletext data base, and to give the broadcaster control of the structuring of this data base. The functions provided to the broadcaster are quite extensive and there are sometimes several ways of achieving the same end result. These complexities are hidden from the user, whose perceptual model of the teletext service may be quite simple.

The NABTS is divided into chapters that correspond approximately to the layers of the Open Systems Interconnection (OSI) model.[10] In this model the layers are independent of one another. The different layers of the NABTS are described in Table I.

Table I. *The seven functional layers of the teletext service.*

Layer		*Teletext functions*
7	Application	Provides a teletext service to the user, allows the broadcaster to structure it, and allows the user to access it.
6	Presentation	Provides instructions for presenting visual information, and conveys additional information to the application layer.
5	Teletext record	Provides a unit of presentation code (a record) together with identifying and descriptive information.
4	Data group	Provides a data unit consisting of a number of data blocks.
3	Data packet	Provides blocks of error-corrected data for a given packet address.
2	Data line	Provides packets consisting of 33 bytes.
1	Data transmission	Provides a bit stream in a TV scan line.

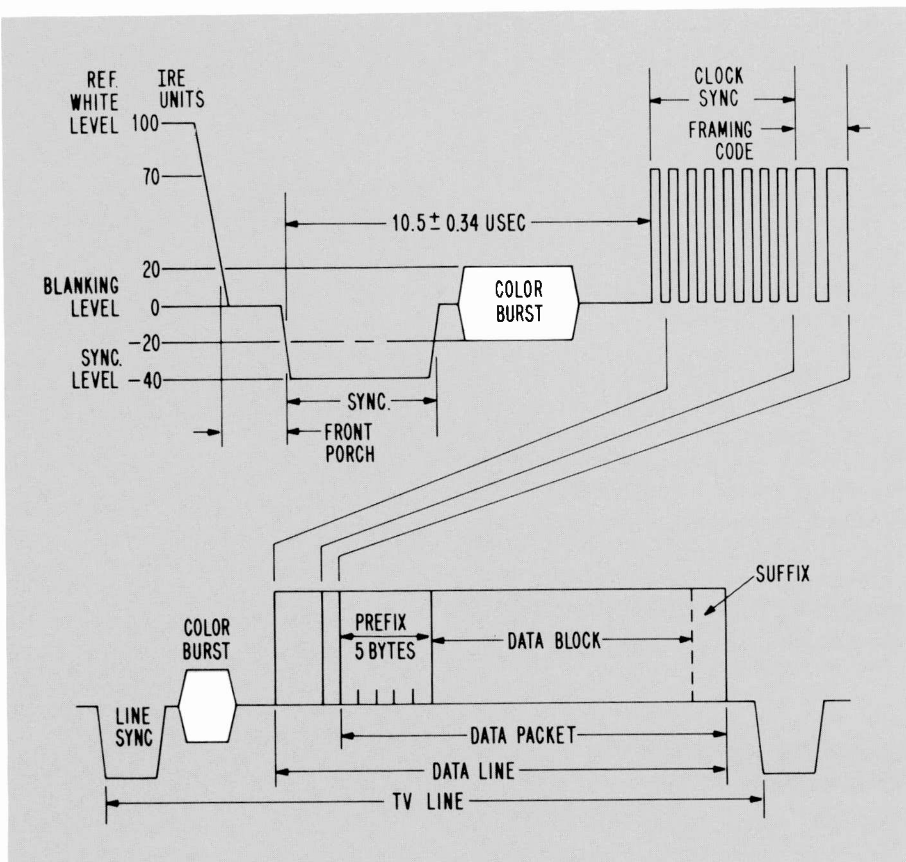

Fig. 3. Structure of the data line. The data line is that part of a TV scan line which contains digital data. The first part of the data line consists of alternating 1's and 0's for bit-timing synchronization. The next part is a framing code for byte synchronization. The remaining part is the data packet, which consists of a prefix, a data block, and a suffix.

Layers of the NABTS

The data transmission layer specifies the physical format in which the bits of information are transmitted. This layer is also regulated by the FCC Report and Order.[1] The FCC specifies the TV-data-line use and sets maximum amplitude levels. The NABTS completes the description of this layer by specifying the bit rate (5.73 Mbits per second), the bit timing, and the pulse shape.

The data line consists of a string of 288 bits transmitted within one TV line. The structure of the data line is shown in Fig. 3. The first 24 bits of the data line constitute the *synchronization sequence* and the remaining 264 bits constitute the *data packet*. The first 16 bits of the synchronization sequence are the *clock synchronization sequence,* which consists of an alternating sequence of ones and zeros. The remaining eight bits constitute the *framing code*, which defines the start of the byte sequence. For broadcast teletext this framing code is 11100111, which was chosen to allow detection even in the presence of a one-bit error.

The data packet is the group of 33 eight-bit bytes following the synchronization sequence in the data line. One bit of each byte is used to provide odd parity. Each data packet starts with a *packet prefix* consisting of five bytes. The remaining bytes are divided between a *data block* and a *suffix.*

The packet prefix bytes are protected by Hamming encoding. The first three bytes of the packet prefix define the *packet address*, which defines the *data channel number*. The next byte is the *continuity index,* which increments each time a packet of the same address is transmitted and can be used by receivers to detect missing packets. The last byte of the packet prefix indicates how the remaining bytes are divided between the data block and the suffix. The suffix contains information that can be used to detect and correct transmission errors in the data block.

The data group consists of an integral number of data blocks as shown in Fig. 4. The data group is divided into a *data group header* and *data group data.* The data group header contains eight bytes that define, among other things, the size of the data group and the size of the last block.

The teletext record is the data group data. Each record is divided into two parts: a *record header* and *record data*. The record header consists of five fixed-format bytes followed by a variable number of extension bytes. The first fixed-format byte defines the record type, which conveys general information about the record. Record type 0 is used in cyclic teletext where all the records are broadcast periodically with only occasional changes. Record type 1 is used in non-cyclic teletext such as captioning. Record type 2 is an *application record* that contains control instructions for the receiver together with general information about the service. Application records do not contain presentation information as do the other records. Record type 3 denotes an important record that must be examined by the receiver such as an *alarm record*.

The second fixed-format byte in the record header indicates the presence of one or more optional extension fields.

The remaining three fixed-format bytes in the record header define part of the *record address*. An additional six bytes of address may be present in the header extension. Thus record addresses may take two forms, a short form consisting of three hexadecimal digits, and a long form consisting of nine hexadecimal digits. Each short address has a long form obtained by adding four leading zeros and two trailing zeros. Records are also identified by the packet address, which defines a data channel. Within each data channel there are therefore over 68 billion different addresses. Even if only decimal digits are used, there are one-billion different addresses. This is considerably more space than is needed by VBI teletext, and somewhat more than is needed by full-field teletext, but it allows for future expansion to large data bases and gives the broadcaster considerable freedom in structuring his data base.

Each record's length is limited to allow receivers to allocate a specific amount of memory for the capture and storage of records. Records may be linked together to allow the broadcasters to compose pages that have lengths of more than this limit. Information on this linking is contained in the record-header extension. Receivers will automatically capture and present all records in a linked series, so that the user will normally be unaware of the structure.

Particular types of record are marked in the record header by a set of flags. The *caption flag* indicates that the record contains a caption message intended to be shown over TV video. This instructs the receiver to put black, white, and "transparent" colors into its color map. The first time that a receiver encounters a caption

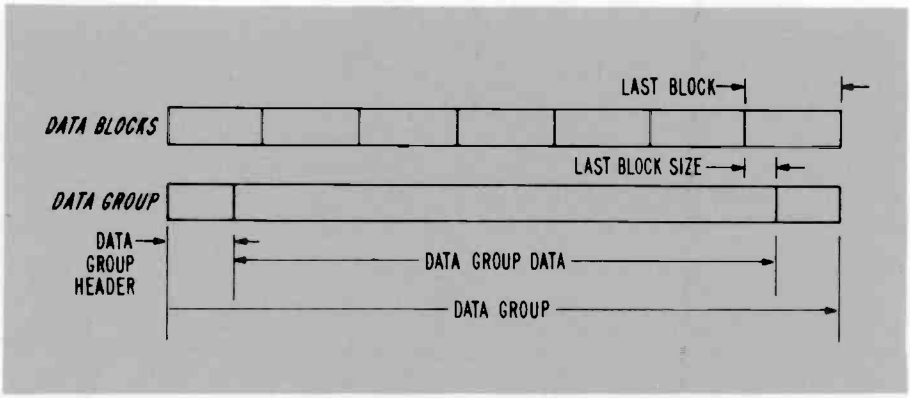

Fig. 4. Data group. A data group consists of an integral number of data blocks. It is divided into a data group header, data group data, and perhaps some unused bytes in the last block. The data group header contains control information. The data group data constitute a teletext record.

flag in a data channel, the entire display bit map is cleared to transparent. This allows the associated TV video to show through the bit map. Code in the caption record is then executed and the resulting caption message displayed. Captions may consist of graphics in addition to text.

The *delay flag* instructs the receiver not to present the information immediately but to wait until a *reveal record*, also identified by flags, is received. This allows, for example, several versions of a caption to be transmitted, perhaps more than once to aid error recovery, and then all versions to be revealed at the same time in synchronization with the TV program.

An *index flag* indicates that the record is an *index record*. A receiver will normally keep a log of index records seen by the user, so when the user requests an index page he will be shown the last one he saw. There is provision for the broadcaster to specifically define an index page number for any page, and there is also a default index structure.

In addition to direct page access, the user is provided with *next* and *more* functions, which are two easy ways to advance through the teletext data base. The *next* function, activated by a single key, is intended to advance the user to the next topic, whereas the *more* function is intended to give the user more information on the same topic. The record header contains provisions allowing the broadcaster to designate any other record in the service as the *next* or *more* page. The addresses of the *next* and *more* records may also be defined by some previous record giving the broadcaster great flexibility in structuring the broadcast teletext data base.

This illustrates a general principle that was followed in defining the NABTS. Although considerable power and inevitable complexity has been built into the NABTS, the complexity has been concealed from the user as far as possible. Thus, when a user invokes the *next* page, a number of structures will be examined by the receiver to determine the address of the *next* page. The exact method by which the receiver determines the *next* page is concealed from the user.

In cyclic teletext the start of a cycle is marked by a *cyclic marker flag*. This may be used by receivers to determine the absence of pages. For example, if a receiver is searching for a user-requested page and two cyclic marker flags are found, then the receiver can be reasonably certain that the page is not present in the cycle and can give an appropriate message to the user.

The broadcaster can inform the receiver to automatically acquire and show a number of records by using the *auto acquire flag*. If the auto acquire flag is high, then the receiver will acquire and show the *more* record without user intervention. The broadcaster can also inform the receiver of the addresses of records that should be precaptured since they are related to the present record and may be needed by the user.

To increase the transmission efficiency of the service, a *support record* has been included in the NABTS. This record, which is identified by a flag, is executed prior to the execution of any record that has a *support needed flag* set high.

Two flags, the *alarm* and *priority flags*, are used in combination to mark records that must be shown if the receiver is in the teletext mode or in the television mode, and records that are *reveal records*, that is, records that cause all delayed records to be shown.

An *update flag* is used to indicate that a record is being frequently updated, as in captioning. The *version number* of a record may also be contained in the record header. This is a number from zero through 15 that is changed by the broadcaster whenever the contents of the record are changed. If a record has an update flag set high, then the receiver will continually reacquire that record, and display it if the version number has changed.

Presentation code. The record data may provide a unit of *presentation code* identified by address, linkage, and version number. The coding of the presentation code follows that of the NAPLPS.

The NAPLPS defines the coding of the graphical and textual information seen by the user. The NAPLPS specifies the coordinate system used, the coding architecture and the detailed coding for both 7-bit and 8-bit environments. In broadcast teletext, one bit of each byte is used for parity, thus the coding takes place in a 7-bit environment. The NAPLPS includes a conformance section, which specifies the requirements that systems must meet if they are to claim conformance with NAPLPS. It contains a complete listing of the predefined displayable characters called the graphic character repertoire. A teletext Service Reference Model (SRM) is contained in an appendix. This SRM specifies the minimum functions of receivers and the maximum functions to be used by broadcasters.

The NAPLPS uses a coordinate system based on a unit screen with x and y coordinates having values from 0 to 1. The display area is defined as the area within which the broadcaster may write. Receivers must make the entire display area visible to the user. The display area is similar to the safe title area;[15] broadcasters are guaranteed that all the display area will be visible to the user. The receiver manufacturer will normally make the display area smaller than the raster. The display area is defined in the teletext SRM as having a width equal to that of the unit screen and a height approximately three quarters of the unit screen.

The basic coding scheme employs character sets and control sets that are accessed by code-extension techniques compatible with ISO 2022.[16,9] The primary character set is ASCII[17]. A supplementary character set adds many useful symbols and characters from other Latin-based languages. The Picture Description Instruction (PDI) set contains instructions for geometric drawings and for changing the color. A mosaic set is based on that of the U.K. system and can be shown in both contiguous and separated modes corresponding to the two U.K. level-1 mosaic sets. A macro set allows the definition of self-contained units of PLPS code and is very useful for increasing transmission efficiency. A Dynamically Redefinable Character Set (DRCS) allows other character shapes to be downloaded by the broadcaster and intermixed with the predefined characters. Two control sets are provided. Control set C0 contains cursor movement controls, code extension controls and other miscellaneous controls. Control set C1 contains macro-definition controls; text-size controls; cursor-style controls; word-wrap, underline and scrolling controls; and other controls.

The PDI set of the NAPLPS provides instructions for drawing geometric figures, and for controlling the attributes of these figures and of alphanumeric text. It uses a mixture of commands (opcodes) and data (operands). The geometric drawing primitives are line, point, arc (which includes circle as a special case), rectangle and polygon. These primitives are drawn by tracing out an area called a *logical pel.* The width and height of the logical pel may be controlled by the broadcaster. The effect is like having a selection of different-size paintbrushes. The PDIs are controlled by the attribute-control functions and may be drawn in several ways. Lines may be drawn solid, dotted, dashed, or dotted and dashed. Geometric shapes may be drawn as outlines or may be filled with a solid color or with a texture of two colors. The textures may be selected from a predefined set or may be downloaded by the broadcaster. The filled shapes may be outlined (this is called highlighting).

Text may be drawn in different orientations, and the character path may be in different directions independent of the character orientation. The spacing between characters and between character rows can be controlled. The spacing can be set to one of three predefined spacings or can be made proportional in which the thinnest letters occupy the least space. The horizontal and vertical character sizes can be controlled independently.

The PDI set also contains instructions for controlling the color. It allows multiple-blink processes to be established whereby colors can be changed in a regular repeating manner. A *wait* command causes the PLPS drawing process to stop for a length of time determined by the broadcaster. Both the blink and wait commands are useful in achieving animation effects.

The teletext SRM specifies that a minimum of 16 simultaneous colors out of a palette of 512 colors must be supported by receivers. It specifies that the minimum display resolution of receivers must be approximately 256 pixels horizontal by 200 pixels vertical. It is instructive to examine the pages in Fig. 1 (see color reproductions on the back cover of this issue) to see how they are coded in NAPLPS. Those who wish to learn more about the NAPLPS can read the excellent series of articles in *Byte* magazine.[18]

The application layer of the NABTS specifies the teletext services provided to the user, the structure of the service, and the method by which the user controls it. It uses functions provided by the lower layers of the service. The user perceives the service as consisting of a number of magazines each divided into pages. A magazine is identical to a data channel that is defined by the packet address. A page may consist of a single record or several records linked together and shown to the user as a unit.

The application layer specifies several service functions, such as *next, more* and *index*, that have already been described. It specifies the *option function,* which allows a user to enter a key sequence to select from a broadcaster-defined menu. Selection of the menu item may result in further code in the same page being executed, or in the acquisition of other pages. Thus, the option function can be used to build a tree-structured data base, or to give the user control over the display for such interactive purposes as playing games.

Video program enhancement allows broadcasters to instruct teletext receivers to display messages over TV video. It can be used, for example, to provide local telephone numbers for national advertisements.

Another function provided by the service is *flash.* This is used to present information to a user upon request while the user is watching a regular TV program. The information might consist of news headlines on a fast-breaking news story, or the latest sports scores as they are updated.

The application layer defines in a general way the user interface to the service . The specification is deliberately incomplete since the service may interact with other services and devices at the receiver.

The coding of transmit macros, which are defined at the presentation level, is specified. Transmit macros define jumps to other pages and define linkages from option keys to macros. They may be combined so that the selection of a particular option instructs the receiver to acquire another page.

The functions provided by the NABTS can be used to provide a class of interactive games. The ability to link arbitrary macros to keys, coupled with the ability of macros to invoke other macros, to execute PLPS code, to redefine the key linkages and to jump to other pages, allows quite complex games to be defined. For example, a key linked to a macro that moves the drawing point a relative distance and then draws an object at the new position of the drawing point can be used to move an object around the screen. Note that the NABTS cannot provide arcade-type games since it lacks such features as collision detection and conditional execution.

Fundamental Service Specification

Chapter 8 of the NABTS contains a definition of the Fundamental Service Specification (FSS), which defines the initial teletext service. It specifies limits on performance of layers 1 through 7 for both the service provider and the receiver. It gives recommendations and guidelines where limits are inappropriate. Some of the more important specifications of the FSS are the interleaving of packets in full-field teletext, the maximum size of a data group, and receiver-function requirements.

Full-field teletext devotes all the TV scan lines to teletext data to the exclusion of TV video. Only 32 of the lines in any field may be devoted to any given data channel. This restriction simplifies the hardware design of teletext receivers by limiting the information flow in any data channel, which reduces the computational requirements.

The FSS restricts the maximum size of a data group to 68 packets. This allows the receiver to set aside a fixed amount of memory (two kilobytes) for a buffer to acquire data groups. From the receiver manufacturer's point of view this is the most logical restriction, but it does cross OSI levels[12] since packets are at layer 3 and the data group is at layer 4. This inconsistency in the standard points both to the difficulties of imposing the OSI model on the real world, and to the historical and evolutionary nature of standards.

For the presentation layer, the FSS specifies that receivers must meet the requirements of the teletext Service Reference Model. It also specifies the functions that receivers must provide to the user. These include direct page access, and the *next, more, index* and *caption* functions. The ways in which the broadcaster may prompt for these functions are defined. Some recommendations for key labeling are also given. This will improve consistency between receivers without restricting receiver manufacturers from following their own designs.

Comparison of NABTS and U.K. teletext systems

The NABTS teletext system, as specified in the EIA NABTS,[14] and the U.K. teletext system for North America, as specified in CCIR Report 957,[3] are compared in Table II. Level 5 (alphaphotographic) of the U.K. teletext system is not included since it is not yet specified. The U.K. page header and the NABTS service row are excluded from the display comparison.

NABTS receiver

The functions provided by the various layers of the NABTS can be better understood by examining the schematic diagram of a typical NABTS receiver shown in Fig. 5. The receiver is assumed to meet the requirements of the FSS of the NABTS.

A *data slicer* examines each line of the baseband signal, determines the signal level, detects the clock synchronization sequence, and produces an output consisting of a series of bits plus a regenerated clock. A *prefix processor* examines the bits from each line and looks for the framing code and packet address. If the packet address is wanted by the *teletext controller,* then the packet is stored in a buffer for further processing.

The first packet in a record contains the record address. If the record is wanted by the teletext controller, then the remaining packets are acquired and the entire record is stored in a *record memory*. Error detection and correction on the record may also be performed at this point.

Upon command from the teletext controller, a *PLPS processor* will read the PLPS code from the stored record, perform calculations and write into a *display bit map* and also change a *color map*. The display bit map consists of RAM in which four bits are allocated to each viewable pixel. It has a resolution approximately 256 pixels horizontal by 200 pixels vertical by 4 bits deep for the broadcast image. An additional area may be provided for locally generated messages, giving a total bit map size of approximately 27 kilobytes. The four bits defining each pixel indicate an entry into the color map. The color map contains 16 colors that may be any 16 from a much larger palette, typically 512 (2^9) or 4096 (2^{12}) colors obtained by allocating three or four bits to each of the three primaries red, green, and blue. Thus, four bits of information from each pixel of the bit map are converted into 9 or 12 bits of color information. The output of the color map is fed to a *mixer switch* that overlays the output of the color map on the TV video upon command from the teletext controller.

In normal teletext mode the color-map output completely overlays the TV video so that only teletext pages can be seen. The color map may, however, contain the color "transparent." When the bit map references this color, the TV video is allowed to pass through the mixer. Thus, by judicious use of colors, including transparent, the service can be used to overlay text and graphic images on TV video. This can be used to provide teletext services such as captioning, and to provide locally generated feedback messages when the receiver is in the television mode.

Future prospects

The NABTS is emerging as the major teletext broadcast system for North America. The NABTS offers substantially greater performance then the U.K. level 1 system, and this is a major factor in an advertiser-sponsored service where appearance of advertiser products and logos are important.

The cost difference between the display functions of the NABTS and U.K. level-1 receivers is projected to drop to less than $10 by the end of this decade.[19] Although the cost of receivers capable of decoding both systems will also decrease, it is unlikely that broadcasters want to split the available transmission bandwidth between them.

The NABTS does not completely specify all areas of the teletext service. For example, it does not specify user-input methods. It is premature to standardize these at present since, without extensive service experience, it is difficult to predict what forms they can or should take. But, in a few years it may be desirable to revise the NABTS to include a more complete specification of some areas.

I expect that the NABTS will be extended to include downloading of computer programs. Although the FCC currently prohibits this, the utility is so great that there will be increasing pressures to permit this extension. For example, the British are already transmitting computer programs as

Table II. *Comparison of NABTS and U.K. teletext systems.*

Function	*NABTS FSS*	*U.K. Teletext System* level 1	level 2	level 3	level 4
Bits per line	288	290[a]	——→		
Framing code	11100111	11100100	——→		
Magazines	1000[b]	8	——→		
Pages per magazine	1000[b]	100	——→		
Extra pages	999999000[b]	3200	——→		
Version number	yes	no	——→		
Normal text resolution[c]	40 × 20	40 × 23	——→		
ASCII	yes	yes	yes	yes	yes
Accented characters	yes	no	yes	yes	yes
Character sizes	47500	2	4	4	4
Character rotation	yes	no	no	no	no
Proportional spacing	yes	no	no	no	no
Mosaics	yes	yes	yes	yes	yes
Smooth mosaics	no	no	yes	yes	yes
DRCS	yes	no	no	yes	yes
Macros	yes	no	no	no	yes
PDIs	yes	no	no	no	yes
Graphical resolution[c]	256 × 200	80 × 69	80 × 69	undefined	undefined
Wait	yes	no	no	no	yes
Colors	16	8	32	32	32
Color palette	512	8	32	4096	262144
User options	96	1	1	1	1
Key linking	yes	no	no	no	no
Next page	yes	yes	yes	yes	yes
More page	yes	no	no	no	no
Support record	yes	no	no	no	no
Application record	yes	no	no	no	no

a Although specified as 290, it may be a misprint for 296.

b The numbers of NABTS magazines and pages are given for decimal numbering. Additional hexadecimal magazines and pages are available.

c Resolution is given as horizontal times vertical resolution.

a supplement to educational and entertainment services. Time Inc. has been developing software downloading protocols in a teletext cable environment. They may submit a protocol for ANSI standardization. This could become a strong contender for use in teletext and videotex services. A software downloading capability will greatly enhance the functions of the teletext service and will provide the basis for a new range of consumer and business products.

The service may be expanded to peripheral devices controlled by downloaded software. For example, a printer may be used to print out discount coupons for manufacturers' products.

It is possible to transmit a classified advertisement service. Such ads would be broadcast only a few times, perhaps only once. Receivers could select among them by performing a key-word search and store those that had been requested by the user. For example, a person who was interested in purchasing a house in Middleton would tell his receiver to capture and store all ads containing the words "house" and "Middleton."

The captioning facility provided by the NABTS is more powerful than that provided by the current line-21 closed-captioning service. It is expected that the NABTS captioning service will also be much less expensive to the user, and so will eventually replace the closed-captioning service.

I believe that the ability to choose timely and attractively presented information without apparent cost will make teletext a popular service, and almost all TV receivers sold will contain NABTS decoders when the incremental cost becomes sufficiently low.

I expect that the NAPLPS will be revised to include new features in a compatible manner within the next few years. There is already pressure to expand and enhance the NAPLPS to add such desirable features as font styles (for example, italics), different shapes for logical pel (for example, circular), photographic capability, sound, and animation. In the long term, it is possible that NAPLPS will replace ASCII as the standard coding scheme for exchanging information.

As memory costs continue to decline, I expect more memory will be included in receivers allowing the storage of more pages from the broadcast cycle. Pocket color TV receivers will become cost effective and, when given full teletext—including photographic capability—could replace many of today's newspapers. Teletext will have a major impact on the performance of TV receivers. The ability to present digitally generated information on a TV screen will lead to improved convergence and resolution in receivers. It will also lead to better control of the raster position and size. Since the NAPLPS display area is rectangular, it

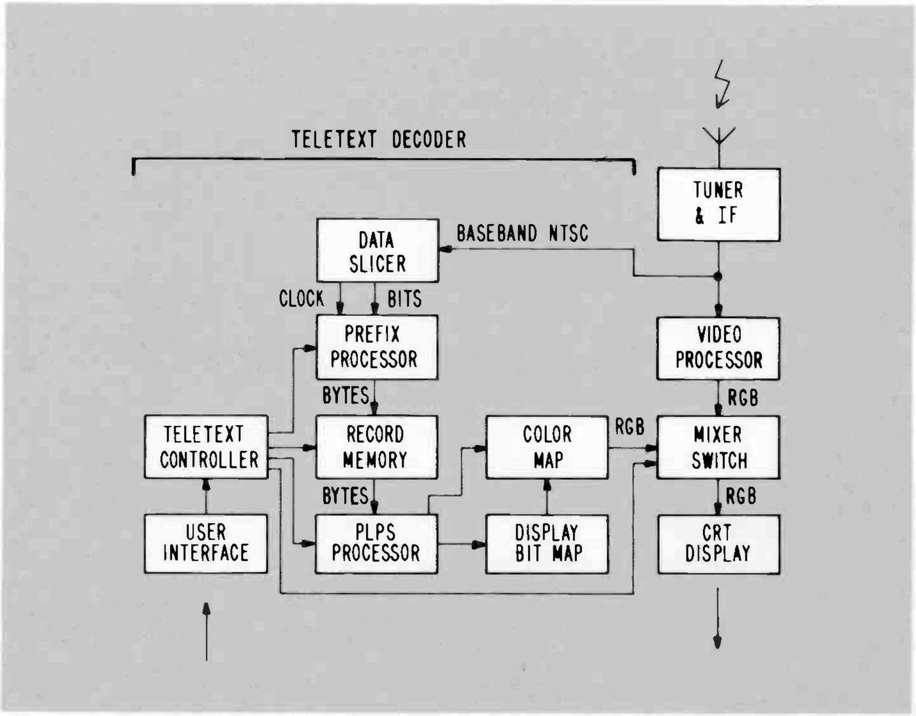

Fig. 5. NABTS teletext receiver. This shows a block diagram of a TV receiver with a built-in NABTS teletext decoder. The teletext decoder takes data from the demodulated baseband signal and constructs teletext pages. The signal from the teletext page has a wider chroma bandwidth than an NTSC signal, so it drives the CRT display directly.

may lead to an increase in the squareness of the corners of TV receivers.

Teletext will also have an impact on regular TV programming. Information reporting, where TV video is not required, may be de-emphasized in regular TV programming and made available in teletext.

After the NABTS and NAPLPS are approved and issued later this year, manufacturers will commit the resources necessary to achieve an optimized decoder design. The first generation of decoders may be somewhat expensive, but LSI/VLSI technology should reduce the incremental cost of NABTS decoders in television receivers in much the same way that calculator costs have declined.

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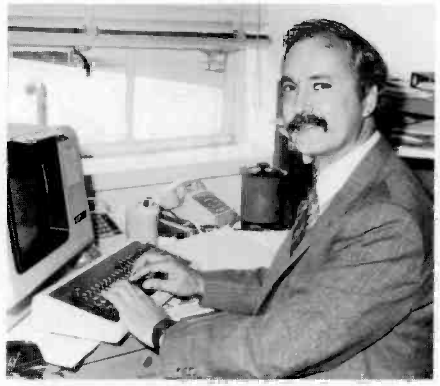

Brian Astle joined the technical staff at RCA Laboratories in 1974. Since then, he has worked on a variety of projects, and has received two RCA Laboratories Outstanding Achievement Awards, one for work on the TK-47 television studio camera and the other for work on teletext standards. He is now a Fellow of the Technical Staff. Mr. Astle received a B.A. degree in physics, with honors, in 1960, and an M.A. degree in 1964, both from Cambridge University, England. He is chairman and editor of the EIA Drafting Group that produced the draft EIA NABTS. He is also chairman of the EIA Special Working Group that has responsibility for the technical content of the NABTS. He is a member of ANSI committee X3L2 and of its working group X3L2.1, which has NAPLPS responsibilities. He is also one of the editors of the NAPLPS.
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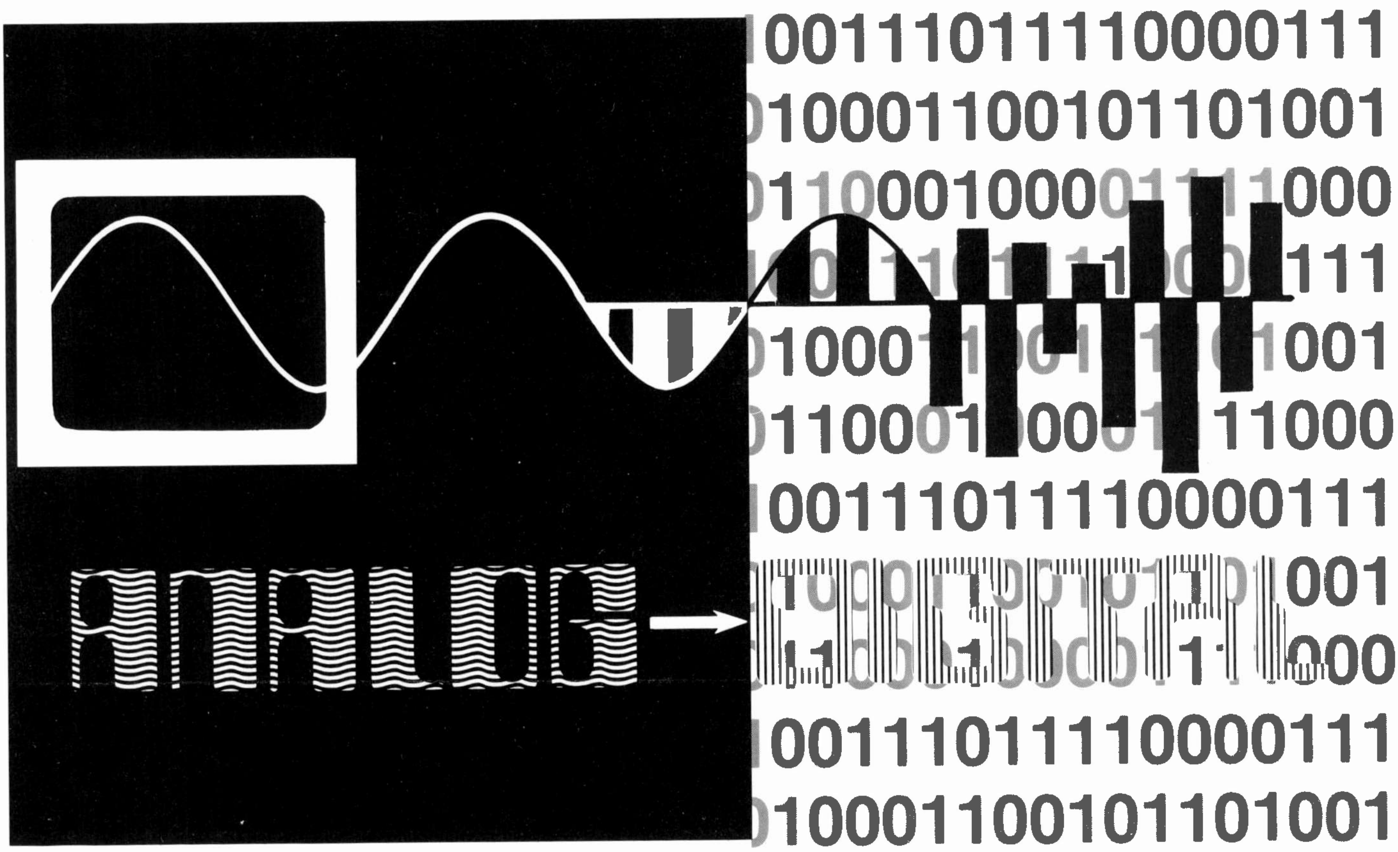
Technology for digital television

"Every analog process in television will be replaced by a digital process as soon as digital technology for that process becomes economical."

—Marlowe's Law of Digital Inevitability



Abstract: *After reviewing the reasons for the growth of digital technology's use in television transmission and reception, the author gives the basic requirements for resolution, data density, processing speed, and bandwidth. The new areas driving digital TV development—A/D converters, semiconductor memory, VLSI, magnetic recording and fiber optics—are described. Next, the author reviews the current status of digital video processing and prognosticates the future of digital TV.*

Final manuscript received July 11, 1983.
Reprint RE-28-5-4

Digital signal processing, which has produced profound changes in our lives through its uses in computers, is now being applied to television. In this article, we will review some of the things that are being done digitally in television, some that are likely to be done in the future, and the technology developments that have made and will continue to make digital television a reality.

Digital TV includes more than just the use of digital circuitry in TV equipment. We already have digital large-scale integration (LSI) in tuners, digital transmission and logic in remote controllers for TV, digital addressing of descramblers, and digital microcomputers controlling broadcast cameras and tape recorders. But, these are *not* digital TV. Digital TV refers to the representation of the television waveform as a series of discrete digital words (called pixels) rather than as a continuous analog waveform.

The advantages of digital over analog processing in television are the same as those that led to the use of digital processing in other fields. For example, digital circuits have smaller parts counts because they do not require passive resistors, capacitors, and coils. Moreover, adjustments for gain, level, bandwidth, and so on, can be eliminated, and performance does not gradually degrade as parts age. Software can be used to conveniently test subsystems during and after manufacture, and natural control of digital TV processors by other digital equipment is possible. In addition, computer-aided-design can be applied to digital integrated circuit design, and new functions can be done digitally that could not be done at all in analog.

Indeed, the attractiveness of digital processing is so great that one could state a rule of digital inevitability: "Every analog process in television will be replaced by a digital process as soon as digital technology for that process becomes economical." We are currently in the early stages of this replacement process. Until now, the still-expensive new digital technology has been accepted only in the broadcast studio, where equipment ordinarily is costly. But soon digital TV technology will spread to other commercial and consumer equipment.

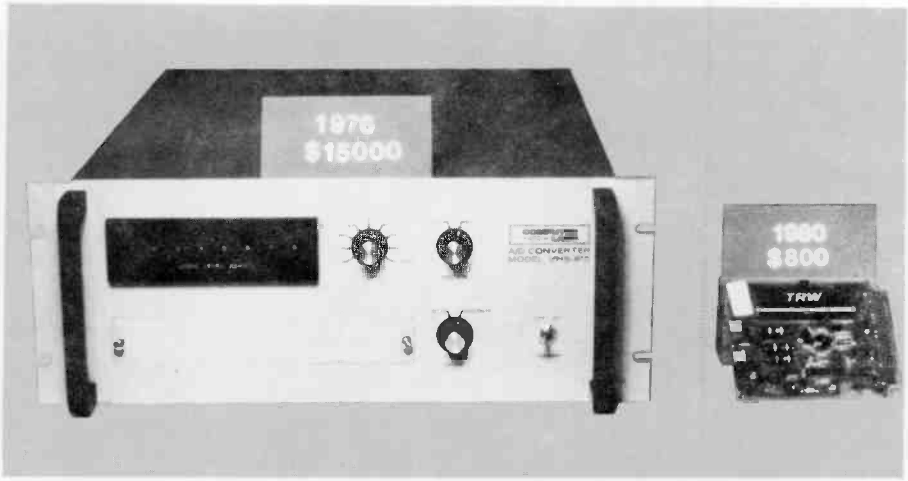


Fig. 1. *A typical 1976 analog-to-digital converter costing $15,000 is shown next to a 1980 converter, which is a fraction of the size and one-twentieth the price. Advanced development by several semiconductor companies, including RCA, is expected to produce price reductions by another factor of twenty.*

General technology requirements

The character of the television signal imposes severe requirements for digital processing. Every TV frame contains a tremendous amount of visual information and each frame is replaced by a new frame thirty times per second. From basic television considerations certain *a priori* requirements can be derived for digital TV technology.

Resolution

The human eye can perceive very subtle differences in brightness and color. A digital TV processor must represent each pixel with fine-enough resolution (determined by the number of bits per pixel) so that when the picture is displayed, brightness and color variations appear to be continuous. The required number of bits per pixel depends on the point, in the long TV distribution chain, where the digital processing occurs.

After leaving the beginning of the chain in the program-originating studio, a signal will be converted between analog and digital several times, and quantization errors accumulate along the way. On the other hand, at the end of the chain (in the receiver) where the signal will only be converted from analog to digital once, no further quantization errors will be introduced. Consequently, higher resolution will be needed for digital TV *production* than for digital TV *reception*. In studio equipment, at least eight bits per pixel are employed, with nine or even ten used in some instances. There are no digital receivers in use yet, but they are expected to employ at most eight bits per pixel, with seven bits a strong possibility.

Data density

The exact amount of data in a single frame depends on the pixel rate of the digital processor and on certain other variables. However, for estimation purposes, each of the nearly 500 lines in a frame can be considered to consist of 1000 pixels. With eight-bit pixels, this corresponds to 0.5 megabytes (Mbytes) of data for a single frame. For comparison, this is equal to the entire capacity of a double-sided dual-density 5¼-inch floppy disc, which is capable of storing a 200-page novel. Thus, any digital TV process that involves temporary storage of all or part of a frame (as many processes do) requires a tremendous amount of storage capacity.

Processing speed

The large amount of data in each TV frame and the rate at which frames are updated imply extremely high data rates. Extending the above estimates, 0.5 Mbytes per frame times 30 frames per second gives a data rate of 15 Mbytes per second. Thus, if an operation—such as averaging two pixels, or multiplying each pixel by a constant—is to be done in real time, the processor must be fast enough to complete an entire operation every 66 nanoseconds. Since digital processors perform complex operations by building up simple basic operations, the required computational rates for the basic operations could be a multiple of 15×10^6 operations per second. Such speeds are near the limits of today's technology, and therefore, require power-consuming and expensive circuits.

Bandwidth

The high data rate of real-time digital television implies a large channel bandwidth for transmission and distribution. Further extending the above estimates, we find that 15 Mbytes per second times 8 bits per byte gives a bit rate of 120 Mbits per second. For this data rate, a channel bandwidth of approximately 60 MHz is required, or ten times the bandwidth of a standard TV broadcast channel. Methods exist to reduce the data rate by sacrificing performance (depending on processing complexity), but there is no way to avoid the inherently high data rate of live digital TV signals. However, the high cost of channel bandwidth for digital TV is partially offset because a digital channel requires a lower signal-to-noise ratio than an analog channel, since the digital data is quantized.

Technology status

In spite of the severe requirements, many new technologies have emerged to permit digital TV to be used for selected applications, and promise to permit its use in many more applications. Some of the main examples are described here.

Analog-to-digital converters

The first step in a digital processor is the conversion of the continuous analog TV waveform to a series of digital words. The

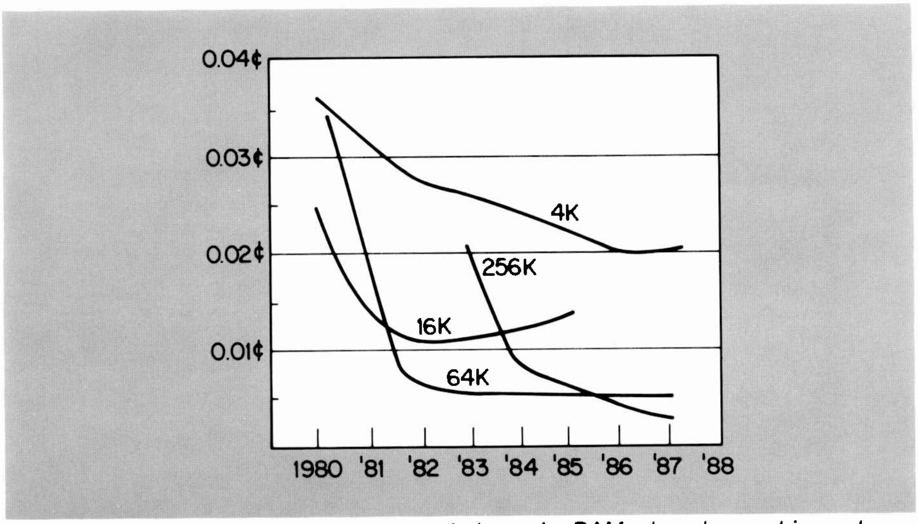


Fig. 2. *The price per bit of memory of dynamic RAMs has been driven down sharply by each fourfold increase in memory size. By mid-1985, the price per bit of 256K RAMs is expected to drop below that of 64K RAMs (*Fortune Magazine, *May 26, 1983, page 154).*

first commercially available 8-bit video A/D converter occupied an 8-inch-high by 19-inch-wide rack of equipment.

Today a converter occupies a single 5-inch by 5-inch circuit card. Figure 1 shows a 1976 converter costing $15,000 alongside a 1980 converter costing $700. At several hundred dollars each, A/D converters are suitable today for commercial TV equipment that may cost tens of thousands of dollars. However, for consumer equipment, the cost of an A/D converter must fall to a few dollars or less. Such low-cost devices for consumer products are expected soon, from RCA and from other semiconductor manufacturers.

Semiconductor memory

The ability to store all or part of a TV frame was first economically achieved by use of the 4K single-chip MOS dynamic RAM in 1975. Since then, increases by factors of four in single-chip memory size have occurred twice—to 16K and to today's 64K. Frame stores based on 4K dynamic RAMs in 1975 occupied twelve large circuit cards. Today, with 64K RAMs, the same storage fits on a single card. The next-generation frame store based on 256K RAMs will require only 16 memory chips. Figure 2 shows the trend memory cost has followed since 1980. If present trends continue in the semiconductor density, a single-chip frame store will not be far away.

Very large scale integration

Up to now, the use of digital processing in expensive broadcast equipment has not involved a high-enough production volume of special circuits to support custom VLSI. Consequently, the only LSI used in digital broadcast equipment has been that developed for other purposes. The chief example is the 64K RAM mentioned above, which is mainly used in computers. For consumer products, however, with high volume and required low cost, VLSI, specifically for digital TV, will be mandatory. In fact, some companies have already announced experimental VLSI chips to do certain TV-receiver processes digitally.

One VLSI that has just been introduced for broadcast TV is the charge-coupled device (CCD) imager. This integrated circuit is not strictly digital. It produces a waveform composed of a discrete series of pixels that have analog amplitudes. However, because the waveform is in the form of discrete pixels, the CCD imager is well suited as a video source for digital processing. RCA demonstrated an experimental CCD broadcast camera at the National Association of Broadcasters Convention in Las Vegas in April of this year.

Magnetic recording

A digital tape recorder must handle both the enormous amount of data and the very high speed required by digital TV. Furthermore, a desirable goal would be that a digital tape recorder use no more tape than the best analog recorder. To achieve a tape usage equal to that of the industry-standard type-C helical recorder, a digital recorder would need a data density of 10^7 bits per square inch and a data rate in excess of 100 Mbits per second. Several companies, including RCA, have demonstrated experimental recorders with this capability. This technology is extremely expensive, and, therefore, its use in consumer TV is not yet foreseen.

Fiber optics

During the past few years, interest in fiber optics for digital TV has grown. The discovery of graded-index fibers with low attenuation (typically 1 dB per mile) at 1.2-μm wavelength, laser transmitters, and avalanche diode receivers all point toward eventual use of fiber for interconnection between digital-TV components that are up to a few miles apart. An example of such an interconnection might be between a digital camera head at an outdoor location (for example, on a golf course) and a remote base station.

The lack of convenient mechanical hardware such as connectors, splicers, and taps has hindered the growth of fiber optics for television use up to now. However, in April, 1983, RCA also demonstrated an experimental digital-TV transmission link over a kilometer of optical fiber at the National Association of Broadcasters Convention.

Status of digital video processing

Digital TV has been in use in broadcast and teleproduction studios since 1975, performing important and sometimes dramatic functions.

The first widespread application of digital TV was for time-base correction in helical tape recorders. The long helical track length (10 inches), combined with the elasticity of the tape, resulted in a timing error of up to a few TV lines. A digital buffer of several TV lines (called a time-base corrector) was used to compensate for this timing error, thus making broadcasts using the helical recorder possible. In current tape recorders, such as the RCA TR800, the time-base corrector also corrects drop-outs by replacing lost signal segments with information from adjacent lines.

The next important digital-TV processor was the frame synchronizer, which was and still is used to align vertical and horizontal framing of incoming TV signals to a studio reference signal. Like the time-base corrector, the frame synchronizer consists of a digital delay, but the synchronizer capacity is an entire frame. The incoming signal is delayed by up to a frame-time to align its vertical and horizontal sync with studio sync. Before the introduction of frame synchronizers, the entire studio sync had to be adjusted to conform to whichever incoming video signal was being broadcast.

A related item is the electronic slide store, which can hold one or more still pictures. A high-speed frame memory is used to buffer the picture being displayed. Other pictures can be stored on computer discs, and transferred to the high-speed memory for real-time display.

Still another processor that uses a video frame store is the digital noise reducer. This equipment adds the previous frame, or a combination of previous frames, to the current frame. Since the picture is highly correlated from frame-to-frame and noise is uncorrelated, this addition increases the signal-to-noise ratio of the picture.

The most dramatic use of digital TV in studios is in real-time picture manipulation. A picture manipulator is essentially a frame store that can be addressed for readout by a different raster than was used for write-in. The read raster can be of a different size than the write raster, to produce a picture compression or magnification, or it can be offset at an arbitrary angle to tip the picture. If the size change is a continuously alternating vertical expansion and compression, the picture appears to tumble toward or away from the viewer. If the angular offset varies continuously, the picture appears to rotate in the plane of the display. Under software control, combinations of these operations can be done together to produce zooming, rotating and/or tumbling images. In very sophisticated picture manipulators, a picture can be mapped onto cylindrical or spherical surfaces of arbitrary and variable dimensions, and multiple images can be superimposed. Many of these manipulations are by now familiar to television viewers.

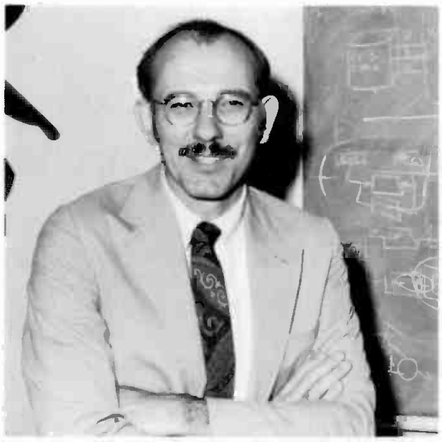
Digital tape recording for television studios has been under development for several years, but so far none is commercially available. Considerable work by international standardization organizations (discussed in detail in other articles in this issue) has been done to prepare for digital recording, which many in the broadcast industry consider likely within the next five years. Much work is underway throughout the world to develop digital TV for consumer products, but none has been offered commercially.

Future directions

Digital TV has established a foothold in broadcast and teleproduction, although the major components of a studio—cameras, switchers, recorders, and distribution—are still analog. Because most of the components and interfaces are still analog, digital components in use today are sometimes called "digital islands in an analog sea." As more studio components incorporate digital processing, the "islands" will become more numerous, and ultimately they will be linked together—that is, they will be connected by digital links instead of by analog links. The digital TV studio of the future will resemble a vast computer system with storage capacity and processing speeds in excess of those of today's most advanced computer systems.

As a consumer product, digital TV has not yet made its debut. The rule of digital inevitability will govern the timing of its introduction. Soon we can expect digital processing in TV receivers, in descramblers for cable and direct-broadcasting satellite receivers, in flat-panel displays, and in novel high-definition television systems. These new digital products will be characterized by levels of performance, compactness, and reliability that are unknown today.

RCA currently has digital research and development projects underway in every facet of television technology. RCA engineers will not merely witness the change from analog to digital TV—we will create much of it.



Frank Marlowe received his Bachelor's Degree in Electrical Engineering from Pratt Institute in 1963. In 1965, he received a Master's Degree in Electrical Engineering from Princeton University, and in 1975, he received a Ph.D. in Electrical Engineering from Rutger's University. In 1963, he joined RCA Laboratories as a Member of Technical Staff on the Research Training program. From 1963 to 1978, he worked on a variety of projects including liquid crystal displays, computer terminals, computer memories, storage tube displays, television sync generators, two-way cable television, video disc mastering, and flat-panel television displays.

In 1978, Dr. Marlowe became Head of the Digital Video Research Group. From 1978 to the present, he has supervised projects in broadcast transmitters, television cameras and tape recorders, digital video research, cable television and direct-broadcast satellites. He currently has a dozen U.S. patents.

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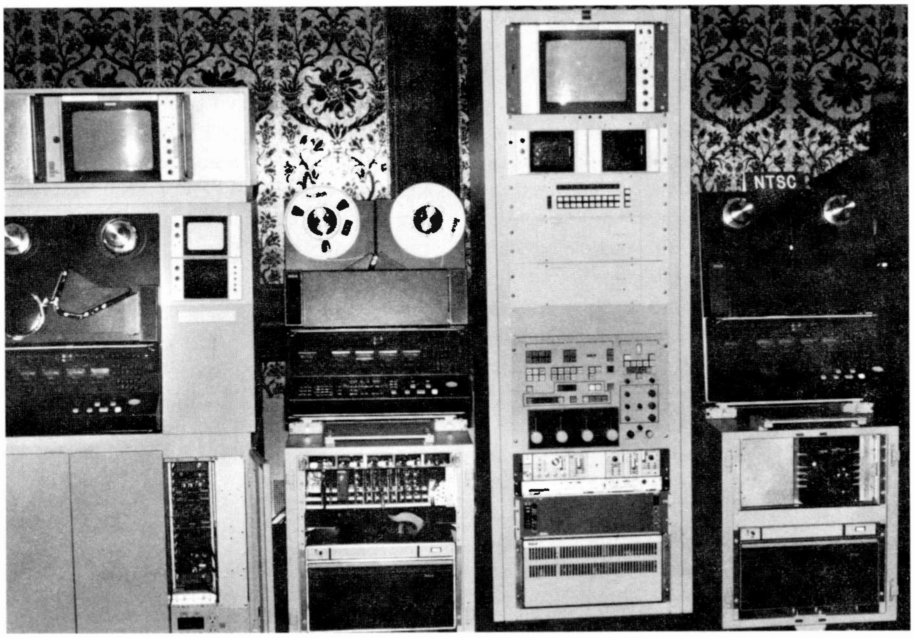
T.M. Gurley | C.J. Haslett

Component analog video recording for studio applications

Separate recording of the parameters, or "components," necessary to reconstruct a color picture offers significant advantages over "composite" recording, whereby signals representing those parameters simultaneously share the same frequency band.

Abstract: *Many technical experts in the television industry view the component analog studio as a stepping stone between today's composite studio and the all-digital studio of tomorrow. A component video format offers advantages such as lower chroma noise in FM transmission and recording channels, ease of manipulation for post-production applications, and freedom from the well-known artifacts associated with composite encoding. An industry effort is currently underway to develop video signal standards for the component analog studio. With a background in component analog recording for electronic news gathering (ENG), RCA engineers are now developing a component videotape recorder (VTR) for more demanding studio applications. Such a VTR satisfies the requirement for higher quality in today's increasingly sophisticated television productions and for emerging alternative forms of program delivery to the home. A prototype system using a modified one-inch helical studio VTR product has been successfully demonstrated to the industry. In this system the luminance and two color-difference signals are time compressed and multiplexed into one active line time, resulting in a signal that has twice the normal bandwidth. Recording and reproduction of this signal require wider-bandwidth video circuits and new parameters for the FM channel in the VTR. Through this effort, RCA is maintaining a leadership position in the field of component analog video.*

Final manuscript received July 28, 1983.
Reprint RE-28-5-5



Equipment for comparing NTSC and component analog recording. Two component analog VTRs are on the left, and an NTSC VTR is on the right. The center rack contains signal-generating, switching, and monitoring equipment.

In the late 1970s, many in the television industry believed that the all-digital studio, with the digital videotape recorder (digital VTR) at its center, would be a reality within five to seven years. However, technological progress has been slower than anticipated, and alternative means for satisfying some of the user requirements for the digital studio have emerged. Recently, the concept of a component analog studio, centered on a component analog VTR, has received much attention—for example, a Working Group on Component Analog Video Standards has been established by the Society of Motion Picture and Television Engineers (SMPTE).

Many experts now believe that the digital VTR as a practical product is still five to seven years away, and that the all-digital studio may not emerge in this decade. For the network broadcasters and major teleproduction houses who will most likely pioneer the component digital studio, component analog video is viewed as a stepping stone from today's composite analog plant. For smaller broadcasters, the component analog studio may serve adequately for many years.

Recognizing the growing interest in component analog video, and convinced of the viability of the component analog VTR as a product, RCA Broadcast Video Systems has undertaken a program of Research in Component Analog Video (RCAV). The primary goal of this program is the development of a video recorder to serve the needs of the component analog studio.

A moving target for the digital VTR

The "Type C" one-inch helical videotape recording format has established a strong foothold in the broadcasting and teleproduction industries since its introduction a half-dozen years ago. It offers higher quality, lower operating and maintenance costs, and more features than the two-inch quadruplex format it displaced. Second-generation Type C machines, such as the RCA TR-800,[1] and continuing improvements in performance and features offered by all manufacturers, present a moving target to the digital VTR.

At the present time, user requirements for digital VTRs cannot be met with the available technology. In the key areas of compatibility with existing systems, editing capability, operational features such as picture-in-shuttle, and cost, analog recording is now superior. Better picture quality remains a primary advantage of digital recording. With the picture quality improvement realizable by recording components, however, the moving analog target may be taking yet another stride ahead.

The stepping stone to digital

Despite the technical advantage of component analog recording over composite recording, economic considerations could limit its acceptance among users recently upgraded to Type C and those likely to be early converts to digital. The stepping-stone scenario is reasonable only if the component analog step is not a large one. Otherwise many users would prefer to wait for the digital VTR. Thus, the success of a component analog VTR might well hinge upon the approach taken in its implementation. An approach based upon the Type C format is particularly attractive and has been the primary thrust of the RCAV effort.

What are components?

To appreciate the advantages of components, one should understand the distinction between component and composite video. All of the information necessary to reconstruct a color picture may be conveyed by specifying three parameters. A "component" video system handles signals representing those parameters separately. In a "composite" system, those signals simultaneously share the same frequency band.

The primary components of a color television system are signals representing the colors red (R), green (G), and blue (B). Human vision does not require the full resolution for the color hue and saturation, or chrominance, information that it does for the brightness, or luminance. So, in comparison with RGB transmission and recording, a substantial amount of bandwidth can be saved by specifying as components a full-bandwidth luminance signal (Y) and two narrower-bandwidth color-difference signals. Each of the color-difference signals may be synthesized by subtracting luminance from a color signal; for example, blue minus luminance (B-Y).

The color system adopted in the United States by the National Television System Committee (NTSC) is a composite system in which the color-difference signals (orange minus Y, magenta minus Y) modulate two quadrature-related subcarriers having a frequency within the luminance band but above most of the luminance energy.[2] To minimize crosstalk between luminance and chrominance, that frequency is further chosen such that the predominant energy of the subcarrier and its sidebands interleaves with that of the luminance.

Why components?

Early digital video standardization efforts were directed toward coding of the composite video signal. After several years of in-depth study on a worldwide scale, interest mounted in component coding. It was recognized that separate digital coding of the luminance and color parts of the video signal provides improved picture quality, facilitates complex signal processing, and eliminates subcarrier-related complications in editing and other production operations.

Those same virtues apply to the handling of analog video in component form. Indeed, several advantages over composite analog recording sought by potential users of component digital machines are actually more a function of component versus composite processing than of digital versus analog techniques.

Why component recording?

Since a component analog video recorder is, essentially, a monochrome VTR whose signal does not contain a color subcarrier, the undesirable characteristics associated with subcarrier processing in composite machines are mitigated. These characteristics fall into three categories—video performance, editing features, and time-base corrector (TBC) performance.

The video performance of an NTSC VTR is impaired by differential gain and differential phase, moire, and color noise. A component VTR cannot create differential gain and phase since these distortions are subcarrier amplitude and phase shifts as a function of luminance level. Moire—visible as a wavy, interfering pattern of lines—is a less significant problem in a component VTR. The primary contributors to moire in a composite machine are the subcarrier-related modulation products appearing in playback of the FM signal that carries the video information on and off tape.

Color noise is the most visible picture impairment and the predominant limitation on multiple-generation performance. Hence, the reduction in color noise over that generated by composite recording is the most significant improvement achieved by a component VTR. The noise spectrum of the baseband video after FM demodulation rises with frequency in the approximate triangular shape shown in Fig. 1. The NTSC color subcarrier and its sidebands occupy the high-noise region of this spectrum above most of the luminance energy. Decoding of the color information impressed upon the subcarrier translates the higher level of noise to more-visible lower frequencies. Since, in a component recorder, the color information does not reside on a subcarrier, it can be recovered without translation of the noise spectrum.

In the NTSC system, the frame rate and subcarrier frequency are related such that the phase relationship between them repeats in a two-frame (four-field) sequence. This requires the VTR to color frame when playback starts so that the off-tape sequence matches that of the studio reference. With no subcarrier, and hence no two-frame sequence or color-framing requirement, a component VTR can achieve a twofold improvement in start-up time, which is important in editing situations. In addition, edit points may be selected in single-frame increments since preservation of subcarrier integrity is not a consideration.

The elimination of subcarrier from the recorded signal simplifies the TBC design and improves its performance in several respects. Residual time-base jitter does not appear as subcarrier phase fluctuations that result in color streaks in the picture from

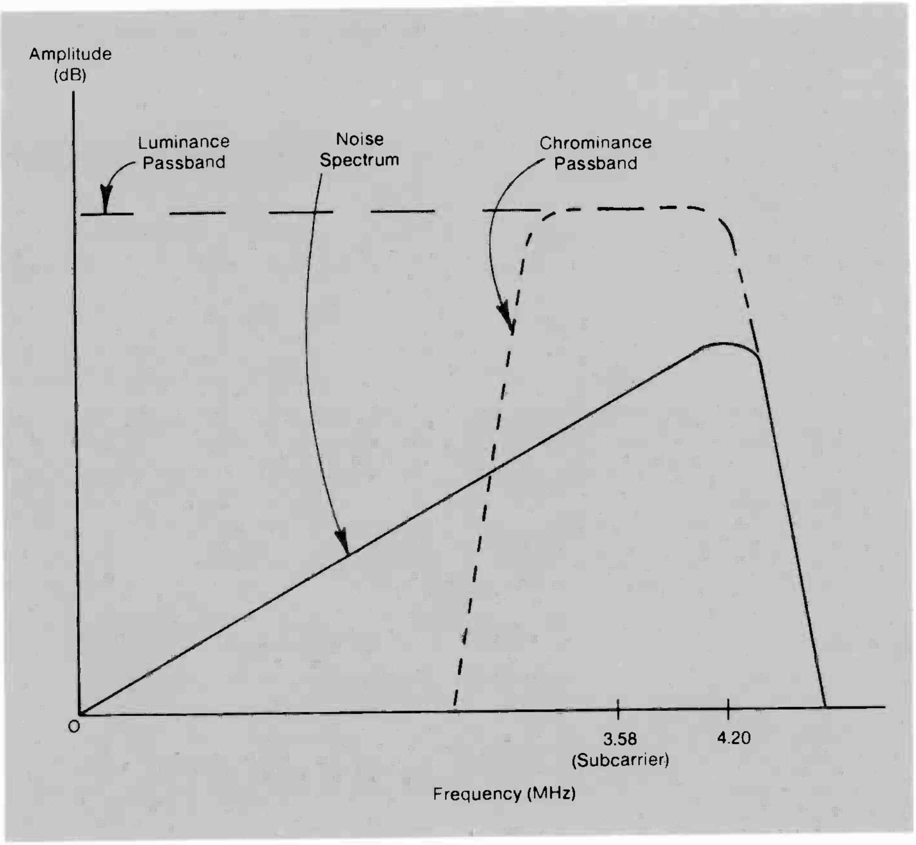


Fig. 1. *Relationship between baseband NTSC video and triangular noise spectra, after FM demodulation, showing the high-noise environment of chrominance.*

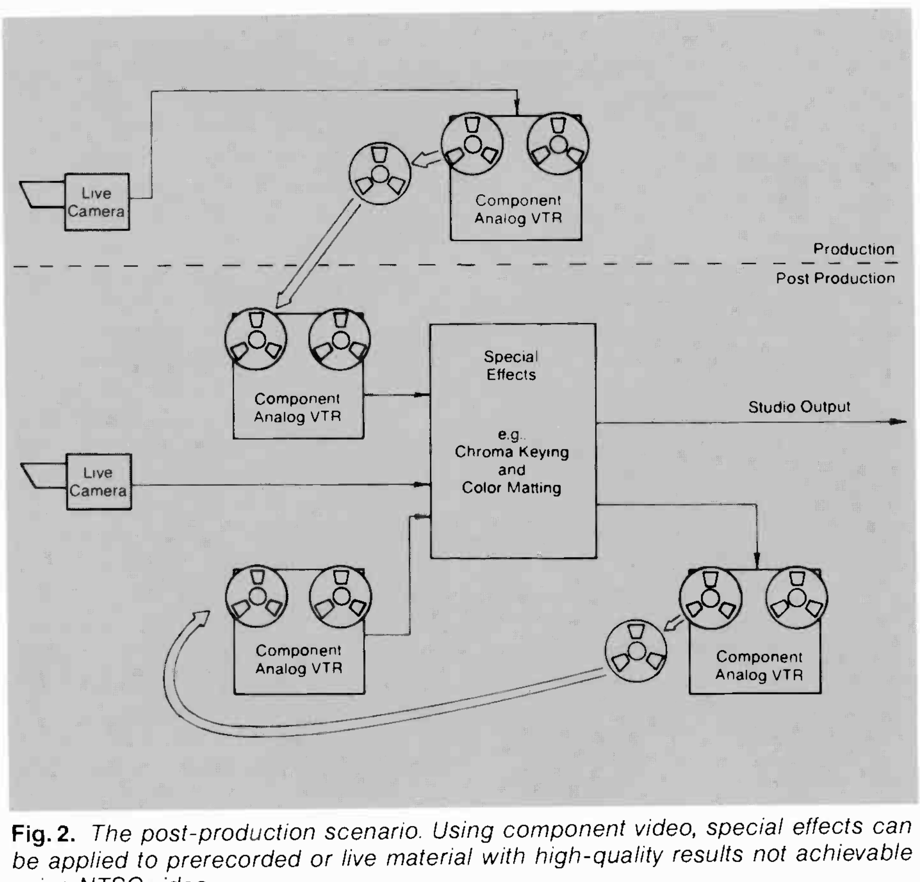


Fig. 2. *The post-production scenario. Using component video, special effects can be applied to prerecorded or live material with high-quality results not achievable using NTSC video.*

undesired hue modulation. Drop-out compensation is more effective. Replacement picture elements need not be selected from those of matching subcarrier phase; this allows elements with closer proximity to the lost video to be used. Higher-quality still and slow-motion playback ("moviola") is possible. In such non-real-time modes, a composite TBC must invert the phase of the chrominance subcarrier periodically to restore the proper two-frame sequence. Chrominance bandwidth reduction is an undesired side-effect of the process. In a component TBC, the absence of subcarrier obviates the need for this chrominance inversion.

The NTSC window

The band-sharing inherent in the NTSC composite encoding method results in a limitation on picture quality imposed upon signals in going through the "NTSC window." Once encoded, luminance and color cannot be separated cleanly.

The most noticeable impairments are cross-luminance and cross-color. Cross-luminance results from contamination of the decoded luminance signal by high-frequency chrominance detail. It is visible as crawling dots at sharp color transitions. Cross-color is produced by high-frequency luminance energy that falls within the chrominance passband and is decoded as spurious color. Familiar as the "plaid jacket effect," it is sometimes also referred to as moire because of its wavy, rainbow-like appearance.

Both of these artifacts can be minimized by the use of a comb filter in the decoder.[3] Undesirable consequences, though, are loss of diagonal resolution and an artifact aptly described as "hanging dots" along horizontal color boundaries.

Breaking the window

Traditionally, origination, assembly, recording, and transmission of programming employ NTSC video. In recent years, production special effects, such as chroma key or color matting and picture squeezing and zooming, have come into increasingly wide use. These effects require that the video signal be manipulated in component form. For highest quality, the components should be obtained before encoding and not derived from composite video. Therefore, these effects cannot be performed well using recorded NTSC material.

The post-production scenario

A decrease in the production cost and an increase in the quality of the end product

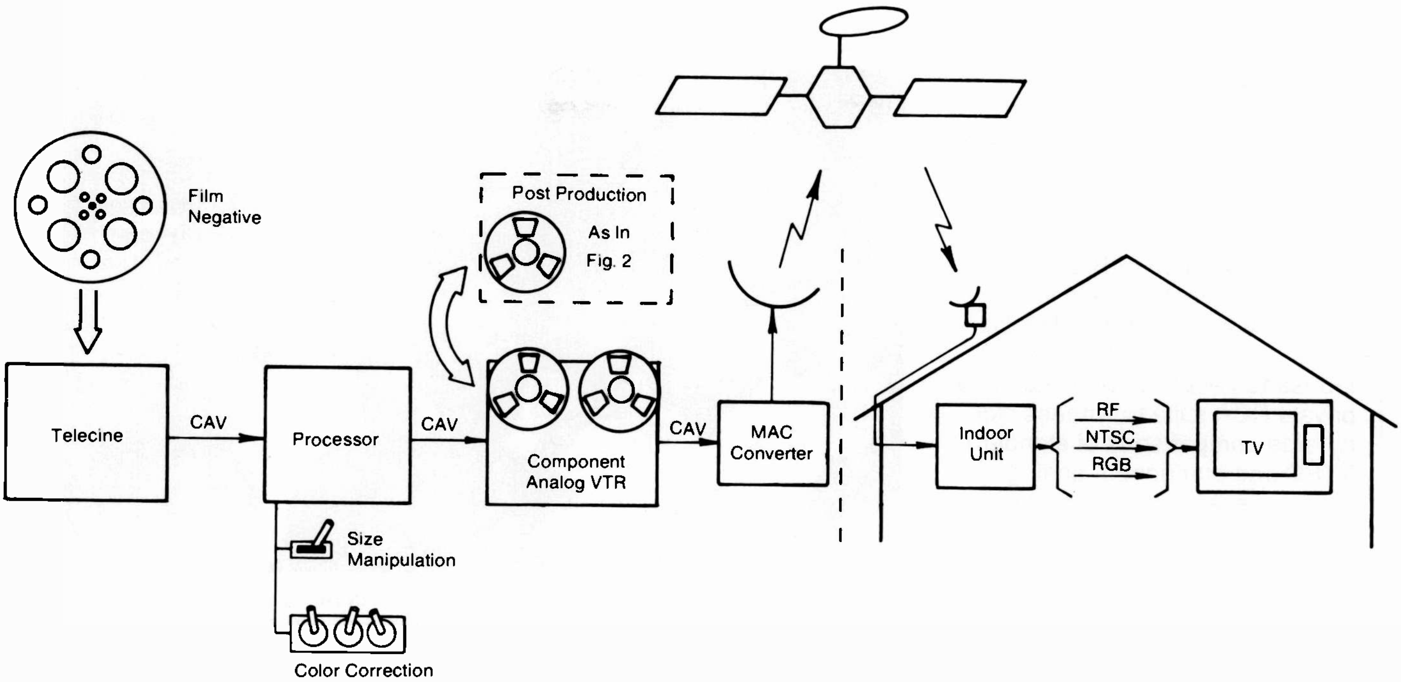


Fig. 3. *The DBS scenario. With an end-to-end component system, high-quality program material could be delivered to the home without the effects of NTSC encoding.*

may be achieved by configuring the entire studio to handle the signal in its component form. As Fig. 2 suggests, special effects may then be applied at any point to either recorded or live material. The signal need pass through the NTSC window only once—at the broadcast transmitter. Until recently, the non-availability of cost-effective component recorders and the efficiency of "single-wire" handling of the NTSC signal, over "three-wire" distribution of components, have precluded interest in such component studios. Both of these factors were considerations in the development of the RCAV signal format.

The DBS scenario

New forms of program delivery to the home need not be constrained to NTSC transmission. In particular, direct broadcasting by satellite (DBS) will probably use component transmission. In the United Kingdom, a technique known as MAC, for Multiplexed Analog Components, has been adopted recently for DBS service. Companies planning such service in this country are looking favorably upon a MAC-like technique for use here.

Figure 3 illustrates a possible DBS scenario. For airing of feature film material, a high-quality negative is transferred to tape, via a telecine having component analog video (CAV) outputs and a processor for color correction and geometric manipulation to ensure that relevant scene action from the wide-screen film is not lost to the aspect ratio of the home television screen. Use of a component analog VTR permits any post-production work, such as addition of titles or creation of trailers, to be done off-tape rather than by repeated handling of the delicate negative.

Transmission of the completed program may require conversion between a component analog format optimized for studio applications and a MAC-like transmission format, which could involve alternate-line chrominance. The NTSC window need not be applied until the signal has reached the indoor unit in the subscriber's home. A conventional television receiver will require NTSC video, either baseband or modulated onto an unused rf channel. However, recently introduced models also can accept RGB component video inputs that bypass the set's NTSC decoder. Ultimately, then, the signal would never pass through NTSC encoding and decoding from the telecine to the home screen.

RCA experience in component recording

Developments in component analog recording have been made by several groups at RCA over the past decade. Individuals involved with this previous work are among the contributors to the RCAV program.

A wideband recording system called ADVISOR was produced by RCA Government Communications Systems for airborne instrumentation applications.[4] Using quadruplex recording, the ADVISOR 152B featured two channels, each having 15-MHz video bandwidth. A future broadcast application was conceived, whereby a wideband luminance signal would be recorded on one channel, while two frequency-division-multiplexed color-difference signals, of narrower bandwidth, were recorded on the other.

A technique of time compression and time-division multiplexing of components was developed at RCA Laboratories in early 1980.[5] For demonstration, two compressed color-difference signals were sequentially multiplexed onto one channel of a two-channel VTR, with luminance being recorded on the other channel. Extension of this approach, to permit multiplexing of all three components on a single channel, is the basis of the RCAV technique.

In 1981, RCA Broadcast Video Systems introduced the Hawkeye recording camera system for Electronic News Gathering (ENG) applications.[6] Using a format called Chroma Trak, Hawkeye records analog components on half-inch tape cassettes. Accessories developed for the Hawkeye system are now permitting users to exploit fully the advantages of component recording by implementing total component editing suites for their ENG operations.

Which components?

In the international deliberations that led to the 1982 adoption of CCIR Recommendation 601, "Encoding Parameters of

RCA demonstrates technical leadership

The RCAV component analog studio VTR was first shown to the broadcasting industry at the National Association of Broadcasters Convention, held in Las Vegas, Nevada in April 1983. During a four-day period, some one-thousand people were invited to a private RCA suite to witness side-by-side comparisons of standard NTSC and component analog playbacks. A marked reduction in color noise and complete absence of the NTSC artifacts of moire and dot crawl in the component video were pointed out in a variety of recorded scenes that included high-resolution pictorial material, test charts, and the obligatory plaid jacket.

International technical experts currently involved in setting signal format standards as well as potential users representing broadcasting, teleproduction, and DBS interests viewed the RCAV demonstration. Presented as a statement of technological feasibility and not as a product introduction, the developmental VTR was regarded by observers as proof of RCA leadership in this emerging field.

Authors Haslett and Gurley point out differences between NTSC and component analog VTR playbacks of material recorded simultaneously from the same sources.

Digital Television for Studios," Y, R-Y, and B-Y were chosen as the components to be encoded. With the digital video standardization work as a precedent, and the goal of having the component analog studio maximally compatible with the future evolution of the digital studio, the decision was made to use Y/R-Y/B-Y components for RCAV. It was further decided to maintain the same bandwidth for each component as proposed by the CCIR. The luminance channel is, thus, specified to be flat to 5.5 MHz, and each of the two color-difference channels is to be flat to 2.75 MHz.

The RCAV format

The MAC satellite transmission system employs time compression of the components in order to multiplex the luminance signal and one color-difference signal within the time of one TV line. The compression ratio was chosen to be inverse to the bandwidth ratio of the components to use most efficiently the available channel bandwidth. The two color-difference signals are transmitted on alternate lines. Thus, the vertical resolution for chrominance is half that for luminance. This compromise for the sake of conserving transponder bandwidth is subjectively acceptable for home viewing. For studio use, however, full vertical chrominance resolution is desirable.

The technique chosen for RCAV is similar to the MAC concept in that components are time-compressed and multiplexed into one TV line. The compression is greater, however, so that both color-difference signals can be transmitted along with the luminance for each line. Since the bandwidths specified for Y, R-Y, and B-Y are in the ratio 4:2:2, the compression ratio is 2:4:4. That is, the luminance signal is compressed to occupy half the line, and each of the color-difference signals is compressed to occupy one-fourth of the line. The required channel bandwidth, then, is 11 MHz for the specified luminance bandwidth of 5.5 MHz.

Figure 4 depicts the RCAV format. The waveform shown represents a color-bar test signal of 100-percent saturation. The luminance signal occupies the first half of the TV line. The horizontal blanking interval is considered part of luminance for this format, so the horizontal sync pulse and its front and back porches (blanking levels that immediately precede and follow the sync pulse) are all compressed two-to-one. Since the color-difference signals are bipolar, they are placed upon a 50-percent-level pedestal with respect to the black-to-white range of the luminance signal. The R-Y component occupies the third quarter of the line, while the B-Y component occupies the fourth quarter. The amplitudes of

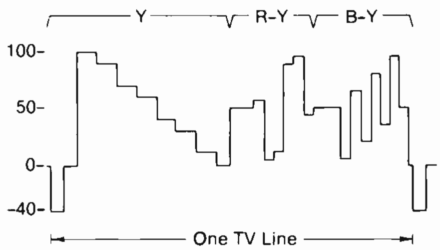


Fig. 4. *The RCAV signal format. A 100-percent-saturated color-bar test signal illustrates the time compression and multiplexing of Y, R-Y, and B-Y components within one TV line.*

R-Y and B-Y are scaled so that, with allowance for headroom, their maximum excursions are the same as the excursion of Y. Each of the color-difference signals is preceded by an interval of 50-percent-level pedestal to permit clamping to restore proper black balance upon demultiplexing of the RCAV signal.

To obviate the need for modification of vertical sync separation circuitry, the RCAV signal retains standard equalizing and serrated vertical sync pulses. However, some advantages can be seen in changing the vertical sync format. Current investigations into this, and other aspects of the RCAV signal format, will lead to recommendations for eventual standardization and incorporation into products.

RCAV recording considerations

For recording purposes, the RCAV signal may be regarded as a standard monochrome TV signal that has a greater bandwidth and a narrower horizontal blanking interval. It follows then that one approach to recording the signal is to modify a standard VTR to cope with those signal characteristics that are unique. Maintaining the features of modern studio VTRs suggests starting with a current Type C studio VTR product. Then, the primary consideration is achieving the required video channel bandwidth of 11 MHz with a machine designed for a 4.2-MHz video channel.

Recording a greater bandwidth video signal mandates changes in the values of certain VTR parameters. However, to facilitate retention of features such as variable play speeds, picture-in-shuttle, and confidence playback during record, it is undesirable to alter scanner speed, tape speed, and head-to-tape writing speed from their original specifications. Therefore, the burden for change rests on the video/FM channel itself. Since the video bandwidth has been established, the optimum FM parameter values depend largely on the required signal-to-noise ratio (SNR) and the tolerable level of spurious signals in the output video. Current research into the various tradeoffs parallels the investigations done previously to develop the high-band quadruplex and Type C FM standards.[7] In addition, other techniques are being employed, such as computer modeling of the FM channel using programs originally developed for the study of FM transmission via satellite.

The almost threefold increase in video bandwidth necessary to handle the RCAV signal requires a commensurate increase in the FM bandwidth. There is a direct increase in the bandwidth of the first-order FM sidebands resulting from the greater bandwidth of the modulating video signal. This, in turn, requires that the lowest carrier frequency be raised to prevent any first-order lower sideband from extending below zero frequency and creating a "folded sideband" at the corresponding positive frequency.

Signal-to-noise ratio

Widebanding the VTR, while maintaining an acceptable SNR, is a formidable challenge. The primary sources of noise in magnetic recording are the tape itself, the magnetic heads, and the dynamics of head-to-tape contact. The dynamics result in separation losses and "scraping," or "rubbing," noise. Scraping noise is induced in the head winding by the magnetostrictive property of ferrite heads under deformation from tape contact. Development of tapes with smoother surfaces and smaller magnetic domains of more uniform orientation will reduce tape-related noise. Further improvements in noise performance will result from development of heads with higher magnetic efficiency and lower sensitivity to rubbing effects.

Losses from physical properties of the tape and head-to-tape separation are the primary contributors to the degradation of SNR when the FM channel is widened and the head-to-tape writing speed is unchanged. The increase in carrier and sideband frequencies means that shorter wavelengths are recorded on tape. This results in fewer magnetic domains per wavelength and closer opposing magnetic fields within the tape. These factors increase demagnetization effects that decrease the signal level preserved. The level of the signal that can be recovered is further reduced since head-to-tape separation loss on playback is inversely proportional to recorded wavelength. These effects lower the carrier level and hence the carrier-to-noise ratio available on playback. Reduction in SNR of the demodulated video follows directly.

The FM demodulation process translates the relatively flat channel noise spectrum into a baseband spectrum that has increasing noise power with frequency. Therefore, rapidly decreasing SNR results from the increasingly higher noise levels encountered as the video bandwidth is raised.

The most direct approach to combat SNR loss is to allow wider deviation of the FM carrier with consequently higher signal output from the demodulator. An effective approach to reduce demodulated high-frequency noise is to pre-emphasize the higher frequencies in the video signal before modulation and attenuate all high frequencies after demodulation. Both linear and nonlinear techniques may be applied.

Moire

The limiting effects of the tape and the intentional limiting applied prior to demodulation unavoidably create harmonics of the carrier and its sidebands. Demodulation of the third-harmonic lower sidebands produces primary spurious frequency components whose number and strength depend upon the carrier location and the frequency and amplitude of the modulating signal. Moire is the visual effect created when these unwanted frequencies fall within the video passband. Raising the carrier frequency moves the higher-amplitude spurious components out of band.

In a VTR that is recording a composite video signal, the predominant cause of moire is the presence of the high-energy, high-frequency subcarrier and its sidebands in the modulating signal. Hence, in that situation, subcarrier is an important consideration in the selection of carrier frequency and level of high-frequency pre-emphasis. Since the RCAV signal contains no subcarrier, more flexibility in the selection of these parameters and an improved level of moire performance are possible.

An RCAV recorder implementation

Based on the foregoing considerations, the best approach for widebanding a VTR to record the RCAV signal is to raise the carrier, to prevent "folded sidebands" and minimize moire, and to increase carrier deviation to improve SNR. However, limiting the SNR improvement is the diminishing carrier-to-noise ratio at higher recorded frequencies. Following this approach, RCA engineers modified an RCA TR-800 Type C studio recorder and a TBC-8000 digital time-base corrector to record and reproduce the RCAV signal.

The FM modulator was adapted to operate with a higher carrier frequency and deviation range, and the FM channel electronics were widebanded. Scaling of various filters was necessary, primarily the linear roll-off filter that precedes the limiter and the demodulator output filter. Magnetic heads with narrower gaps were fabricated to resolve the shorter recorded wavelengths during playback. The playback equalizer was redesigned to correct the frequency characteristics of the larger-bandwidth playback channel.

In the video domain, evaluation and some redesign of amplifiers in the input, output, and monitoring paths were necessary to ensure flat frequency response to 11 MHz without significant distortion. All video clamp circuits required adjustment to operate inside the narrower back-porch interval. Pulse-processing circuits required adaptation to separate accurately the narrower RCAV horizontal sync pulses and thus maintain proper timing references for various servo systems.

The companion digital time-base corrector also required modifications to accommodate the playback RCAV signal. As in the VTR, analog video circuits were altered for wider bandwidth and proper clamping

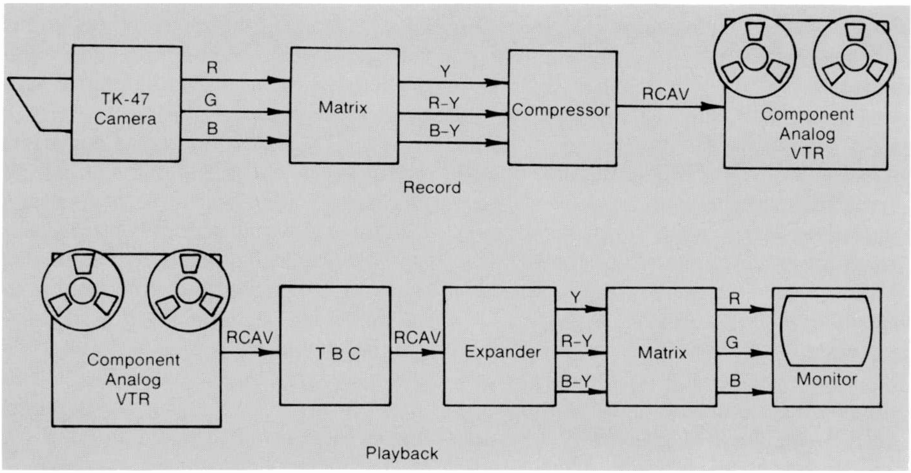


Fig. 5. *Major elements of the demonstration system for recording and playing back the RCAV signal.*

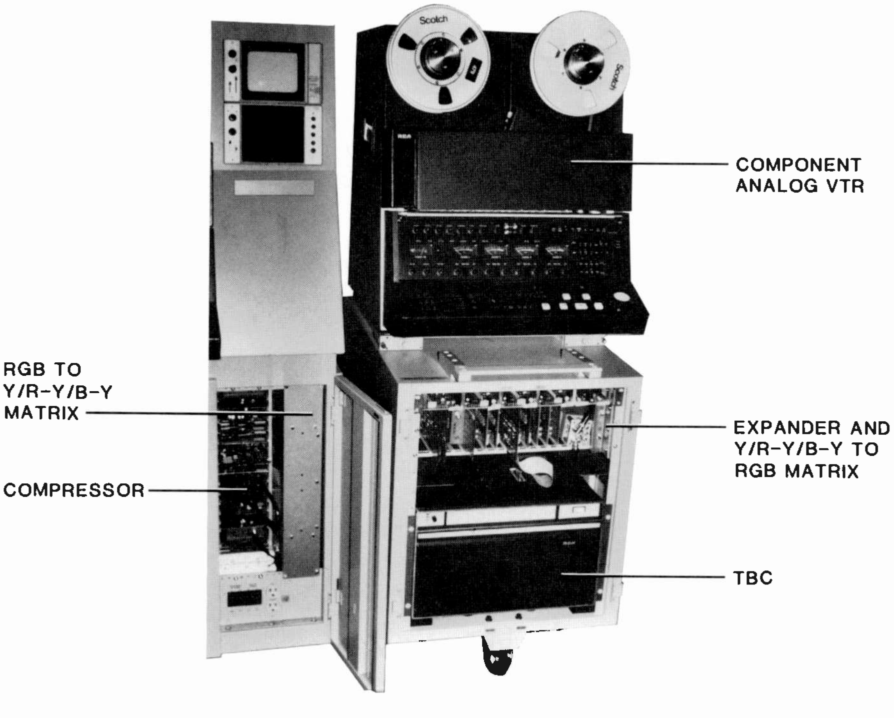


Fig. 6. *RCAV demonstration hardware. The key pieces of equipment indicated are interconnected as shown in Fig. 5.*

and sync separation. The analog-to-digital (A/D) converter, memory, and digital-to-analog (D/A) converter clocks were raised in frequency, and the anti-aliasing and clock rejection filters were scaled. The memory was reorganized to handle the higher clock frequency and a greater number of samples per line.

A demonstration system

The hardware assembled to demonstrate the recording and reproduction of the RCAV signal format is diagrammed in Fig. 5 and pictured in Fig. 6. An RCA TK-47 studio color television camera is the source of video for the demonstration. A simple matrix circuit transforms the RGB signals from the camera into Y, R-Y, and B-Y. Horizontal and vertical sync are added to Y at this point. These signals are applied to a digital compressor that converts them into the RCAV format. This signal then becomes the VTR input.

The VTR plays back the RCAV signal through the TBC to remove timing errors. A digital expander then converts the output RCAV signal back into the three simultaneous independent signals, Y, R-Y, and B-Y. A second matrix, the inverse of the first, develops RGB components that are then displayed on a standard RGB picture monitor.

Although not parts of the VTR proper, the compressor and expander are vital to the demonstration system as interface between existing RGB studio equipment and the RCAV signal. In the compressor, the incoming Y, R-Y, and B-Y components are low-pass filtered, digitized by A/D converters, and written into individual Y, R-Y, and B-Y memories during one TV line time. Each memory is two TV lines long to ensure enough data storage locations for the incoming line while the previous line is being compressed. During the first half of the next TV line, Y is read out of its memory at twice the writing speed. This effectively compresses it to one-half line time and doubles its bandwidth. During the third and fourth quarters of the line, R-Y and B-Y, respectively, are read out of their memories at four times the writing speed, effectively compressing them to one-quarter line time and quadrupling their bandwidths. The resulting data are converted to an analog signal by a single D/A converter, and filtered to eliminate the clock frequency.

The expander performs the inverse function of restoring the compressed Y, R-Y, and B-Y signals to their original real-time relationships. Since the expansion process and the preceding time-base correction process are both digital, the RCAV signal is passed directly from the TBC to the expander in digital form. This, then, eliminates a D/A stage with filtering in the TBC and an A/D stage with filtering in the expander.

As the expander receives the RCAV data, the first half of each TV line is written into a Y memory, the third quarter of the line is written into an R-Y memory, and the last quarter of the line is written into a B-Y memory. As in the compressor, each memory is two TV lines long to provide sufficient storage for the next incoming TV line while the present line is being expanded. During the next TV line, data are read out of the luminance memory at half the writing speed and out of the color-difference memories at one-fourth the writing speed. This expands each component back to a length of one TV line.

By starting the reading of all three memories together, the correct registration of Y, R-Y, and B-Y for each line is obtained. These signals are then D/A converted and low-pass filtered to provide analog waveforms. A sharp cut-off elliptical filter is used for Y. Slower roll-off Gaussian filters are used for R-Y and B-Y, since ringing is subjectively more disturbing on color transitions. To ensure black balance, R-Y and B-Y are clamped during their 50-percent-pedestal intervals.

Ideally, compression should be done by each video source, which would originate an RCAV, or similar, signal for distribution in the studio. Expansion would be required only for display purposes. All intervening elements of the system, including recorders, would accept and deliver the compressed signal. Availability of such a component VTR will spur development of compatible switchers, effects devices, and other system elements that will make possible the "single-wire" component analog studio.

RCA's industry position

RCA has been an active participant in the digital video standardization effort during the past nine years, playing a leading role in the discussions and demonstrations that resulted in the adoption of worldwide standards embodied in CCIR Recommendation 601. That position of industry leadership is continuing as technical experts debate the issues of component analog video standardization. RCA is a major contributor to the efforts of the SMPTE Working Group on Component Analog Video Standards and its sub-groups.

First to demonstrate a studio-quality component analog VTR, based on the Type C format, at the 1983 National Association of Broadcasters Convention, RCA is conveying an image of technical leadership to the user community. Such demonstrations of progress and discussions with key potential users, concerning their requirements, combine with ongoing engineering research to provide direction to RCA's industry participation.

The goal of all of these efforts is to ensure that RCA is well positioned to manufacture and market a component analog studio VTR whenever industry standards are set.

Tom Gurley is Unit Manager, Tape Advanced Development Engineering, Broadcast Video Systems, and recently has been associated with the TR-800, Hawkeye, Digital VTR, and RCAV programs. With RCA since 1970, he was involved in television systems engineering, studio automation, and digital video product development. His professional experience in the broadcasting industry spans more than eighteen years. He has been active in digital video standardization and is currently Secretary of the SMPTE Working Group on Component Analog Video Standards and a member of its Sub-Group on System Design. A Duke University graduate, he earned an MSE in EE from the University of Pennsylvania. He holds two patents and memberships in SMPTE, IEEE, Eta Kappa Nu, and Tau Beta Pi.

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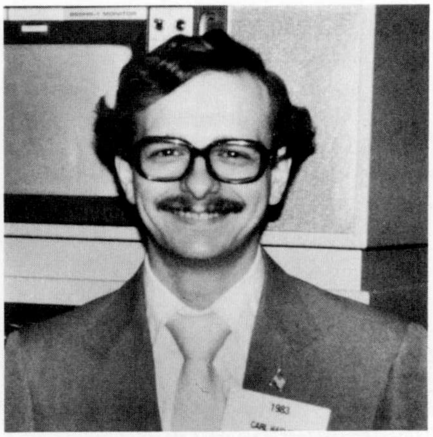

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G.A. Reitmeier

Digital videotape recorders: Tape format and error-concealment considerations

An appropriate combination of tape format and error-concealment techniques can provide a highly "transparent" digital videotape recorder (DVTR) without the need for complex error-correcting codes.

The potential advantages of digital videotape recording present some of the strongest incentives to implement and make widespread use of digital television standards in the broadcasting and teleproduction industry. Analog recording of the NTSC (National Television System Committee) signal is currently the greatest limiting factor in achieving ultra-high-quality television pictures in the studio, and is likely to remain so.

Although much industry activity is devoted to (time-) multiplexed analog component (MAC) television signals,[1,2] which slightly increase the chrominance bandwidth and eliminate NTSC artifacts, digital recording remains vastly superior. In any analog-recording technique, each successive recording further degrades the quality of the television signal, introducing both nonlinearities and noise. A television program typically goes through eight to ten re-recordings in the process of post-production and distribution, and considerable time and effort is spent developing judicious editing sequences to conserve the number of re-recordings. Therefore, the transparency and quality of the videotape recorder is of great importance to the industry.

Since a digital videotape recorder (DVTR) will record the 4:2:2 digital studio standard,[3,4] it will have outstanding picture quality; and since digital information is highly insensitive to nonlinearities and noise, the DVTR will be essentially a transparent device. The only problems will be bit errors resulting from dropouts caused by surface imperfections in the tape, which can result in burst errors affecting as much as one quarter of a television line worth of data. The same problem occurs in analog VTRs, where the dropout is concealed by averaging the video on adjacent scan lines, with the proper weighting to correctly accommodate the line-to-line subcarrier phase reversal of NTSC. By selecting a tape format that has an appropriate error pattern in response to a dropout, it becomes possible to use much more sophisticated error concealment in a DVTR.

Although it is possible to design complex error-correcting codes having long burst-error-correcting capability, there are several problems in applying these techniques to DVTRs. First, the burst-error length that must be corrected is very long, demanding a long code block that requires many computations at very high speed. Secondly, since this function is a record-side process, the required coding hardware must be included even in a portable recorder, which places severe constraints on size, weight, and power. On the other hand, error concealment is a replay-side process, which means that concealment hardware need only be present in a studio recorder that plays back tapes made on a portable recorder. And finally, the probability notwithstanding, any error-correcting code will occasionally fail, resulting in catastrophic errors that must be concealed. Therefore, the purpose of this paper is to discuss DVTR recording formats and error-concealment techniques that can provide the high performance required in a DVTR, without the use of complex coding techniques.

Abstract: *Digital videotape recorders (DVTRs) could give greatly increased quality and "transparency." Burst errors resulting from tape dropouts are the biggest obstacle to a fully transparent recorder. An appropriate tape format can shuffle the data, arranging it so that a burst error in the data results in a pattern of single-pixel errors in the television picture. Digital signal-processing techniques can then provide error concealment with an extremely high level of quality. Thus, the proper combination of tape format and error concealment can provide a highly transparent DVTR without the use of complex error-correcting codes.*

Final manuscript received July 29, 1983.
Reprint RE-28-5-6

Tape formats

The design of a recording format for a DVTR involves a complex set of tradeoffs in both mechanical and electrical characteristics, which greatly impact the performance of the machine.[5] Although these issues are far too complex to fully address here, it is possible to isolate and discuss some of the electrical characteristics that relate to error management. It is certain that the DVTR will use helical-scan recording consisting of multiple

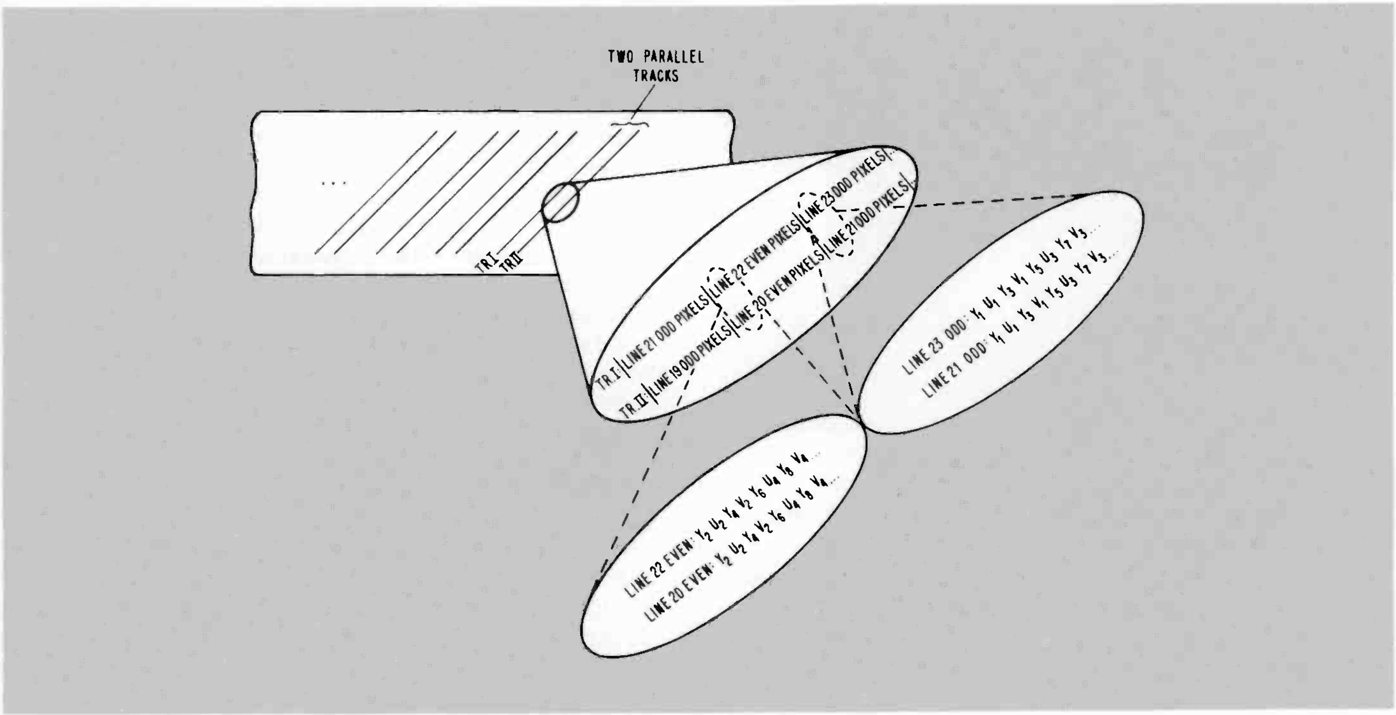

Fig. 1. *Tape format for a digital videotape recorder consisting of two parallel tracks, with a two-line track offset delay, each track alternately recording odd and even pixels from each television line.*

parallel tracks (probably two) to record the 4:2:2 digital video standard. Indeed, the DVTR can eliminate the effects of tape dropouts by error-concealment techniques alone. This results from the fact that, unlike an analog recorder, a DVTR need not record data that is adjacent on the television raster on adjacent positions on the tape. The digital data may easily be rearranged, or "shuffled," so that even a large burst error will not affect more than one pixel within a spatially adjacent "neighborhood" on the television raster. Furthermore, this shuffling may be accomplished with relatively simple circuitry consisting of delay lines and switches; no complex framestore is required.

Consider the arrangement shown in Fig. 1. The odd pixels (of both luminance and color-difference signals) from the odd scan lines and the even pixels from the even scan lines are recorded on track 1, while the remaining pixels are recorded on track 2. Even if an entire track containing half the data is lost, this arrangement results in an error pattern that is a "checkerboard," shown in Fig. 2, where an erroneous pixel is surrounded by valid pixels from which it can be reconstructed. Furthermore, a two-line "track-offset delay" is inserted between tracks 1 and 2 in Fig. 1, so that in the event of a short simultaneous loss of both tracks, as would be caused by a longitudinal scratch on the tape, two different checkerboard error patterns occur, separated on the television raster by the amount of the delay.

The track-offset delay is a function of the maximum expected dropout length, which is typically one fourth of a line, and other data-blocking constraints (such as those required to achieve an acceptable range of variable-speed replay). Therefore, this delay must be chosen so that neither an along-track nor a longitudinal defect results in the loss of horizontally or vertically adjacent information. This delay may be either electrical or mechanical and is clearly a minor addition to the DVTR hardware, especially considering that it makes possible the use of sophisticated error-concealment techniques under the most severe conditions.

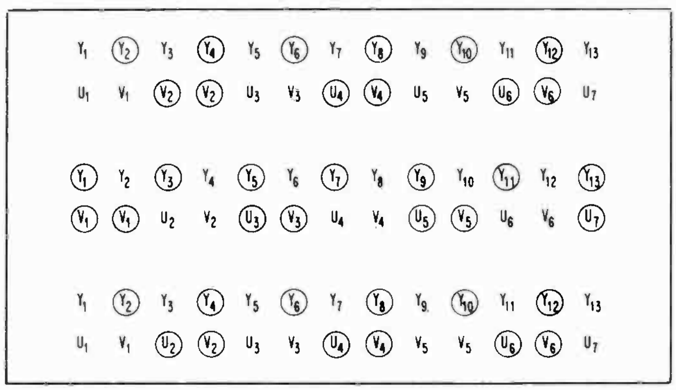

Fig. 2. *Error pattern resulting from the loss of an entire track in the tape format of Fig. 1. The circled samples are erroneous. Note that each erroneous sample has valid pixels of the same component that are horizontally and vertically adjacent.*

The tape format shown in Fig. 1 (or one similar to it) is easily implemented but, because of the data organization, transforms burst errors resulting from tape dropouts to checkerboard-patterned single-pixel errors in the television signal, which can be concealed with much better accuracy than a continuous error.

Error detection

Now that we have established an approach for the DVTR tape format that produces acceptable error patterns, we might also briefly discuss how an error might be detected so that error concealment can be activated. Perhaps the simplest and oldest method of error detection is to detect a loss of signal amplitude. In a DVTR, it is also likely that some form of channel coding will be used, which transforms the serialized bit stream resulting

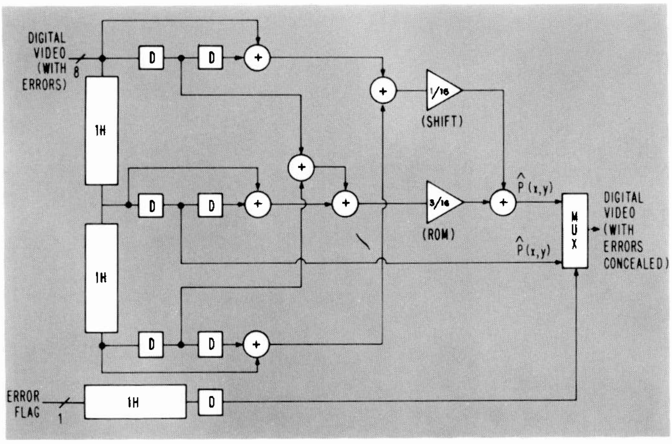

Fig. 3. *Linear estimator for the luminance channel.*

from the pulse-code-modulated (PCM) coding into a form more suitable for recording on magnetic tape.

Many such codes have been proposed, all having their own virtues.[6] Some channel codes contain no dc component, and are thus easily passed through the rotary transformer located in the headwheel, while other codes contain certain invalid sequences of transitions, which can be used for error-detection purposes. By this last method, even if some errors go undetected, certainly enough errors could be detected to define the occurrence of a dropout and to activate concealment mechanisms. Finally, the use of error-detecting source codes is well known, and these codes can be relatively simple, since only error detection (and not correction) is required.

In a high-performance DVTR, it is desirable to combine all of these detection techniques, to provide a high level of confidence that no error will slip through undetected and thus unconcealed. Perhaps the most powerful balance of error-management strategies is to combine very simple error-correcting source codes, which are intended to handle random bit-errors, with sophisticated error-concealment techniques, which are intended to handle tape dropouts. With this in mind, let us discuss the error-concealment techniques themselves.

Error concealment

Consider the error pattern shown in Fig. 2, where the circled samples represent erroneous pixels. Note that each erroneous pixel is surrounded by a pattern of spatially adjacent pixels of the same component (Y, U or V). In the previously discussed case of dropout compensation in analog VTRs, only information from adjacent scan lines is available to form an estimate.

The chief virtue of data shuffling in the DVTR recording format is that the error pattern resulting from a dropout contains a pattern of horizontally, vertically, and diagonally adjacent pixels that can be used to conceal the erroneous pixel. A linear estimate for the erroneous sample can be formed by computing a linear combination of the spatially adjacent pixels, and the erroneous pixel is concealed simply by substituting the estimate for the actual pixel when indicated by an error flag (derived by the methods previously discussed). One example of a linear estimator is a weighted average consisting of 3/16 times each of the four pixels that are horizontally and vertically adjacent and 1/16 times each of the four pixels that are diagonally adjacent within a 3×3 cell centered at the erroneous pixel. The linear estimate $\hat{p}(x,y)$ is thus

$$\begin{aligned}\hat{p}(x,y) = {} & (1/16)p(x-1,y-1) + (3/16)p(x,y-1) \\ & + (1/16)p(x+1,y-1) + (3/16)p(x-1,y) \\ & + (3/16)p(x+1,y) + (1/16)p(x-1,y+1) \\ & + (3/16)p(x,y+1) + (1/16)p(x+1,y+1)\end{aligned}$$

where $p(x,y)$ represents the pixel value at location (x,y) on the television raster.

This estimator can be implemented for the luminance channel as shown in Fig. 3. Two 1H delay lines provide access to three adjacent scan lines on the television raster, while the two pixel delays on each tap of the vertical delay line provide access to three pixels. Thus, this delay-line structure provides access to the 3×3 spatial neighborhood required by the linear estimator. The line delays can be implemented with RAM and a line-length counter, while the pixel delays are simply latches. A network of three adders provides the sum of the four pixels, which are diagonally adjacent to the center pixel, and the output can be simply shifted to the right by four bits to multiply the result by the factor of 1/16.

A similar network adds the four pixels, which are horizontally and vertically adjacent to the center pixel, and this output is used to address a read-only memory (ROM), whose contents contain the address times the factor 3/16. One final adder produces the estimate $\hat{p}(x,y)$, which is input to a multiplexor along with the center pixel $p(x,y)$. The multiplexor is controlled by an error flag delayed by another bit plane to match the delay of the center pixel $p(x,y)$, so that when an error occurs, the estimate is substituted for the erroneous pixel.

A similar system can be implemented to time-multiplex the two chrominance signals and provide error concealment with hardware operating at the same speed as that of the luminance concealer, differing slightly in the delay-line structure, to account for the multiplexing.

The use of two-dimensional linear estimators offers a substantial improvement over the simple vertical estimators used in analog recorders, since they take advantage of redundancy in all directions of the image. Linear estimators, however, suffer from performance problems because of the Nyquist criterion and can introduce artifacts on sharp edges and regions containing much high-frequency energy, which are subjectively very important to picture quality.

Consider the use of the above estimator on a picture where the top scan line is black, and the middle and bottom ones are white. The estimate for an erroneous pixel on the middle line would be 5/16 black and 11/16 white, resulting in a gray pixel rather than a white one. In the case where both top and bottom lines are black and the middle one white, an estimate for an erroneous pixel would be 10/16 black and 6/16 white, resulting in a dark-gray pixel. In the presence of a dropout affecting a large portion of data there are many such artifacts, and they occur in a pattern, which makes them more noticeable and objectionable than that of a truly isolated single-pixel error, although it is considerably better than the concentrated error that would result if no shuffling were used in the recording format.

Figure 4 illustrates a picture containing a large number of simulated dropouts, only *one* of which might occur every ten seconds in a poorly performing DVTR. The results of performing error concealment using the linear estimator are shown in Fig. 5, and although most of the errors are removed, some artifacts are clearly visible. Although most error concealment artifacts happen "on the fly" in a continuous replay, and are not frozen for close scrutiny, DVTRs will often be called on to provide "freeze-frame" replay as a special effect. More important,

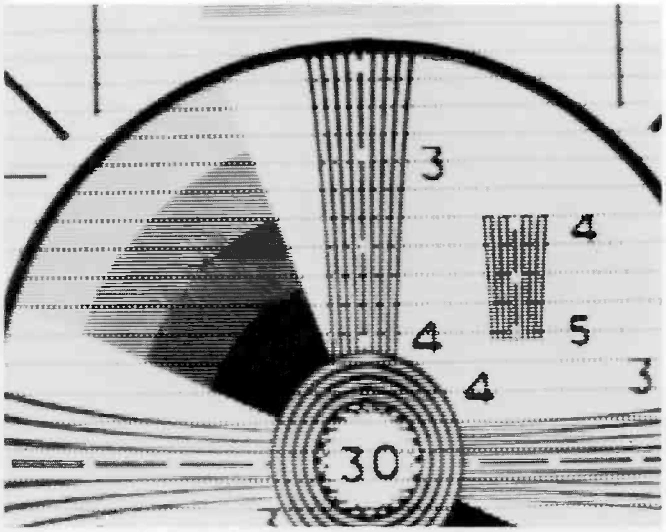

Fig. 4. *Picture containing simulated dropouts, as illustrated in Fig. 2.*

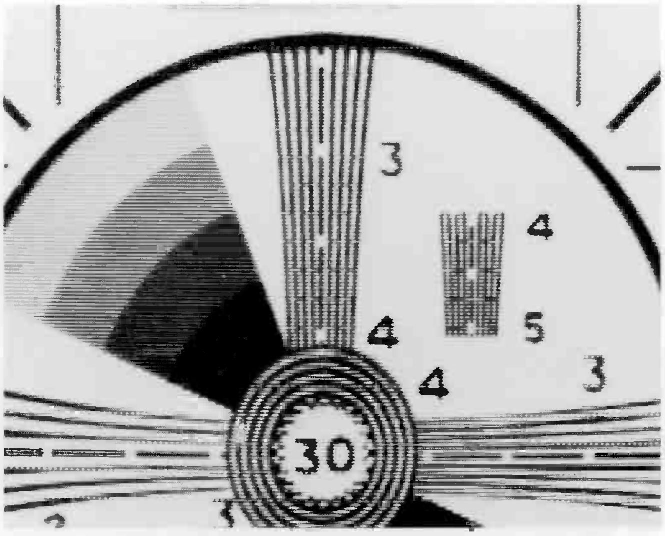

Fig. 5. *The results of error concealment by use of the linear estimator. Artifacts are visible on edges, particularly in the high-frequency wedge.*

the cascading of dropout errors, when making multiple generations of tape recordings, means that error concealment of extremely high quality is desired, and this level of quality cannot be provided by linear estimators.

Perhaps one of the greatest potential advantages of digital signal processing is the ability of digital circuits to make decisions and perform appropriate actions, thus "adapting" themselves to the input signal. To address the edge-response limitation of linear estimators, consider the possibility of switching between horizontal and vertical estimates based on some criterion supplied by the spatially adjacent pixels.

One such technique is the so-called "minimum-difference" algorithm, which can be described as follows. First, the absolute value of the difference between the pixels to the left and right of the erroneous pixel is computed, and the same computation is performed for the pixels above and below the erroneous pixel. Then, whichever pair has the minimum difference will be averaged and used as the estimate. A block diagram of this system for the luminance channel is shown in Fig. 6. A delay line similar to that in Fig. 4 provides access to the required spatial neighborhood. A subtractor computes the difference between the pixels to the left and right of the erroneous pixel, and the absolute value of this difference is found. This may be achieved by use of a ROM, or by performing a 2's complement inversion (invert and add one) if the difference is negative. Complement inversion requires the use of XNOR gates and an adder. The same network is used to compute the absolute difference of the pixels above and below the erroneous pixel, and both absolute differences are input to a digital comparator, whose output controls a multiplexor to select between a horizontal average $\hat{p}_H$ (x,y) and a vertical average $\hat{p}_V$ (x,y) provided by the respective adders. A final multiplexor is controlled by a delayed error flag to substitute the minimum difference estimate $\hat{p}_A$ (x,y) for the center pixel, $p(x,y)$ when an error occurs.

As in the case of the linear estimator, a similar system can be implemented for the chrominance signals by time-multiplexing them and modifying the delay-line structure. However, a significant simplifcation can be achieved by obtaining the minimum-difference information from the luminance error-concealment channel, thus avoiding the replication of the minimum-difference decision-making circuitry in the chrominance channel. This sim-

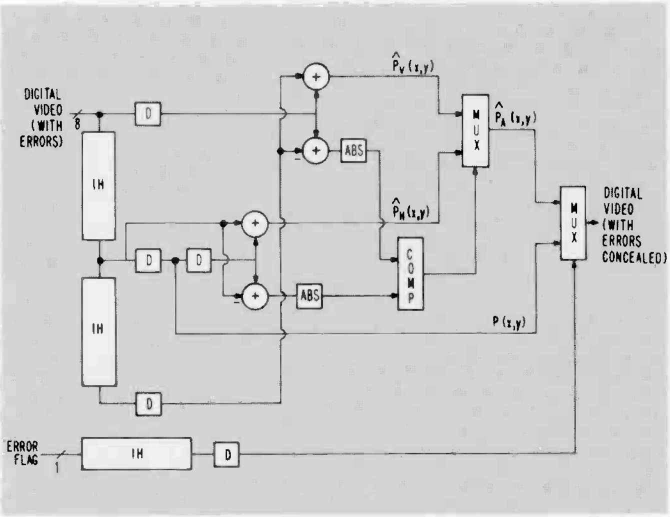

Fig. 6. *Minimum-difference adaptive estimator for the luminance channel.*

plification is based on the reasonable assumption that the luminance and chrominance resolution will be in the same direction.

The minimum-difference technique works quite well on horizontal and vertical edges. Consider the example of a vertical edge consisting of a black-to-white transition, where the erroneous pixel was originally white. The horizontal pair will have a large difference (since one is white, and the other is black), while the vertical pair will have a small difference (since both are white), and hence, the vertical pair will be averaged and used to replace the erroneous pixel, correctly resulting in a white estimate. Had a similar situation existed for a horizontal edge, a horizontal estimate would have been correctly chosen. Thus, the minimum-difference technique has an important advantage over linear estimators in that it has perfect response to horizontal or vertical edges. In addition, the increase in hardware complexity over linear estimators is really quite small.

The minimum-difference algorithm is not without its own problems, however, since it can sometimes be "fooled" into estimating in the wrong direction by very-high-frequency picture

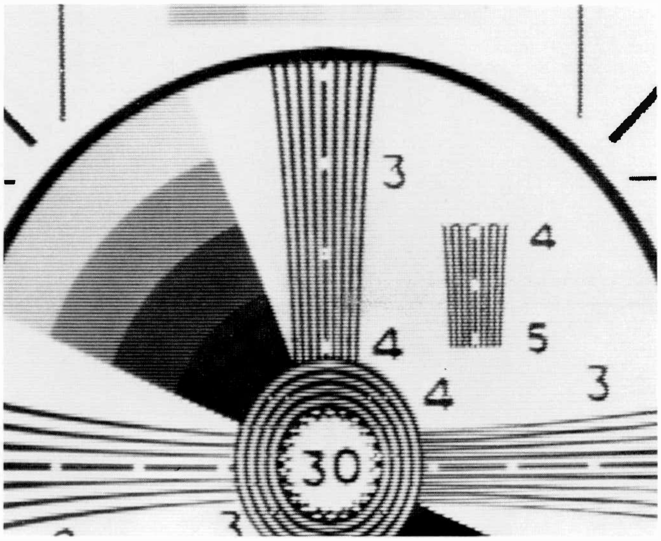

Fig. 7. *The results of error concealment by a more sophisticated adaptive estimator. Note the improvement over linear estimation. The remaining artifacts occur only in areas of high diagonal resolution.*

content or by diagonal edges. Slightly more sophisticated control over the selection of horizontal or vertical estimates can be achieved by examining more of the spatially adjacent pixels, and these techniques provide great improvements in the concealment performance with only a minor increase in hardware complexity. The results from the use of such an adaptive concealer are shown in Fig. 7, and this level of high performance and reasonable complexity is very well suited to a practical DVTR.

Conclusions

Many technical obstacles must be overcome before the DVTR can become a commercial reality. For example, the conflicting design requirements for extremely high bit-packing density (needed to provide reasonable tape consumption) and for tight mechanical tolerances (required for tape interchangeability) must be resolved. This is only one of the many difficult questions that must be solved and agreed upon by standardization committees, such as those in the Society of Motion Picture and Television Engineers (SMPTE) and the European Broadcasting Union (EBU). However, the problem of managing errors must inevitably be addressed in any digital recording or transmission system, and the combination of simple error-detecting-and-correcting codes with sophisticated error-concealment techniques is a very powerful approach. The appropriate use of tape format to distribute dropout errors in the television raster allows the use of two-dimensional signal processing to conceal errors.

Linear estimators suffer from their poor response on edges and from high frequency patterns, which result in objectionable artifacts. Adaptive estimators can be designed to achieve excellent performance without requiring excessive hardware complexity, and can indeed provide broadcast-quality error concealment for digital videotape recorders and digital video transmission systems, offering high quality at a low cost.

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A. Acampora

Wideband picture detail restoration in a digital NTSC comb-filter system

Digital filters used with the digital comb-filter provide chrominance-detail separation with wider bandwidth vertical detail placement.

The separation of NTSC video signals into their component parts, luminance (L) and chrominance (C), is an important step in the implementation of many video-processing systems. A comb filter, usually the first unit in a separation system, takes advantage of the line-to-line correlation of luminance and line-to-line phase reversal of chrominance to achieve separation.[1] In the case where each line is the same as the previous one, such as a vertical color bar test signal, the comb filter provides excellent separation of L and C. However, if the signal contains dissimilarities from one line to the next, then these vertical transitions become "smoothed" in the L and C outputs. For example, a sharp black-to-white luminance transition results in a black-to-gray-to-white transition in the L signal—a loss of vertical definition.

Abstract: *There are many video signal processes where NTSC composite signals are separted into the luminance and chrominance components. The common method of accomplishing this is line combing. In such cases, the separated signals suffer noticeable loss of vertical resolution. This image detail can be recovered using appropriate filters and re-insertion hardware. This paper describes the mechanism for restoring vertical detail, over as wide a bandwidth as practical, by using digital filters to recover the missing picture detail.*

Final manuscript received June 21, 1983.
Reprint RE-28-5-7

Spectrally, the comb filter actually consists of two complementary sinusoidal filters, one to pass only luminance spectral pickets and another to pass only chrominance spectral pickets and their respective sidebands. In a signal without sharp vertical transitions, the sidebands do not extend far from the corresponding pickets and the comb filter adequately separates L and C. However, a vertical transition results in a widening of the sideband structure, causing some luminance information to fall into the stopband of the L comb filter and, consequently, into the passband of the C comb filter. Similarly, chrominance information appears at the output of the L comb filter during vertical transitions. The smoothing of luminance vertical edges is called a loss of vertical detail.

The chrominance signal has a much narrower bandwidth than the luminance signal and, consequently, does not supply much detail to the picture. Because of this quality, the vertical smoothing effect of the comb filter on chrominance is not a great concern. However, it is vital that separated luminance have good vertical and horizontal resolution such that the smoothing of luminance vertical edges is quite apparent. The signals necessary to restore the luminance vertical resolution exist along with the chrominance signal at the chrominance comb-filter output. Fortunately, chrominance energy is centered at the 3.58-MHz color subcarrier, extending at most 1.5 MHz down from this point, while the misplaced vertical detail is concentrated in the 0- to 2-MHz range. This allows a lowpass filter to extract this luminance detail from the chrominance signal for reinsertion into the luminance channel. Conversely, a bandpass filter can extract the chrominance information from the combined chrominance-plus-luminance-detail signal. Note that some high-frequency vertical detail information might not be recovered, because it falls into the chrominance frequency range. However, this high-frequency vertical detail is not generally observable and its loss does not significantly reduce picture quality.

Figure 1 is the block diagram of a system to separate luminance (L) and chrominance (C) and also to restore the vertical detail. A one-line (1H) delay and two full adders comprise a comb filter, producing luminance minus vertical detail (L−VD) and chrominance plus luminance vertical detail (C+VD). A bandpass filter extracts chrominance from the C+VD signal while a lowpass filter extracts vertical detail from the same signal. The L−VD signal is delayed by an amount equaling the lowpass filter delay, and is summed with the vertical detail to produce restored luminance.

Filter specifications

It is difficult to define suitable bandwidths and cutoff frequencies for the filters mentioned above. Although it is desirable to retrieve as much vertical detail as possible, chrominance bandwidth must not be severely compromised. Regardless of their cutoff frequencies, the lowpass and bandpass filters of Fig. 1 must not introduce signifi-

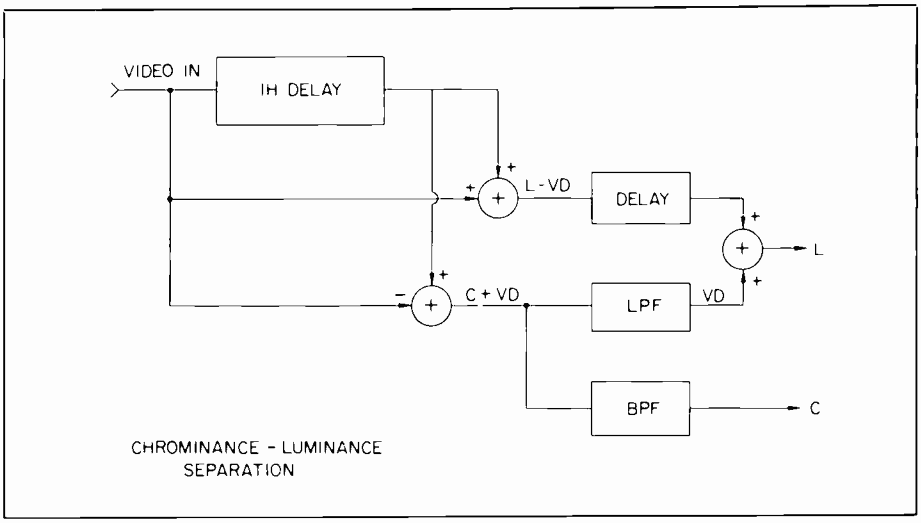

Fig. 1. *By adding and subtracting a composite video signal from the same signal delayed by one horizontal line (1H), luminance and chrominance can be separated. However, vertical detail must be recovered by lowpass filtering the chrominance, and inserting those low frequency signals back into luminance.*

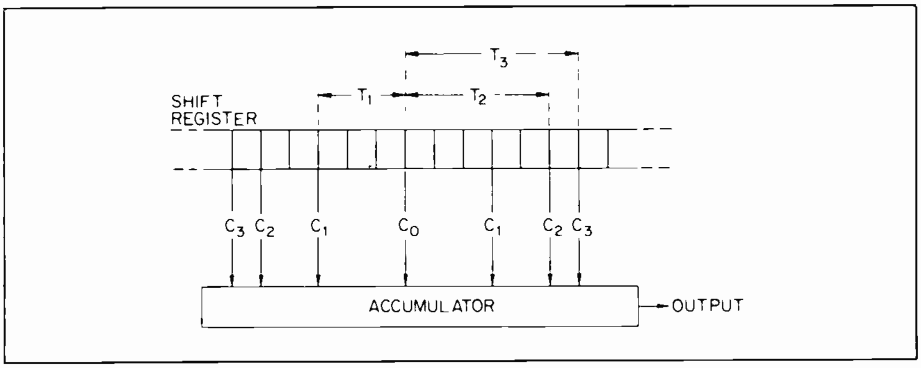

Fig. 2. *In the digital filter implementation, the data is clocked through shift register stages. Selected register outputs are weighted and accumulated with other weighted taps to form the desired frequency response.*

cant phase distortion. This means the filters must be of a linear phase type or have suitable phase compensation.

Linear-phase-response filters can be realized using a tapped-delay line. In a tapped-delay-line filter, a number of delay increments are placed in series, and signal is tapped off after each delay. Each of these signals is multipled by a weighting factor and, finally, all are summed together to produce the output. To obtain linear phase, the weighting factors and delay increments must be symmetrical about the center point of the delay line. This type of filter can be readily implemented in a digital system, where exact delay increments (that is, the duration of the clock period) are available through the use of shift registers. Because of this, the remainder of this paper will focus on the development of digital filters used with a digital comb filter to provide chrominance-luminance separation with wideband vertical detail placement.

General filter configuration

The form for the digital filter just described is shown in Fig. 2. Here, the signal at the center of the filter is weighted by C_0 and accumulated with other symmetrically-placed pairs of taps—each respectively multiplied by weighting factors by C_1, C_2, C_3, and so on. These taps are each displaced by delay increments T_1, T_2, T_3, and so on. The variables to be selected include the tap weights, the tap spacings, and the total number of taps.

These variables go hand-in-hand with the characteristics of the filter to be designed. In the case of vertical detail/chrominance separation, some important properties are:

- A filter that is simply implemented.
- A filter that preserves as much vertical detail without compromising the chrominance signal, that is, has a good shape factor.
- A filter with zero gain at 3.58 MHz and unit gain at dc for the lowpass filter, and vice-versa for the bandpass filter.
- A filter using binary coefficients, that is, coefficients that are a power of 2 or a sum of powers of 2.

The first criterion suggests that a maximum of four taps be used. The second and third criteria determine the tap spacing and weights. In a digital implementation, the delay increments T_1, T_2, . . . must be integral multiples of the clock frequency. Further, the popular clock frequency for digitizing an NTSC video signal is four times that of the color carriers, or approximately 14.32 MHz. Therefore, the smallest delay increment is about 70 ns. In addition, since the clock rate is related to color subcarrier, it is convenient to also relate the filter cut-off frequency to this

Why wider bandwidth detail restoration?

The digital filters presented in this article have wider bandwidths than the analog filters currently used to extract vertical detail in pictures. This wider response (by nearly a factor of two) improves the spatial frequency response over a larger range of spatial angles, especially those angles along the diagonals.

As discussed in the article, widening the passband response requires sharper skirt selectivity to avoid inserting chrominance dots, along with the desired picture detail, into the luminance. This higher selectivity creates the problems of delay equalization near the passband edges, and the threat that the filter step response will cause "ringing." Both of these occurrences create noticeable artifacts in the picture.

The digital approach described overcomes both these design problems. First, a symmetrical digital filter design has linear phase (and therefore no delay distortion) everywhere in its response. Second, the choice of tap spacing and coefficients controls both the frequency and step response so that a suitable compromise can be made with regard to filter rejection, and "ringing" artifacts.

subcarrier. Within the constraints of passing as much detail signal as possible up to 2 MHz, a natural 6 dB cut-off of one-half subcarrier (approximately 1.8 MHz) seems adequate. This, coupled with the second and third criteria, yields tap spacings of $T_1 = 2$ clocks, $T_2 = 6$ clocks, and $T_3 = 10$ clocks.

The final criterion is important from a digital-implementation viewpoint because it eliminates the need for multipliers. Multiplication by a factor of 2^n, where n is any integer, is merely a bit shift of n places. Consequently, in a parallel-wired digital system, multiplication by powers of 2 can be wired-in and, therefore, require no multipliers. Also, multiplication by a factor that is a sum of any number of these powers of 2 reduces to an addition process. For instance, the factor 3/4 equals 1/2 plus 1/4 so multiplication by 3/4 can be accomplished by adding 1/2 of the signal to 1/4 of the signal. As a result, it is highly desirable to choose coefficients that can be expressed in this way. However, choosing coefficients in this manner may not always be consistent with the previous considerations of filter shape. But, starting from an initial choice of Fourier series coefficients for C_0, C_1, C_2, and C_3, and massaging these coefficients towards the binary constraint seems practical. Some practical considerations that also enter into the choice of coefficients are:

1. To achieve unit gain in the passbands—$C_0 + 2(C_1 + C_2 = C_3) = 1$;
2. To provide about 5% of pre- and post-shoot (prior to any nonlinear processing) on the vertical detail—$|C_2 + C_3| \simeq 0.05$; and
3. To avoid excessive ringing on these edges, $|C_3| \leq 0.02$. These constraints lead to coefficients of $C_0 = 1/2$, $C_1 = 5/16$, $C_2 = -5/64$, $C_3 = 1/64$.

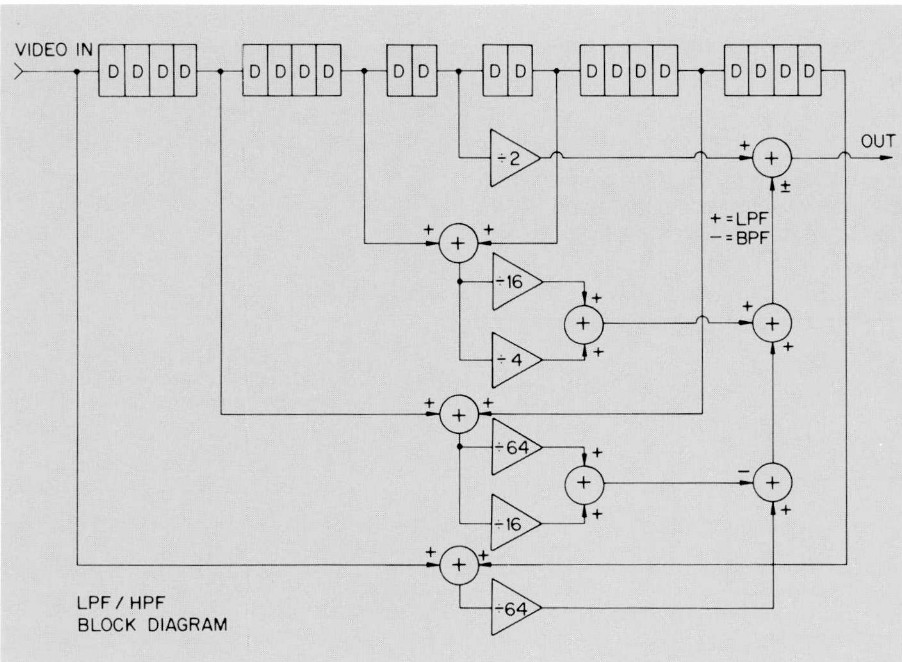

Fig. 3. *In the final form of the filter, each delay block D corresponds to one stage of a shift register clocked at 4 times the color subcarrier. The coefficients are derived by successive additions of fractional powers of two, thereby avoiding costly multipliers.*

The actual filter

The final form of the filter is shown in Fig. 3. The tap spacings are set as described earlier. Each delay block "D" corresponds to one stage of a shift register clocked at four times the color carrier. Notice that the coefficients are derived by successive addition of fractional powers of two. Also, since digital full adders are two-port devices, the actual accumulation is accomplished through a series of additions.

An intrinsic property of the filter is that both lowpass and bandpass versions are obtained from the same hardware configuration by either adding the accumulated

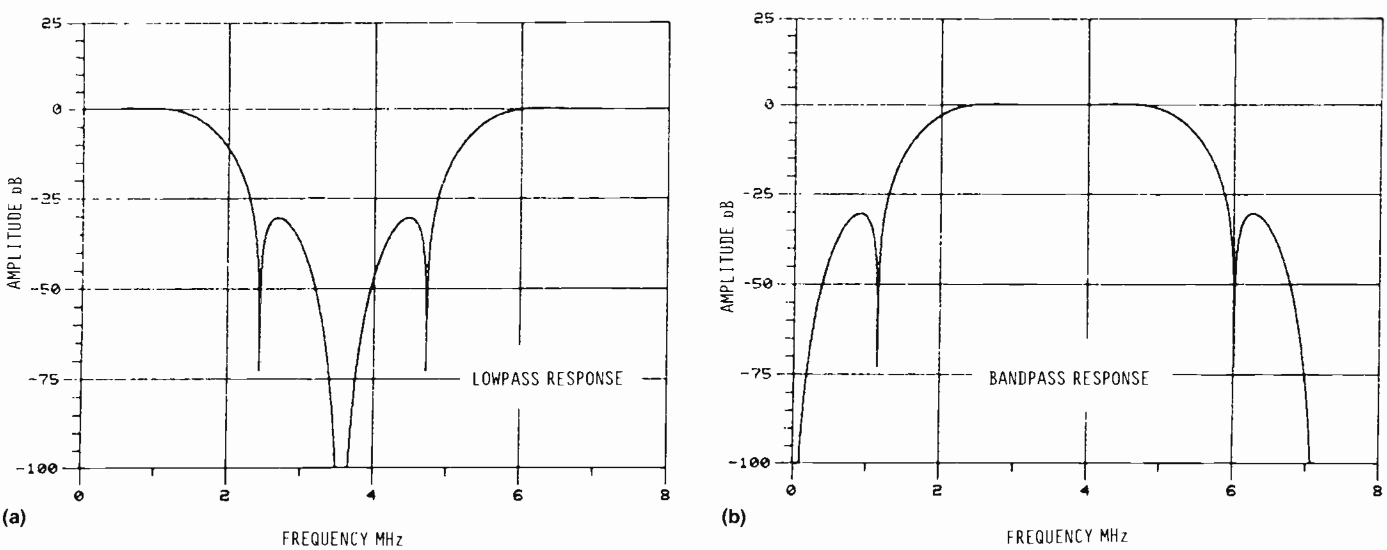

Fig. 4. *Theoretical lowpass and bandpass responses.* **(a)** *The lowpass response shows excellent passband flatness and selectivity for filtering the vertical detail.* **(b)** *The bandpass response is centered at 3.58 MHz, and filters the chrominance information.*

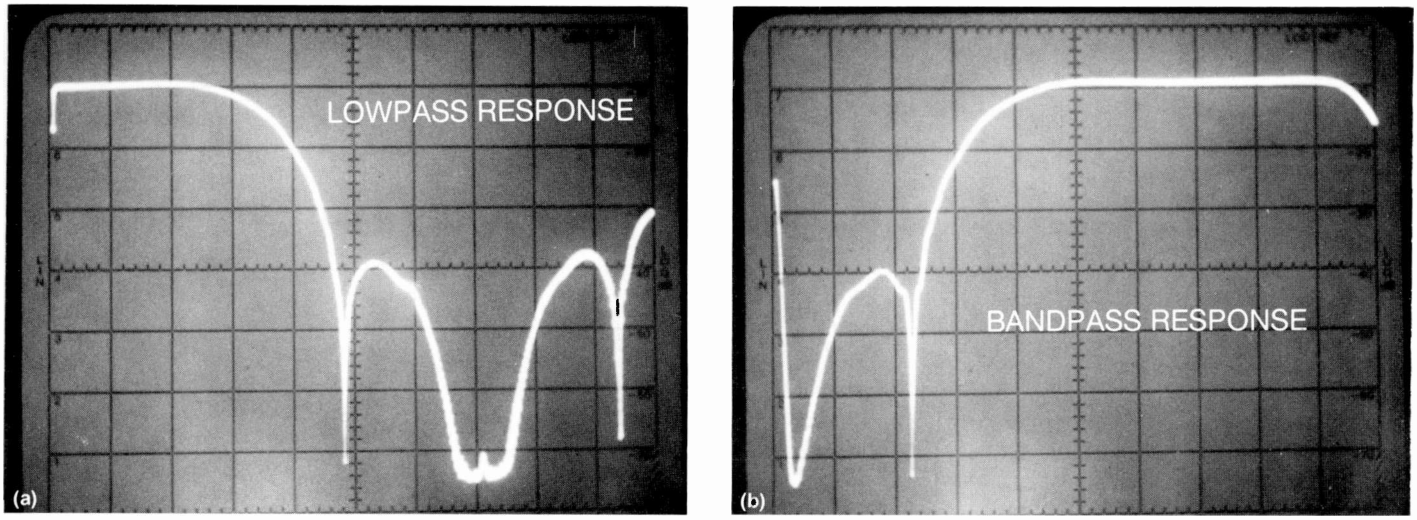

Fig. 5. *The measured responses closely match the theoretical ones given in Fig. 4. The scale in the photographs is 10 dB/division vertically, and 0.5 MHz/division horizontally.*

tap pairs to the center-tap (LPF) or subtracting them from the center-tap (BPF).

Results

The analytical results of this filter are shown in Figs. 4a and 4b for the lowpass and bandpass cases, respectively. The measured responses of these filters are also shown in Fig. 5. These measurements, taken with a spectrum analyzer, show the digital circuit does indeed approximate the theoretical case.

The response is down 6 dB at 1.8 MHz and remains no less than 30 dB down over the range of the color sidebands. Notice that there is extremely high rejection in the high-color-energy region around 3.58 MHz. The response to a vertical step with the chosen coefficients has a "ringing" term of about 1.5% and pre- and post-overshoots of 6.25%.

For an 8-bit parallel input, satisfactory operation was found by using 12-bit accumulators within the internal summations of the filter. The final result was truncated to 10 bits. Additionally, care was taken to properly pipeline the digital filter to account for internal path delays.

Acknowledgment

Many thanks to Gary Saulnier, now at MIT, who, as a summer student in the Rensselaer Polytechnic Institute co-op program, provided invaluable help in the filter design and implementation.

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Al Acampora joined RCA in 1959, at the Advanced Communications Laboratories in New York. His work involved all phases of military and commercial communications. In 1970, he joined RCA Global Communications, as Staff Engineer and, in 1973, he was awarded the David Sarnoff Outstanding Achievement Award for his work in narrowband video transmission. Since joining RCA Laboratories, Princeton, New Jersey, as a Member of the Technical Staff in 1978, Al has continued his work in communications systems. His initial programs involved video processing for teleconferencing applications. He has been involved in digital implementation of video-processing systems, especially for existing and next-generation satellite transmission, and he has contributed to the development of digital television receivers. In 1982, he was promoted to Senior Member of the Technical Staff.

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Some power considerations for consumer-type high-definition-television displays

Power dissipation in the display-related circuitry and components will have a decisive influence on television receiver design, as new technology and digital processing techniques lead the way to the high-performance television systems of the future.

Further improvement in the quality of the picture displayed by commercial television receivers is difficult to achieve within the framework of existing display techniques. Additional improvement could be obtained through improvements in color picture tubes, better signal processing, and/or through modification of current NTSC standards. Approaches are being explored that do not require a change in transmission standards, but provide an improvement in observed picture quality through the elimination of certain artifacts in the picture.

Almost all techniques under evaluation for improvement of observed picture quality require a change in the horizontal scanning system from the current 525-line interlaced system to a 525-line non-interlaced (progressive-scan) system. This would involve an increase in the horizontal scanning rate from 15.75 kHz to 31.5 kHz (48 kHz may be considered for some European systems), but would not require any change in the transmitted signal. Therefore, there would be no effect on reproduction of pictures by receivers already in the field. Benefits of the non-interlaced scanning system would be the almost complete elimination of such artifacts in the picture as large-area flicker, interline flicker, line breakup, and line crawl.

If standard deflection techniques are used and the ratio of trace time to retrace time is kept constant, operation of the horizontal scanning system at double the normal scan rate presents major problems due to stresses imposed on the horizontal output transistor and damper. It also results in increased high-frequency losses in the deflection yoke. The bandwidth required for kine-drive circuitry is doubled for the same horizontal resolution in the picture. This paper presents the results of an investigation of switching device and deflection yoke losses for horizontal scanning rates from 15.75 kHz through 63 kHz, covering the complete range under consideration for U.S. and European consumer television as well as for high-resolution computer displays. Kine driver design and dissipation is discussed for bandwidth to 32 MHz.

Abstract: *One technique under evaluation for improvement of observed picture quality is a change in the horizontal scanning system in the receiver from the current 525-line interlaced system to a 525-line non-interlaced (progressive) system. This would involve an increase in the horizontal scanning rate from 15.75 kHz to 31.5 kHz (48 kHz may be considered for some European systems), but would not require any changes in the transmitted signal. Benefits of the non-interlaced scanning system would be the almost complete elimination of such artifacts in the picture as large area flicker, interline flicker, line breakup and line crawl.*

Operation of the horizontal scanning system at double the normal scan rate presents major problems in the stresses imposed on the active devices used in the scanning switch. It also results in an increase in the high-frequency losses in the deflection yoke. When the scan rate is doubled, the bandwidth of kinescope drivers also must be doubled to maintain resolution, and in turn, this can affect power dissipation.

This paper was presented to the SMPTE Study Group for HDTV and is intended to familiarize engineers who are not commonly involved in the design of display systems with the issues of high-definition displays for consumer products. Some parts of this paper were rewritten and new parts have been added. Conventional power, deflection and kinescope drive circuitry and its limitations will be examined, and some difficulties of applying it to high-definition television will be shown.

Final manuscript received August 25, 1983.
Reprint RE-28-5-8

Basic horizontal deflection circuit

In its simplest embodiment, the horizontal deflection system of a conventional televi-

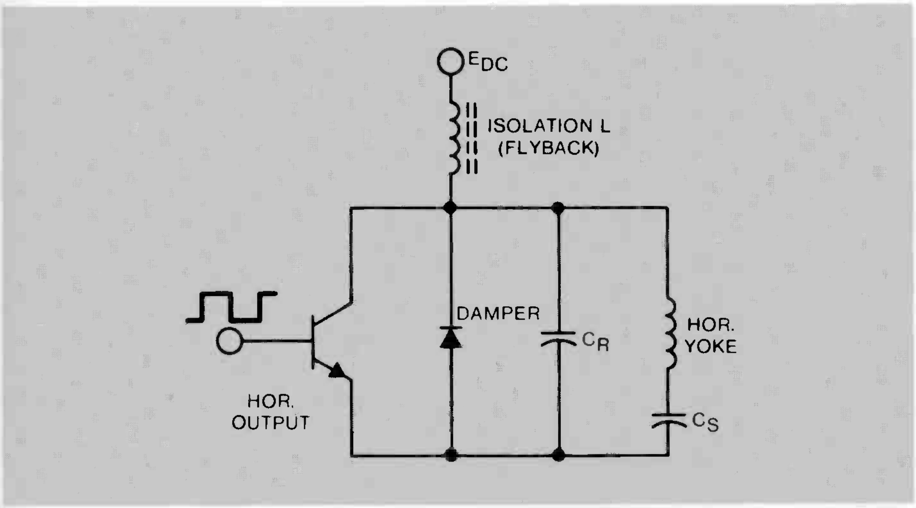

Fig. 1. *Basic horizontal deflection circuit. The horizontal deflection system of a conventional television receiver consists of a magnetic deflection coil, a power source and one or more switches.*

sion receiver consists of a magnetic deflection coil, a power source and one or more switches. Figure 1 shows such a deflection system while Fig. 2 shows its associated current and voltage waveforms.

The switch in this case is a combination of a transistor and a diode (damper). The circuit includes a retrace capacitor C_R that, together with the deflection coil L_y and the flyback coil, determines the length of the retrace interval. It also includes capacitor C_s, which provides the dual function of dc-blocking and S-shaping. An actual deflection circuit used in a receiver would normally also include pincushion- and linearity-correction circuitry plus a winding on the flyback coil to provide a source of high voltage for the picture tube. The correction circuitry and the high-voltage generation can cause the delivery, by the deflection system, of 50 extra watts of power, and consequently can increase the current flowing in the switch devices. The effects of this additional power on dissipation in the switching devices has been ignored in this paper, but the probability of this added dissipation should be kept in mind by the circuit designer.

Factors affecting deflection switch and yoke dissipations

For purposes of this investigation, it was assumed that deflection-yoke materials and geometries now being used in television receivers would continue to be used at the higher scanning rates and that the ratio of trace time to retrace time would be a constant for all scanning rates. Therefore, for a given deflection angle and high voltage, the peak stored energy in the deflection yoke would be the same, regardless of the scanning rate.

The yoke current is not normally an ideal sawtooth waveform. The S-shaping capacitor in series with the yoke produces a slight "flattening" of the waveform near the beginning and end of trace time, while the retrace capacitor in shunt with the yoke produces a sinusoidal current waveform during retrace. Measured values of yoke current indicate that the actual rms yoke current is

$$I_{rms} = (2/3)\, I_{yoke}\ \text{peak} \qquad (1)$$

This value is used for the calculations in this paper.

The peak voltage on the yoke and on the deflection switch is inversely proportional to retrace time. Therefore, for a given deflection yoke, if the scanning rate is doubled and the retrace time is cut in half, then the peak yoke voltage will double and the peak switch voltage will nearly double. If these components will not withstand this high voltage or will not have an adequate safety factor, then yoke inductance must be decreased and peak current must be increased to keep the peak voltage within the desired limit and still have sufficient scan.

A voltage of about 1000 volts is considered to be a safe design voltage for conventional deflection yokes and switching devices. Therefore, for the calculations and measurements described in this paper, yoke inductance and peak currents were adjusted to keep the peak switch voltage below 1000 volts.

The storage time of the horizontal output transistor increases with peak collector current if saturation is to be maintained until the end of trace. Storage times of typical devices vary from 4 μs to 10 μs. The transistor base drive must be off or reversed at a time that is 4 to 10 μs before the transistor turns off.

The turnoff time of the horizontal output transistor will increase slightly with higher collector currents and proper base drive will be difficult if storage times are high and on-times are reduced. Turnoff waveforms are dependent on the base drive as well as on the characteristics of the transistor, so the rms value of the transistor current during turnoff is difficult to predict. For the calculations in this paper, the turnoff current of the transistor was assumed to follow a ramp.* Fall time, as published by the transistor manufacturer, is measured between the 90 percent and 10 percent points on the curve and may vary from 0.4 μs to 1 μs, depending on the manufacturer. Since the rate of change of current before the 10 percent point and after the 90 percent point is less than it is between these two points, the turnoff time has been assumed to be approximately 1.3 times the fall time. Under improper drive conditions, a turnoff current may have a long "tail" extending well into retrace time. Although the magnitude of this tail may be quite low and the dissipation associated with it quite low, it can be very destructive, because the current during this interval is carried by a tiny fraction of the transistor chip area.

For state-of-the-art horizontal output devices, the current gain may be 3 or less. Since it is imperative that the device remain saturated during trace time, a base drive of 0.4 times the collector current is not out of the question, and this value is used for the calculations of dissipation resulting from base drive.

Tuning effects from the high-voltage flyback transformer can also influence power dissipation, especially during retrace. The analysis, on which this paper is based, does not include variations due to tuning effects, but such effects *can* influence the dissipations in the circuit, in some cases, substantially.

Power dissipation as a result of leakage currents during retrace has been ignored because such effects are usually very low in silicon devices. The effects of the saturation voltage of the horizontal output transistor during storage time depend on the

* This assumption yields a dissipation that is slightly higher than the actual value at 16 kHz. An assumption of a parabolic waveform (see Reference 1) yields a dissipation value somewhat lower than the actual value, although the calculations are rigorously correct.

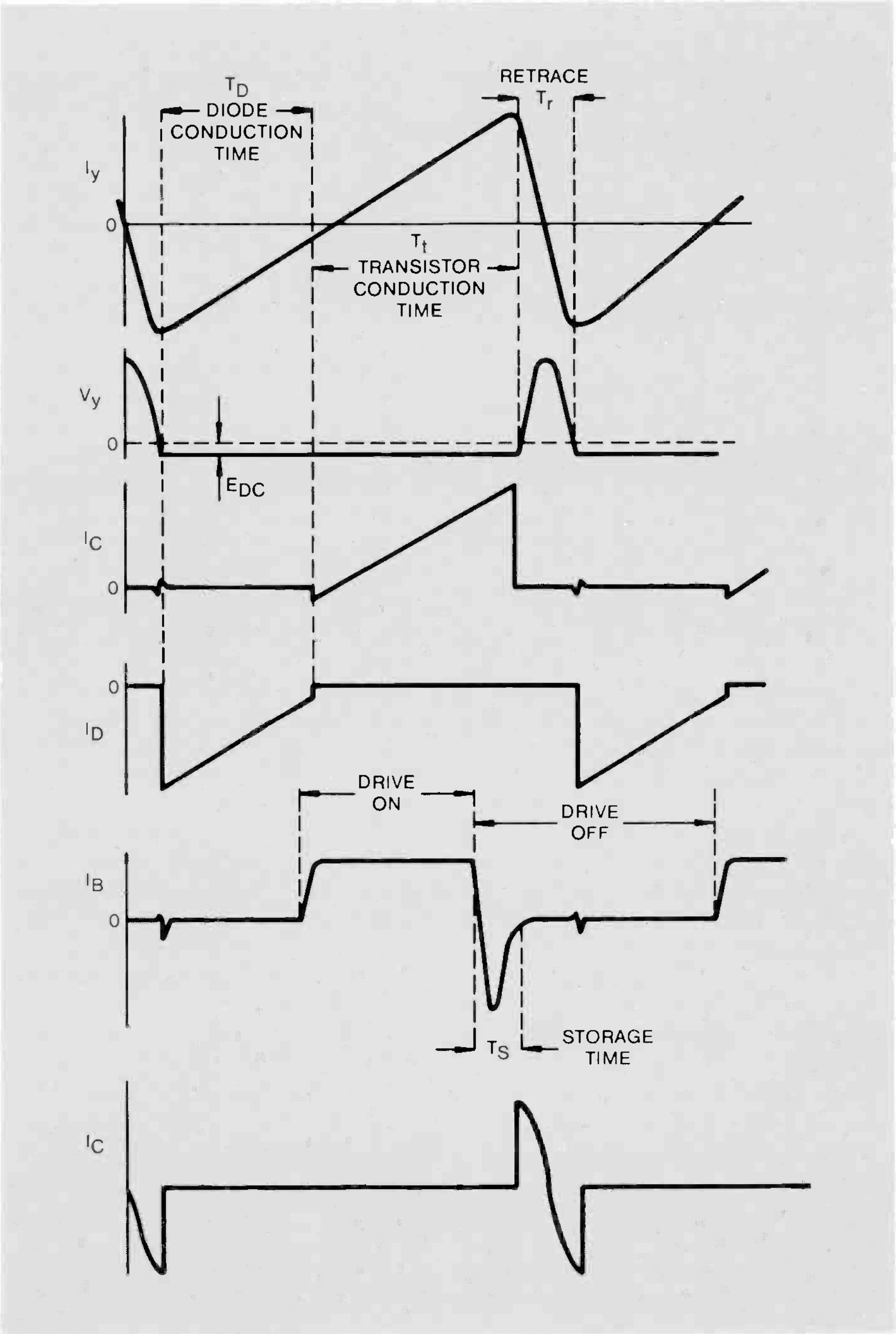

Fig. 2. *The waveforms in a basic horizontal deflection system. Shown from top to bottom: yoke current, yoke voltage, transistor current, damper diode current, transistor base current, retrace capacitor* (C_R) *current.*

design of the base-drive circuitry and on the characteristics of the transistor.

Trace switch power dissipation

The power in the horizontal output switch can be separated into two parts: the power dissipated in the transistor and the power dissipated in the damper diode. The power dissipated in the transistor is the sum of the power dissipation due to collector current during trace, the dissipation due to base drive, and the dissipation during retrace.

The power during retrace represents the scan-frequency-dependent portion of the transistor dissipation. The total power dissipation in a fast horizontal output transistor, at 16 kHz, was calculated to be 1.47 watts (see Table I). This appears to be a low dissipation for a device in a TO-3 package. However, since fall time of the collector current is temperature-dependent as well as drive-dependent, the horizontal output transistor should be operated at a junction temperature below 115°C in order to avoid any lengthening of fall time that could lead to a thermal runaway condition. In the example just given, if the fall time were to increase from 0.4 μs to 1 μs, the transistor dissipation would increase by a factor of almost three to about 4.3 watts.

The power dissipated by the damper is a function of the rms damper current and the conducting voltage drop across the damper. If the damper is used with the horizontal output transistor in the previous example, the power dissipated by the damper is 0.4 watts.

It is assumed that there is no direct frequency-related dissipation in the damper diode.

Horizontal output transistor and damper dissipation at other scanning rates may be calculated in the same manner as for the example just given. Although transistor storage time and turnoff time will increase slightly at higher scan rates, it is assumed that, with careful adjustment of the base drive and with a specially selected horizontal output transistor, the previously-used turnoff values can be used. The results of these calculations are listed in Table I. Other assumptions made are

1. Direct-current supply voltage is the same for all scan rates
2. Peak stored energy in the yoke is constant for all scan rates.
3. Ratio of trace time to retrace time is constant for all scan rates.
4. Transistor fall times lie in the range from 0.4 to 1 μs.
5. Peak retrace voltage is the same (990 volts) at all scan rates.
6. The waveform of the retrace voltage across the trace switch is a half sine wave.
7. Dissipation due to leakage currents in the horizontal output transistor and damper during retrace is negligibly small.

Measurement of yoke dissipation

Calculation of dissipation in the deflection yoke is very difficult, so these losses were determined by actual measurement. Tests were run using approximately 4.7 mJ of stored energy in the yoke. This approximates the stored energy required for horizontal deflection using a 110° picture tube operating at a high voltage of 30 kV. The circuitry used for the dissipation measurements is shown in Fig. 3.

Table I. *Horizontal output transistor and damper dissipation at different scan rates. Transistor dissipation rises almost exponentially while damper dissipation rises linearly with scan rate.*

Scanning rate (kHz)	*Retrace time* (T_r) *in* μs	*Peak retrace volts* (V_s)	*DC supply volts* (E_{DC})	*Peak switch current (A)*	*Peak base current (A)*	*Transistor dissipation* (W)*	*Damper dissipation (W)*
15.75	12	990	128	3	1.2	1.4 to 4.3	0.4
31.5	6	990	128	6	2.4	7.6 to 28.7	0.83
48	3.94	990	128	9	3.6	19 to 84	1.3
63	3	990	128	12	4.8	35 to 165	1.8

* Lower value is for fall time of 0.4 μs. Higher value is for fall time of 1 μs.

The base-drive circuit shown in Fig. 3 was not intended to be an optimum drive circuit for a specific frequency. However, it provided a convenient method of supplying adequate drive with good turnoff capability at all desired scanning rates without the problem associated with optimizing a base-drive transformer for each scanning rate. The positive supply to the drive transistors was adjusted to provide the required forward base drive, while the negative supply was adjusted to provide ample turnoff drive with minimum turnoff "tail" of the horizontal output transistor collector current. Since the power input at the higher scanning rates was considerable, the horizontal output stage was cooled by directing a fan at the heat sink being used.

The diode unit of an ITR (selected to withstand 1000 volts) was used as a damper and it was bolted directly to the heat sink in order to keep its temperature to a safe value. Although a conventional damper diode would have been satisfactory at the 15.75-kHz scanning rate, its slow turn-on characteristic made it unsatisfactory for either 31.5-kHz or 63-kHz operation. In addition, the dissipation resulting from the high forward current mandated a damper diode that could be mounted with good thermal contact to the heat sink for adequate cooling.

A conventional horizontal output transistor has such slow turnoff that it invariably fails within a few seconds operation at 63 kHz. However, it was found that a device originally designed for high-frequency inverter operation, turned off in about 200 ns, and performed quite well at 63 kHz (RCA 2N6754). Therefore, this device was used as the horizontal output transistor in all the tests.

Deflection yokes used for the yoke dissipation measurements were made with multiple horizontal windings. All the windings were used in each test, but they were connected in the appropriate series, parallel, or series/parallel combination to provide inductance values ranging from 1.04 millihenries (mH) at 15.75 kHz to 65 μH at 63 kHz. Tests were run on a yoke using RCA 804 ferrite and on yokes using cores made by two other ferrite suppliers. Except for differences in the core material, all three yokes were identical in construction.

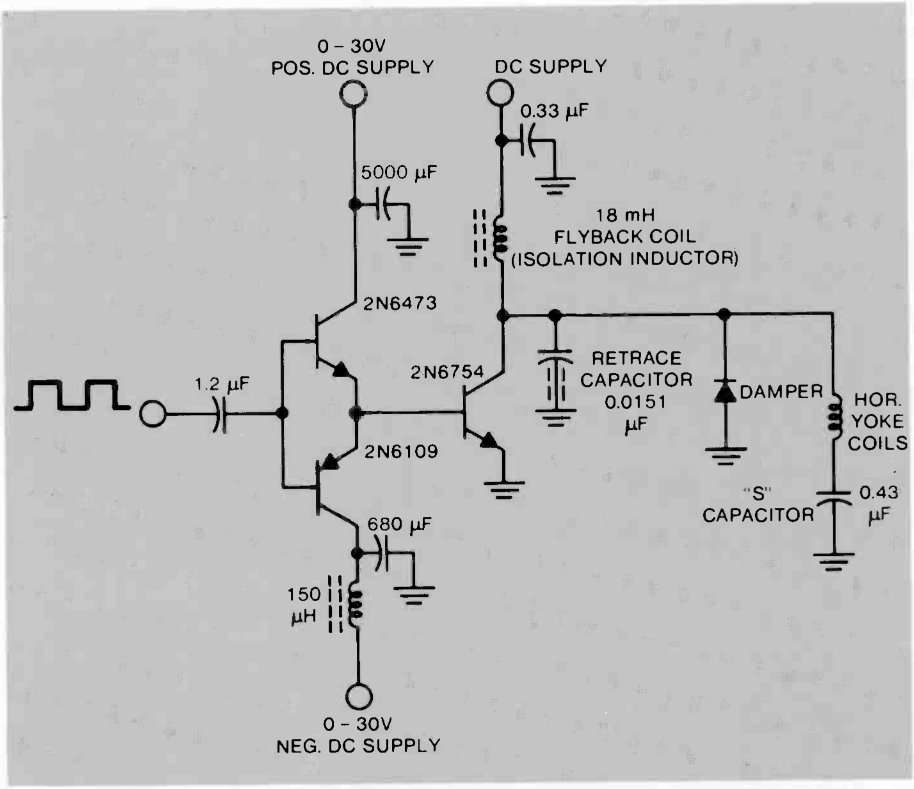

Fig. 3. *Test circuit for measuring yoke losses. This is similar to the basic deflection circuit in Fig. 1. The push-pull drive circuit can be optimized for the different scan frequencies. The current and temperature of the horizontal yoke coils is monitored during the test.*

A thermocouple was cemented to the core of each yoke in order to measure core temperature. The entire yoke was placed inside an insulated container and a second thermocouple was suspended inside the container approximately two inches above the yoke to measure ambient temperature. A curve showing core-temperature rise above ambient versus total power dissipation was obtained for each yoke by applying dc power to the yoke. A typical power-dissipation curve is shown in Fig. 4. This curve was used to convert core temperature rise, during the test, into yoke dissipation.

The vertical yoke winding did not carry any vertical deflection current during the tests. However, the vertical windings are normally shorted at the horizontal frequency by the vertical circuit, so the vertical coils were shorted during the test by a large capacitor (0.33 μF).

Power dissipation in the deflection yoke results from three factors

1. I^2R losses in the windings.
2. Eddy current losses in the windings.
3. Hysteresis and eddy current losses in the ferrite yoke core.

hours of operation, the inductance of the winding dropped drastically and peak yoke current increased significantly. Attempts to run this yoke at 63 kHz were abandoned.

Horizontal deflection yoke loss for the three yoke core materials tested at 15.75, 31.5, and 63 kHz are plotted as a function of frequency in Fig. 5. Although the yoke using ferrite "A" core material could not be tested at 63 kHz, an extrapolation of the curve out to 63 kHz is shown dotted to provide an indication of the losses that might occur if some way (such as fan cooling) could be found to keep the core temperature below the Curie point. The curves in Fig. 5 show that, at the 15.75 kHz scanning rate, the combined hysteresis and eddy current losses are about equal to the I^2R losses in the windings. As the scanning rate is increased, and the retrace time is shortened, core losses and eddy current losses in the copper become a large portion of the total loss.

One interesting observation, upon examining the curves of Figs. 5a and 5c, is the difference in core loss between RCA 804 material and ferrite "B" material. At the 15.75-kHz scanning rate, the two materials have essentially the same loss. At 31.5 kHz, the core loss for RCA 804 material is about 30 percent less than for ferrite "B" material. However, at 63 kHz, ferrite "B" material has a total loss about 20 percent less than RCA 804 material. This probably is due to the relative effects of hysteresis and eddy currents on the total core loss.

At 15.75 kHz, the total loss is primarily due to hysteresis and at that scan rate, the two materials have similar losses. At 31.5 kHz, hysteresis is still the dominant factor, but the 804 material shows lower hysteresis loss. However, at 63 kHz, eddy currents become a significant factor and, since ferrite "B" material has much higher resistivity than 804 material, it has lower eddy current loss.

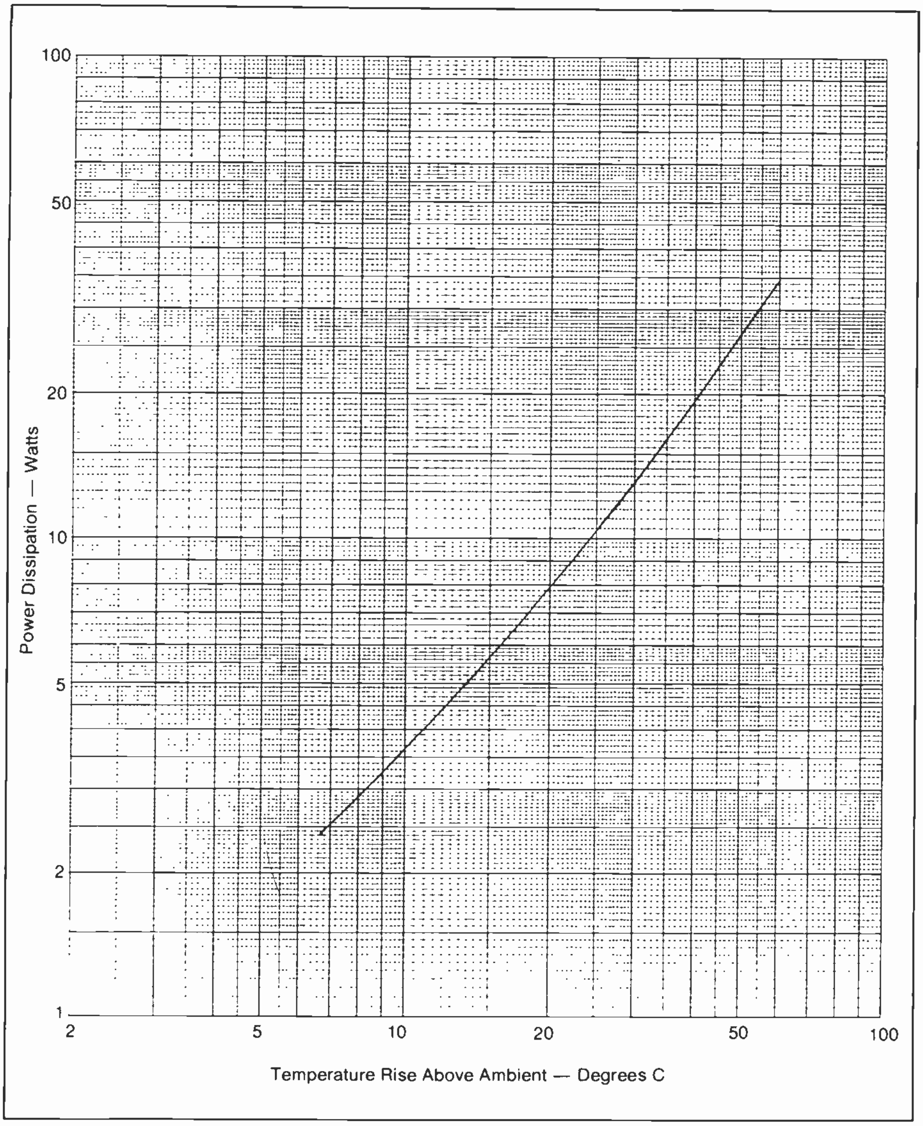

Fig. 4. *Calibration curve for yoke dissipation. A curve like this, showing core-temperature above ambient versus total power dissipation, was obtained for each yoke by applying dc power to the yoke windings.*

I^2R losses in the deflection coil are not a function of frequency. However, since the coil is heated by the ferrite core, which does increase in temperature as frequency increases, the copper resistance will increase with frequency.

I^2R losses in the windings can be calculated quite easily when the rms yoke current and winding resistance are measured at the operating temperature. However, there is no practical way to separate eddy current losses in the winding from hysteresis and eddy current losses in the ferrite. When the I^2R losses at the 15.75-kHz scanning rate with a retrace time of 12.3 μs are subtracted from the yoke losses, the sum of eddy current losses in the yoke windings and the losses in the ferrite is about 3.6 watts. Practically all of this loss occurs during the retrace interval.

At the higher scanning rates there will be some increase in core loss and copper eddy current loss during trace time, but most of these losses will still occur during the retrace interval. An approximate value for the loss occurring during the 6.1-μs retrace interval at 31.5 kHz can be obtained by increasing the retrace capacitor to obtain a retrace time of 12.3 μs and noting the decrease in dc power to the deflection system. Similarly, the decrease in dc power to the deflection system at the 63-kHz scanning rate when retrace time is increased from 3.1 to 6.1 μs can be used to obtain an approximate value for the losses occurring during retrace at 63 kHz.

One of the core materials tested (ferrite "A"), apparently had a rather low Curie temperature and it was not possible to operate it at 63 kHz. Within less than two

Figure 6 shows a typical curve of yoke dissipation as a function of retrace time. At the very short retrace times used for the higher scanning rates, the losses increase rapidly. For example, if the retrace time at a scanning rate of 31.5 kHz is increased from 5 μs to 7 μs, the yoke losses are reduced by about 1.8 watts, or about 12 percent. This suggests that, if the yoke temperature is close to the 105°C maximum rating or slightly above, it might be reduced and kept within the desired temperature rating by a slight increase in the retrace time. If a large decrease in yoke temperature is required, it may be neces-

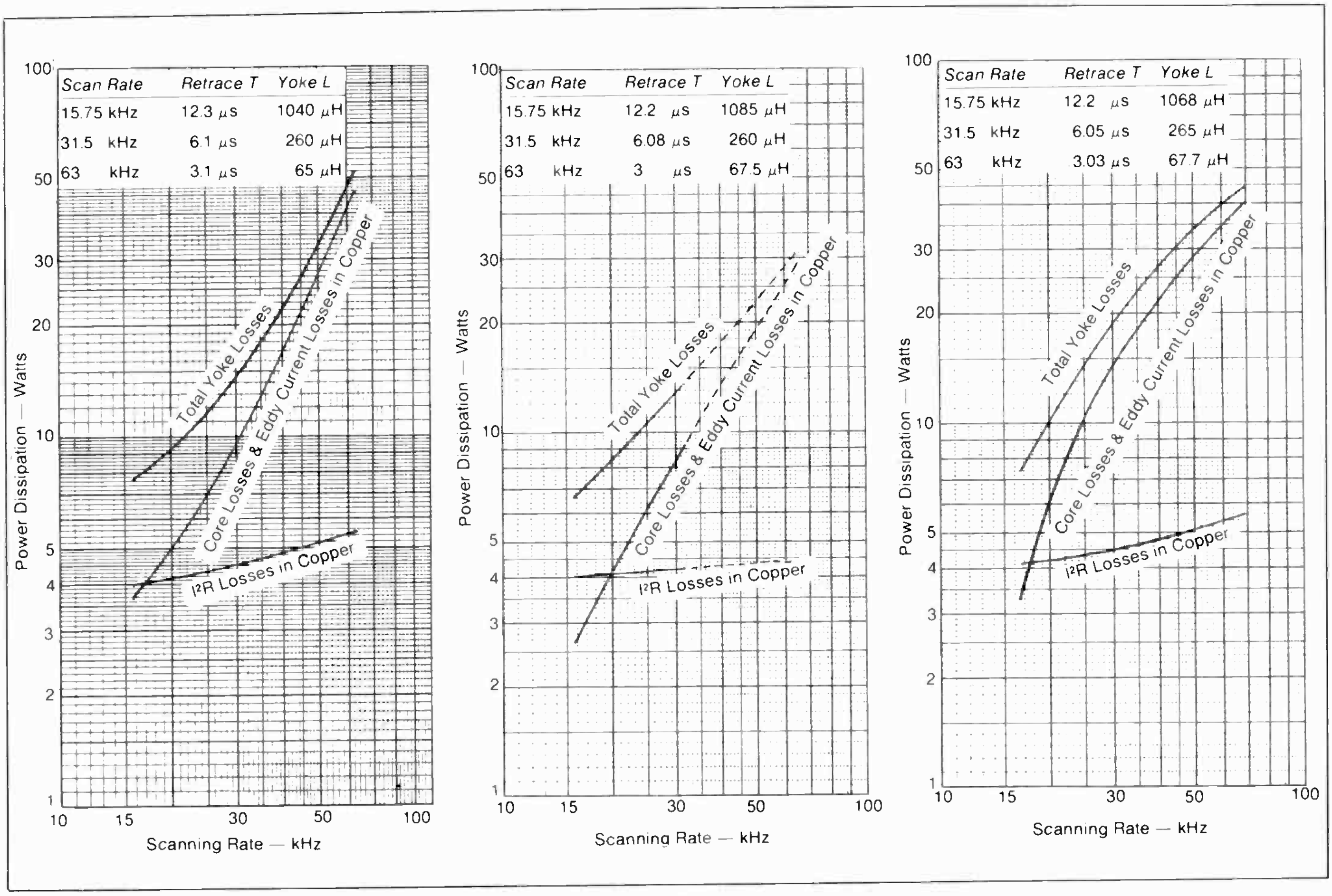

Fig. 5. *Deflection yoke losses as a function of horizontal scanning rate and different ferrite materials. Material "A" is lowest in loss at 16 kHz, but could not be operated above 32 kHz because of low Curie temperature. Dissipation of all materials is excessive at 64 kHz.*

sary to use a lower-loss core material, to use litz wire for the windings, or change the flyback tuning to reduce the harmonic content of the retrace pulse.

Successful implementation of higher scanning rate systems in television receivers will probably include new circuit approaches as well as improvements in devices and in deflection yokes.

Video circuits

National Television System Committee (NTSC) standards provide a maximum video signal bandwidth of approximately 4.2 MHz with a 15.7-kHz horizontal line rate. Accordingly, the video circuit bandwidth in a conventional receiver need not be substantially greater than 4.2 MHz for maximum horizontal resolution of television images. To preserve horizontal resolution capability in a progressive scan receiver, any decrease in active horizontal scan time must be accompanied by a proportional increase in video-circuit bandwidth. Doubling the horizontal scan rate to 31.5 kHz can halve the active scan time and necessitate a video circuit bandwidth of approximately 8.4 MHz for equivalent horizontal resolution of the NTSC signal.

With regard to video-circuit power dissipation, greatest demands are imposed by the output driver stages that must provide at least 100 volts peak-to-peak video at the picture-tube cathodes. Increased driver-circuit bandwidth, to accommodate a high-definition system, generally entails increased power dissipation and higher-performance output transistors. An analysis has been made of the power required by output-driver circuits of the type used in conventional receivers when redesigned to meet the needs of a high-definition receiver.

Class A cascode transistor pair

A widely-used output-driver circuit employing two transistors in a cascode connection with inductive shunt peaking is depicted in Fig. 7. Electrical drive and bias requirements for TV picture-tube displays call for a V_{CC} supply of typically +200 volts with substantial current source capability. Typically, the V_{BB} is +11 volts at low current requirements, and V_{EE} is +3.4 volts with substantial current sink capability. The ratio of R_L to R_E typically ranges from 40 to 80. The capacitance C_L includes Q_2's collector-base capacitance, stray wiring and picture tube socket capacitance in addition to the picture tube electrode capacitance. Typically, $C_L \geqq 12$ pF. A peaking coil L is usually included in Q_2's collector circuit to extend the circuit bandwidth by a factor of approximately 1.7.

If the gain-bandwidth products of Q_1 and Q_2 are sufficiently large, the bandwidth of the circuit in Fig. 7 can be expressed as

$$\mathrm{BW} = 1.7/2\pi\ R_L C_L. \qquad (2)$$

Using typical values for V_{CC}, V_{BB}, V_{BE}, α_1, and α_2, the maximum power dissipated by Q_2 is

$$P_{Q2\ MAX} = 4.0 \times 10^{-7} \times \mathrm{BW}$$

and the corresponding power dissipated by Q_1 is

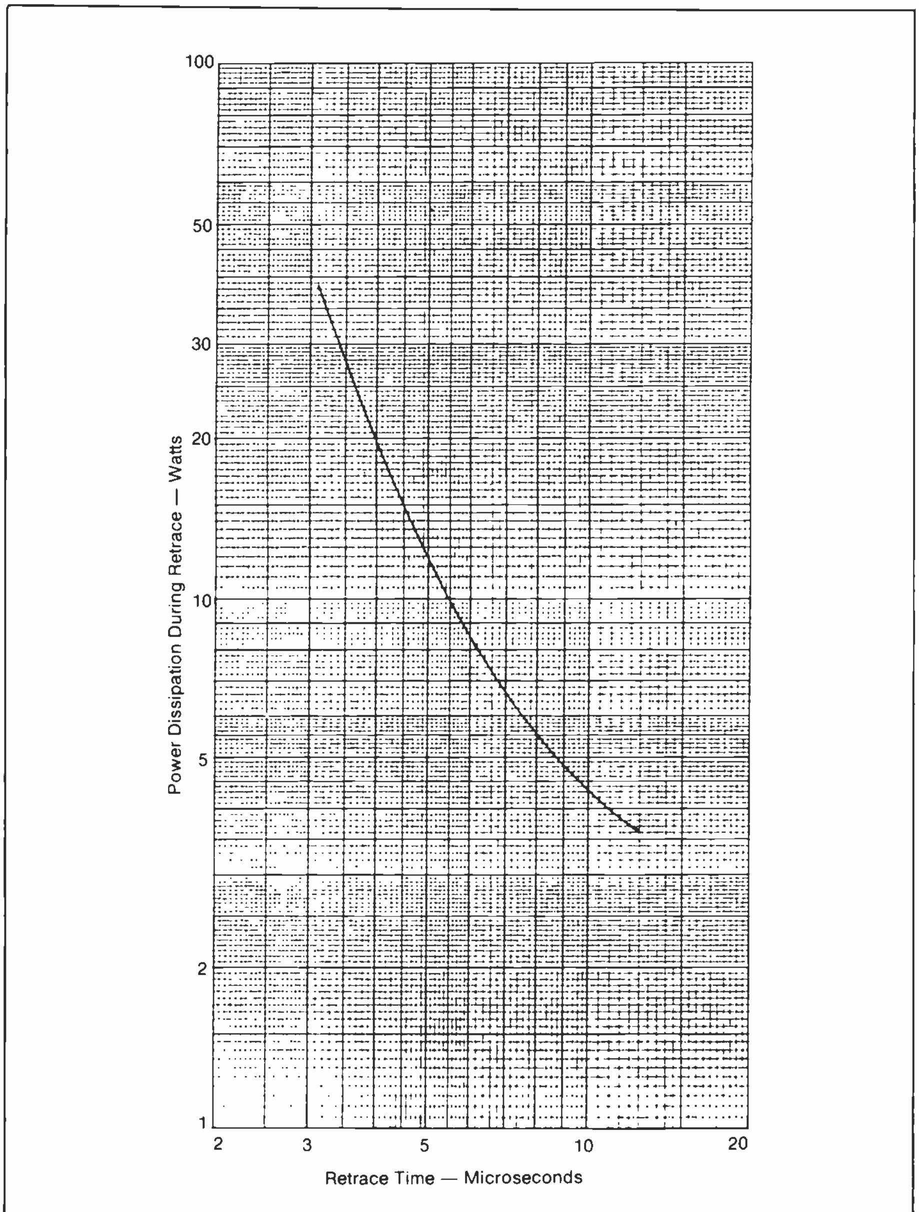

Fig. 6. *Deflection yoke losses as a function of retrace time. At the very short retrace times used for higher scanning rates, the losses increase rapidly.*

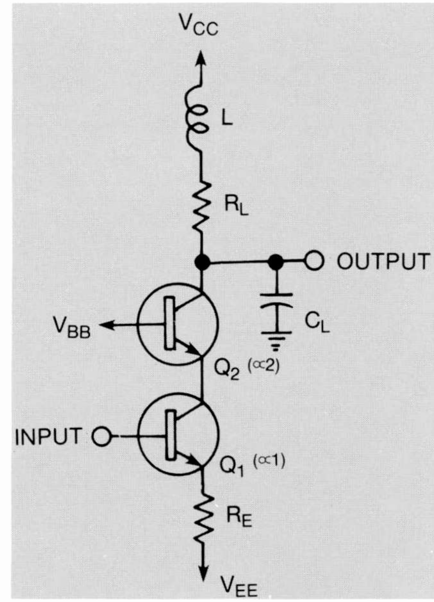

Fig. 7. *Simplified cascode-driver circuit that has found widespread use in TV receivers. Q_2 is a common-base stage that provides a low impedance load on Q_1, a common-emitter stage.*

$$P_{Q1} = 2.44 \times 10^{-8} \times BW.$$

Power that must be supplied to the circuit by the V_{CC} voltage source is $P_{VCC} = 8.43 \times 10^{-7} \times BW$.

As bandwidth increases, power increases in direct proportion for transistors Q_1 and Q_2 and the supply source V_{CC}. Table II lists calculated power for multiples of the maximum NTSC video bandwidth of 4.2 MHz. With three identical output driver circuits operating from a common V_{CC} supply, the total power for V_{CC} is three times the aforementioned value, and this total power is included in Table II.

With the cascode pair circuit configuration of Fig. 7, power dissipated in Q_2 becomes a critical problem at the larger bandwidths necessary for high-definition television, because most transistors cannot meet the requirements of power, voltage, high gain-bandwidth, and low collector-base capacitance. Nevertheless, linear, high-resolution, color data display-tube applications requiring less than half the peak-to-peak drive of high-definition television have used the cascode-pair circuit to achieve bandwidths as wide as 40 MHz. To reduce power, the data display driver circuits operate with V_{CC} supply voltages less than +100 volts, and output signals are capacitively coupled to display-tube cathodes where dc-restoration circuits are employed to maintain proper cathode bias. To ensure wide bandwidths, R_L resistance less than 1000 ohm is used along with transistors exhibiting gain-bandwidths 1 GHz or greater at collector currents as high as 100 mA.

For example, a 40-MHz data-display driver capable of 40 volts peak-to-peak can operate with $V_{CC} = +60$ volts and $V_{BB} = +6$ volts. With $V_{C2} = 1/2\,(V_{CC} + V_{BB} - V_{BE})$, maximum power dissipated by Q_2 is 1.33 watts, and for the same V_{C2}, power supplied by the V_{CC} source is 2.92 watts per driver. The power compares favorably with that listed in Table II for a 4.2-MHz-bandwidth television application. However, both transistor costs and output-circuit complexity tend to increase with wide-bandwidth data-display applications of the cascode-pair circuit.

Active load with feedback

Calculated power in Table II for the class-A cascode circuit is a function of static or quiescent currents and voltages, where the static current depends upon the desired bandwidth. To reduce power dissipation and yet maintain a constant bandwidth and peak-to-peak output voltage, a reduction in quiescent current is required without bandwidth penalty. The active load driver circuit shown in Fig. 8 represents one such design.

Essentially, Q_1 operates like a class-A amplifier with collector load resistance R_L. However, unlike most class-A amplifiers, "active load" devices Q_2 and D_2 are interposed between the capacitive load C_L and

Table II. *Cascode-transistor pair output-circuit power requirements.*

Circuit BW (MHz)	*P_{Q1} (W)*	*P_{Q2} (W)*	*P_{VCC} (W)*	*3 x P_{VCC} (W)*
4.2	0.10	1.7	3.5	10.5
8.4	0.20	3.4	7.1	21.3
16.8	0.41	6.7	14.2	42.6
33.6	0.82	13.4	28.3	85.0

Table III. *Active load output circuit power requirements with $V_P = 0$.*

Circuit BW (MHz)	*P_{Q1} (W)*	*P_{Q2} (W)*	*P_{VCC} (W)*	*3 x P_{VCC} (W)*
4.2	1.04	0.20	2.48	7.44
8.4	2.07	0.20	4.57	13.7
16.8	4.15	0.20	8.73	26.2
33.6	8.30	0.20	17.1	51.2

Table IV. *Active load output circuit power requirements with V_P = 50 volts.*

Circuit BW (MHz)	*P_{Q1} (W)*	*P_{Q2} (W)*	*P_{VCC} (W)*	*3 x P_{VCC} (W)*
4.2	1.40	0.68	3.49	10.5
8.4	2.79	1.19	6.58	19.7
16.8	5.58	2.20	12.8	38.3
33.6	11.2	4.22	25.1	75.4

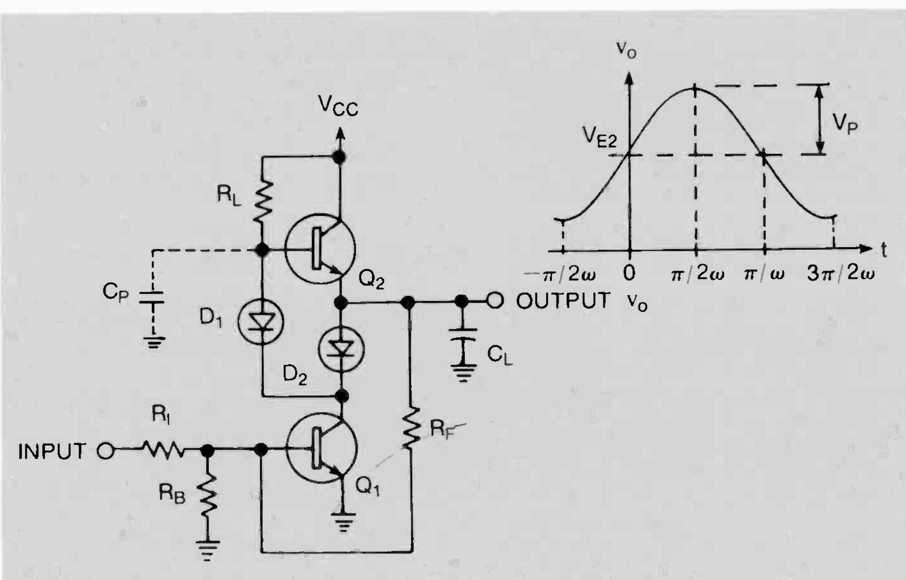

Fig. 8. *Low-power, active-load driver circuit with response limiting parasitic capacitance C_P. Power dissipation is calculated for a peak-to-peak sinusoidal output signal voltage of 2 V_P and signal frequency of ω.*

Q_1's collector or R_L. With fast, positive-going output-voltage transitions (when ω is large and $-\pi/2\omega < t < \pi/2\omega$), D_2 is non-conductive, and the load C_L is charged by Q_2, which functions like an emitter follower. With fast, negative-going output-voltage transitions (when ω is large and $\pi/2\omega < t < 3\pi/2\omega$), D_2 is forward biased, and C_L is discharged by Q_1.

With each fast transition reversal (when ω is large and $t = \pi/2\omega$, $3\pi/2\omega$), the diode threshold voltage of D_2 introduces a small discontinuity that is minimized by the complementary diode threshold of D_1. In addition, a large amount of negative feedback serves to eliminate any visible distortion of the output signal.

Relatively large bandwidths are possible at low quiescent currents with the active load circuit. For the quiescent condition (when $\omega = 0$ and $V_P = 0$), D_2 is nonconductive, collector-bias current for Q_1 is provided via R_L and D_1, and Q_2's emitter bias current flows through R_F. The quiescent current of Q_2 is not critical, and by using a large feedback resistance R_F, the current can be small. Quiescent current of Q_1 is determined by R_L and bandwidth requirements. If Q_1's gain-bandwidth is large in comparison, circuit bandwidth may be expressed as

$$\mathrm{BW} = 1/2\pi R_L C_P \qquad (3)$$

where C_P includes stray wiring capacitance at the collector of Q_1 and the base of Q_2 along with collector-base capacitances of Q_1 and Q_2.

Power dissipated as a function of bandwidth is calculated for an output voltage

$$v_o = V_{E2} + V_P \sin \omega t \qquad (4)$$

where V_{E2} = Q_2's quiescent emitter voltage, and V_P and ω are the peak amplitude and angular frequency of a sinusoidal output signal.

Power dissipated in Q_1 consists of the sum of static and dynamic power. With typical values, maximum static power is dissipated in Q_1 when V_{E2} is approximately equal to $V_{CC}/2$. Dynamic power tends to increase with output signal voltage V_P and signal frequency ω. Representative maximum total power in Q_1 is calculated as a function of bandwidth and output signal voltage by setting $V_{E2} = V_{CC}/2$ and $\omega = 2\pi\mathrm{BW}$, which yields

$$P_{Q1\,max} = \mathrm{BW} \times 2.47 \times 10^{-7} \times (1 + V_P \times 9.44 \times 10^{-3} - V_P^2 \times 5.05 \times 10^{-5}). \qquad (5)$$

Power dissipated in Q_2 is the sum of static and dynamic power terms. Using typical circuit parameter values, total power in Q_2 as a function of bandwidth and output signal voltage becomes

$$P_{Q2} = 1.99 \times 10^{-1} (1 + V_P\,\mathrm{BW} \times 1.21 \times 10^{-8} - V_P^2 \times 5.04 \times 10^{-5}) \qquad (6)$$

when $\omega = 2\pi\mathrm{BW}$ and $V_{E2} = V_{CC}/2$.

Similarly, power supplied by the V_{CC} source includes static and dynamic terms. With typical parameter values and when $\omega = 2\pi\mathrm{BW}$ and $V_{E2} = V_{CC}/2$, V_{CC} power is

$$P_{VCC} = 3.97 \times 10^{-1} (1 + \mathrm{BW} \times 1.25 \times 10^{-6} + V_P\,\mathrm{BW} \times 1.21 \times 10^{-8}) \qquad (7)$$

Results of power calculations for Q_1, Q_2, and V_{CC} in the active load circuit with bandwidths that are multiples of 4.2 MHz are listed in Table III for $V_P = 0$ and in Table IV for V_P = 50 volts. Values in

Table III represent static power or the power required with a picture containing only low-frequency, low-amplitude signal components. Total power is listed in Table IV for a 100-volt peak-to-peak output signal at the upper frequency limit of the circuit and represents the condition for a picture full of high-contrast, fine detail.

Comparing the cascode-transistor pair (Table II) with the active load circuit (Tables III and IV), it will be seen that V_{CC} power required for a picture containing very little detail is significantly less for the active load circuit.

However, nearly the same power is required for a picture full of high-contrast detail. It will also be noted that both transistors in the active-load circuit dissipate substantial power for a highly detailed picture, but only one transistor, Q_2, in the cascode-pair circuit must dissipate substantial power.

Commonly, for bandwidths in excess of 12 MHz, Active Load Kine Drivers do not consume less power than class-A amplifiers, but are more complex and expensive. Also, the unavoidable high-level feedback circuit can degrade the transient behavior limiting their application to bandwidths below 15 MHz.

Conclusion

The information presented in this paper is intended to describe the extent and nature of the problems to be solved on the road to high-performance TV displays. It is hoped that it will be helpful to develop new circuit approaches and components to achieve this performance at reasonable cost and acceptable reliability.

Work is continuing in deflection systems, power supplies and video signal circuits, all areas outlined in this paper. The overall goal is to develop circuits for broad bandwidth and lower power consumption.

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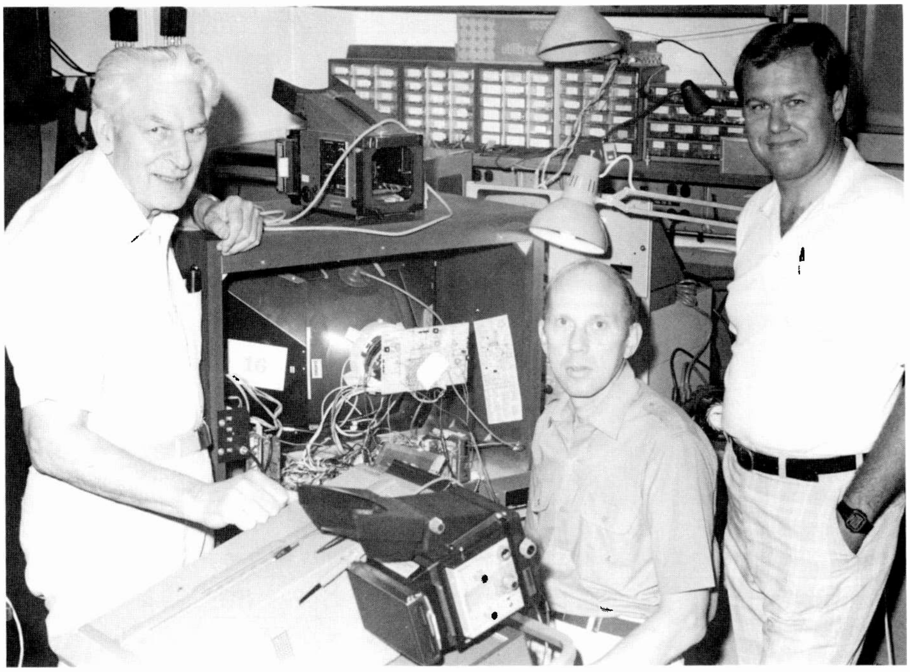

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For more detailed information on the formulas and derivations used in this paper, contact the authors.

D.F. Hakala

Post-molding processing is a unique requirement for VideoDisc

The "wash-lube" portion of VideoDisc manufacturing process is the final touch that protects the disc-stylus interface.

The processing required to manufacture a CED VideoDisc does not end with the VideoDisc molding operation. Two additional process steps—chemical surface treatment and lubrication—are required to make a highly reliable, long-lived product.

The component additives (lubricants, stabilizers, plasticizers, and process aids) in the disc-formulation compound provide good molding and release characteristics, but are also potential candidates, as are polyvinyl chloride (PVC) degradation products, for migration to the surface of the disc. A thin surface film and/or debris can accumulate under certain conditions. These imperfections will raise the stylus from the surface, thus drastically reducing the signal level. When the carrier level drops enough, the video and audio signals cannot be recovered and extremely poor picture and sound results upon playback through a TV receiver. This phenomenon is known as carrier distress and occurs on an untreated disc as an aging, moisture-sensitivity, or temperature-stress problem. A chemical surface treatment stabilizes the disc surface and protects it against aging and environmentally-caused failures (Fig. 1).

The disc surface is played with a diamond stylus and, if the disc surface is untreated, both the disc and the stylus will suffer from wear. To prevent this, a thin film of lubricant is applied to the disc in the final process step before insertion into the caddy and packaging (Fig. 2).

Abstract: *The author reviews the VideoDisc chemical surface treatment and lubrication process steps. The chemical reasons for the treatments are given, and the chemical solutions used are described. Moreover, the author discusses the equipment considerations and environmental tests undertaken to prove out the process.*

Final manuscript received June 13, 1983.
Reprint RE-28-5-9

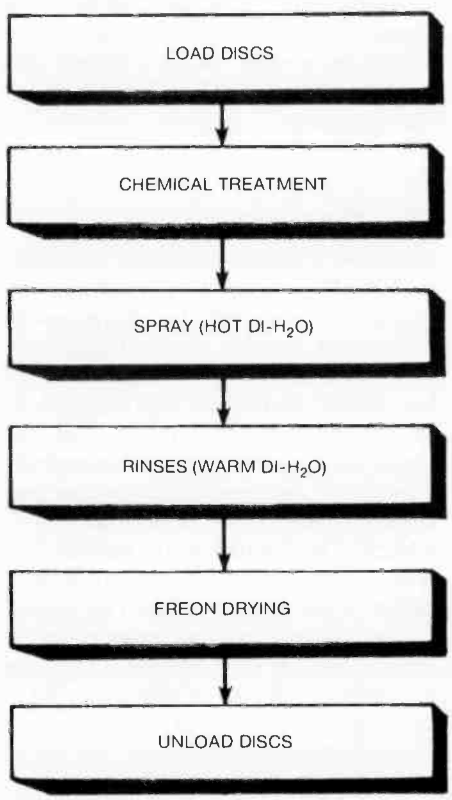

Fig. 1. *Post-molding process.*

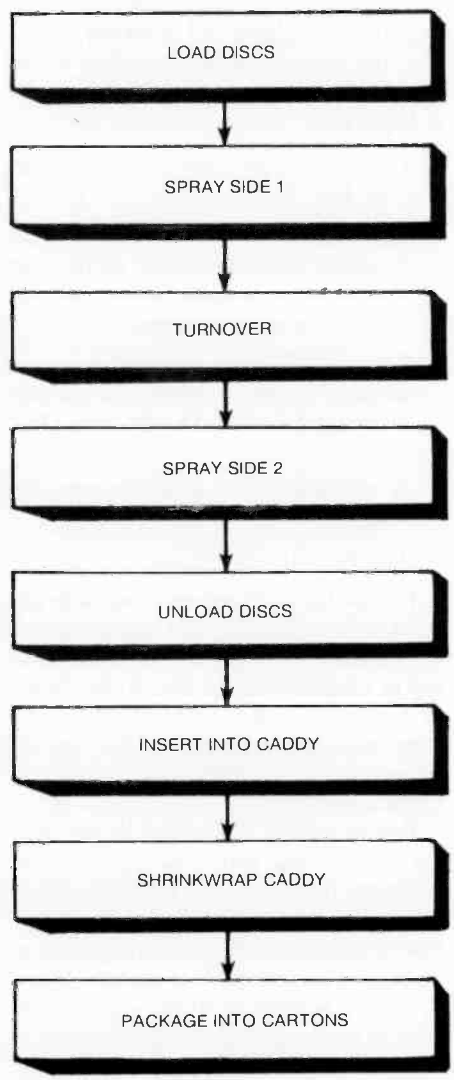

Fig. 2. *Lubrication/packing.*

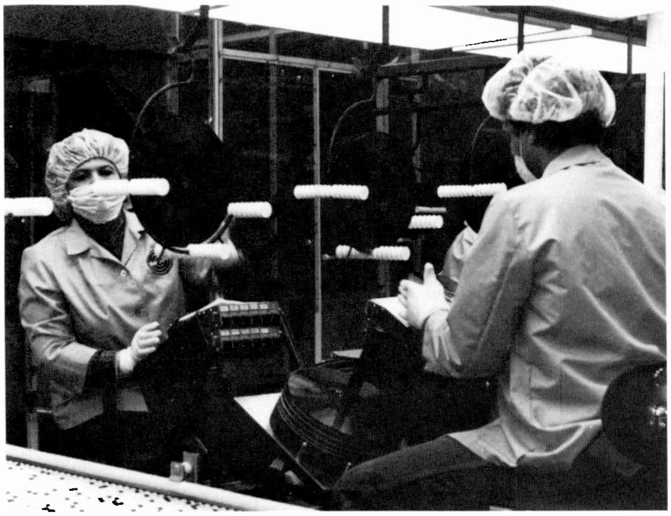

Fig. 3. *Conveyor loading. The surface-treatment-line conveyor is loaded with VideoDiscs.*

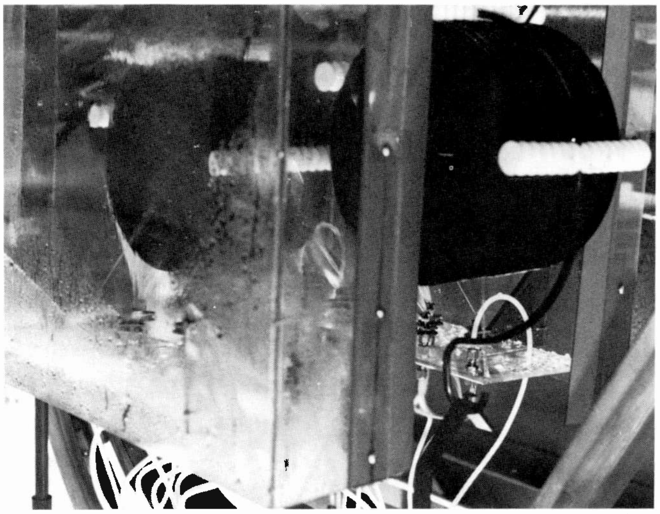

Fig. 4. *Spray chamber. The discs are sprayed with hot deionized water to remove surface contaminants.*

Chemical surface treatment

The primary purpose of the treatment process is the removal and near-surface depletion of undesirable organic additives, degradation by-products, and metal-salt impurities that can migrate to the surface of the disc. Discs are treated in a process sequence as follows:

1. Discs are loaded onto conveyor racks (Fig. 3).
2. The discs are immersed in a chemical treatment bath containing amine and surface-active components that provide uniform chemical treatment.
3. The residual film is removed through a series of highly purified, filtered, deionized water sprays and dip rinses (Fig. 4).
4. A chemical vapor dryer removes the water film by displacement drying.
5. The discs are unloaded from the rack.

Because the video and audio signal amplitudes are so minute (~850 angstroms and ~90 angstroms respectively), the fluids coming in contact with the disc surface must be particulate- and colloid-free. The water must not only be deionized, but also requires submicron-filtration and colloid-removal steps.

Process control is achieved by monitoring the chemical bath concentrations, the pH in the rinse tanks, the pH in the chemical vapor dryer (to monitor decomposition resulting in acid), and the organic and particulate contaminants in the rinse tanks.

Surface analysis of plastics is difficult at best. However, during the development of the process, research based on Secondary Ion Mass Spectrometry (SIMS) confirmed the existence of a depletion layer of metal-ion salts that results from the treatment process.[1,2] Further, Fourier Transform Infrared Spectroscopy (FTIR) coupled with a reflection sample device was used to monitor the surface enrichment of certain formulation additives relative to bulk concentrations.[3] Indications are that a "native" lubricant layer is also removed in the treatment. Variations in spatial uniformity and thickness appear to depend on the press process. The amount of wetting and spreading of the lubricant on the surfaces of untreated discs varies significantly.[4] The chemical treatment step has the side benefit of making a more uniform surface that more readily accepts the subsequently applied lubricant.

Disc lubrication

After the chemical treatment operation, the VideoDisc is loaded on a carrier mounted on a conveyor belt. The disc is carried into a spray chamber. At this point, a solvent containing a low concentration of lubricant is atomized through a spray nozzle directed at the disc (Fig. 5). The disc leaves the chamber and is automatically turned over and repositioned on the conveyor. The other side of the disc is then lubricated in a second spray chamber. The conveyor then carries the disc to the next station, where it is inserted into the caddy.

The thickness and uniformity of the oil on the disc are the parameters of prime importance. Nominal oil thicknesses are in the range of 200 to 400 angstroms. At lower thicknesses, stylus wear can occur. At greater thicknesses, the oil does not conform as well to the disc surface and can act as a particle trap as well as cause a drop in signal level when the thickness becomes extreme.

The solution flow rate, atomization pressure, nozzle geometry, and nozzle oscillation rate are optimized for a given line-speed to provide for good oil distribution. The solution is filtered directly before atomization. The air used to atomize the solution is provided by a modified compressor designed to give particle-free air. Commercial oil-free compressors, even those for hospital use, have proven far too dirty for this application.

The solvent is tested to specifications even more stringent than for a reagent-grade material. The lubricant consists of two species. A silicone of the type

$$(CH_3)_3Si - O \left[\begin{array}{c} CH_3 \\ | \\ Si \\ | \\ R \end{array} \right]_n O - Si\,(CH_3)_3$$

is used to provide the lubricating qualities, while a modified silicone additive is used to enhance uniform oil spreading, even in moist environments. The lubricant material specifications are very demanding and the properties measured include the following:

- specific gravity;
- surface tension;
- viscosity;
- molecular-weight distribution;
- trace organic impurities; and
- trace inorganic impurities.

Control of the oil thickness is monitored

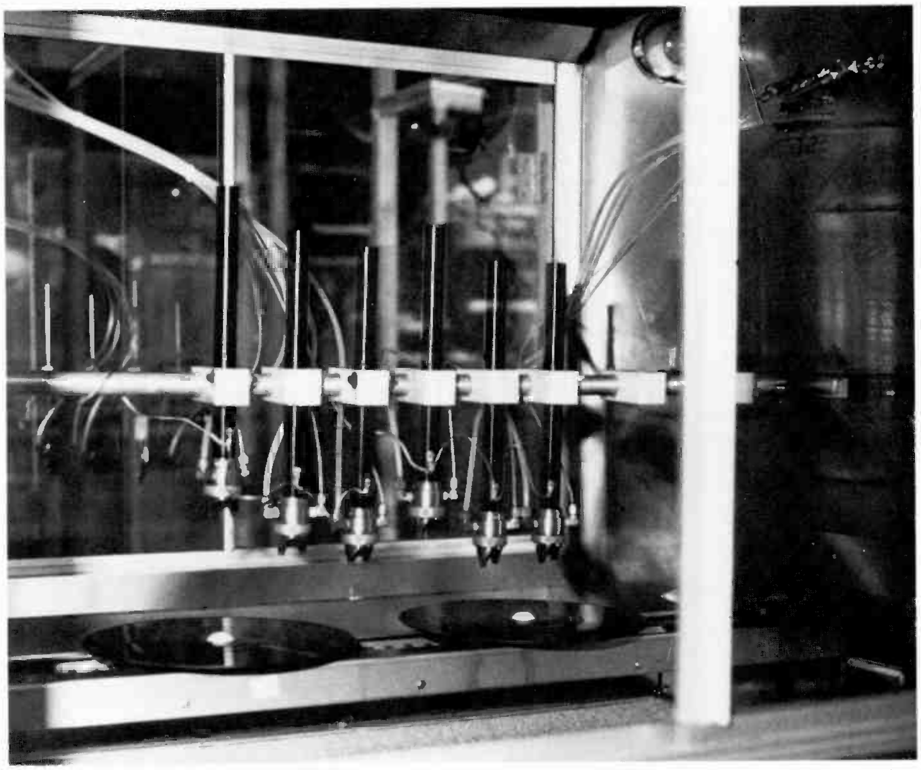

Fig. 5. *Lubrication spray chamber. A dilute solution of lubricant is sprayed on the discs.*

by our use of X-ray fluorescence spectrometry on a routine basis.

Equipment considerations

In addition to critical process conditions and chemical requirements, equipment-design considerations are important to successful operation of the surface treatment/lubrication process.

Rack design is critical in both protecting a disc against damage in transport through the treatment operations while also allowing effective rinsing and drying. Conveyors must be constructed so tank contamination is minimized or eliminated. Materials of construction are, in general, high-grade stainless steel or Teflon to minimize contamination.

The lubrication-line turnover demands that a delicate product be handled automatically at a high rate of speed. Nozzle design and layout are important in producing a uniform lubricant layer over the disc surface. Safe handling of the solvent necessitates strict grounding requirements coupled with an automatic vapor-detection/explosion-suppression system. Economics of the process are assisted by a highly efficient solvent-recovery system that not only prevents contamination of the environment, but permits reclamation of an expensive raw material.

Environmental tests

Post-molding processes are carried out for two major reasons:

1. reduced disc/stylus frictional wear, and
2. improved stability to extremes of environment.

The treatment process was developed to meet stringent criteria under a wide variety of environmental stresses. Examples include:

- Hot condensation stress (1 hr)
- High temperature and high humidity (48 hr)
- Low humidity ($<$15% relative humidity)
- High temperature (130°F), and low temperature (−40°F)
- New Orleans Worst Day tests (a 28-times repeat of a 24-hour cycle that includes both a 85°F, 95% relative humidity environment and a 105°F, 55% relative humidity environment).

After they are stressed, the discs must meet all physical specifications (for example, warp and acceleration) and playback criteria for carrier distress, skipping, and video and audio signal/noise.

These tests are used for process development and periodic process/product audits, and are not intended as routine quality-control tools.

Summary

The disc-lubricant layer increases stylus life by approximately two orders of magnitude. The incidence of carrier distress (under environmental stress) is reduced approximately two orders of magnitude as a result of the chemical surface treatment (20 to 30 seconds per side versus less than 0.2 seconds per side). Obviously, to make a quality product, both steps are critical. Much effort at VideoDisc Operations and the RCA Laboratories was expended in the development and successful implementation of the operations.

Additional developments will bring technological rewards. An improved understanding of disc-surface physics and chemistry, and their relation to formulation and molding process conditions, will result in a more efficient surface treatment and lubrication.

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Missile and Surface Radar

A. Afrashteh
Design and Testing of L-Band Solid State Amplifier—Symposium of Computer-Aided Microwave Engineering, RCA Labs, Princeton, N.J. (4/15/83)

J.A. Bauer | P. Bronecke
R. Kolc | R. Schelhorn
Overview and Applications of Surface Mounted Technology—Surface Mounted Technology, Dallas, Tex. (5/16-17/83)

F.J. Buckley
Software Quality Assurance—Panel Chairperson, IEEE Second Software Engineering Standards Application Workshop, San Francisco, Calif. (5/17-19/83)

F.J. Buckley
Software Quality Assurance—IEEE Software Quality Assurance, Williamsburg, Va. (4/18-20/83)

R. Clark
Computer Controlled Testing of the Column Beamformer Assemblies—Symposium of Computer-Aided Microwave Engineering, RCA Labs, Princeton, N.J. (4/15/83)

D.C. Drumheller
The History of the Applicon Users Group— Applicon User's Group Eighth Annual Meeting, Dallas, Tex. (5/9/83)

W.C. Grubb, Jr.
Minicomputers and Microcomputers for Non-Electrical Engineers—Drexel University, Philadelphia, Pa. (5/20/83)

L.E. Kitchen
Application of Your Personal Computer to Engineering Management Tasks—IEEE Engineering Management Meeting, Philadelphia, Pa. (4/83)

N.R. Landry | E.J. Kent
Precision Combiner Networks for Phased Array Antennas—International IEEE/APS Symposium, Houston, Tex. (5/26/83)

H.D. Lewis
Coordination of Extended Range Air Defense with AEGIS S-Band Data Link— ADPA Fire Control Symposium, Colorado Springs, Colo. (5/3-4/83)

J. Nesbit | V. Stachejko
Design of 6-Bit Diode Phase Shifter Using ANA—Symposium of Computer-Aided Microwave Engineering, RCA Labs, Princeton, N.J. (4/15/83)

A.K. McGee
Beamforming Modeling for Rapid Design Adjustment—Symposium of Computer-Aided Microwave Engineering, RCA Labs, Princeton, N.J. (4/15/83)

L.C. Pickus
Today's Displays in the Conference of Tomorrow—30th International Technical Communication Conference, St. Louis, Mo. 30th ITCC *Proceedings* (5/4/83)

F. Reifler
A Vector Wave Equation for Neutrinos— American Institute of Physics—*Journal of Mathematical Physics*

P.S. Sawkar | T.J. Forquer | R.P. Perry
Programmable Modular Signal Processor—A Data Flow Computer System for Real Time Signal Processing—1983 Int'l. Conference on Parallel Processing (IEEE), Bellaire, Mich. (8/23-26/83)

A. Schwarzmann
High Power Diode Time Delay Switch— Symposium of Computer-Aided Microwave Engineering, RCA Labs, Princeton, N.J. (4/15/83)

G.M. Sparks
Ground Clutter Modeling and Detection of Low Speed Targets in the Presence of Ground Clutter Using a Ground Based Radar—U.S. Military Academy, 29th Annual Tri-Service Radar Symposium (6/14-15-16/83)

S.A. Steele
Fail-Safe System Architectures (Vu-Graphs)—Data Processing Management Association, Education Foundation, (DPMAEF) Computers in Defense, Torrance, Calif. (6/9-10/83)

T.O. Vinson | T.P. Speas
AEGIS Logistics Analysis—18th Annual Logistics Symposium, Atlanta, Ga. (8/10-11/83)

A.W. Wainwright
Expanded IO 8 BASIC Capabilities— Applicon User's Group Eighth Annual Meeting, Dallas, Tex. (5/9/83)

R.S. Wang
Logic Analysis and The Tools—NCC National Computer Conference, ACM Software Engineering Symposium, Anaheim, Calif., NCC *Proceedings* (5/17/83)

M.L. Weisbein
I'd Rather Be Programming, or A View From the Quality End of Software Engineering—ASQC Meeting, Philadelphia, Pa. (5/19/83)

L.H. Yorinks
Automatic Alignment of a Low Sidelobe Phased Array Antenna—Symposium of Computer-Aided Microwave Engineering, RCA Labs, Princeton, N.J. (4/15/83)

L.H. Yorinks
Automated Testing and Alignment of Modern Phased Array Antennas—Seminar on Modern Phased Array Antenna Technology, UCLA, Calif.

Engineering News and Highlights

Andrews is Director of ATL

Dr. Ronald A. Andrews has been appointed Director of the Advanced Technology Laboratories of RCA's Government Systems Division. He is responsible for all activities of the organization, which develops technologies in computer systems, applied physics, solid-state circuits, electro-optics, signal processing and systems development.

Before joining RCA, Dr. Andrews served in systems engineering and technical engineering management positions at Xerox Corp.'s Webster, N.Y. facility. Earlier, he was Branch Head for Optical Physics and Laser Interactions at the Naval Research Laboratory, Washington, D.C.

Author of about 30 articles in American Physical Society and Institute of Electrical and Electronics (IEEE) Journals, Dr. Andrews is a fellow of the American Physical Society and the Optical Society of America, as well as senior member of the IEEE. He also is a member of the Phi Beta Kappa and Sigma Xi honorary societies.

Dr. Andrews received bachelor's and doctor's degrees in physics from Wayne State University, and a master's degree from Massachusetts Institute of Technology as a part of the Sloan Fellows Program. He holds several patents in laser physics and xerography.

Terrano is Education Administrator

Bob Terrano recently joined RCA as an Administrator with the Corporate Engineering Education staff, located at the RCA Technical Excellence Center in Princeton, N.J. He will be a part of that activity's efforts to create and promote useful videotape-based technical courses. He is an experienced educator and engineer. Most recently, he was Director, Technical Education, for the New Jersey Department of Education Division of Vocational Education and Career Preparation. Mr. Terrano received a B.S. in Industrial Engineering from the New Jersey Institute of Technology in 1972, and an M.A. in Education, Jersey City State College in 1976.

Contact him at:
RCA Corporate Engineering Education
Princeton, N.J.
TACNET: 226-2149

Moss named Technical Information Systems Manager

Gerry Moss recently joined RCA as Manager of Technical Information Systems in the Engineering Information activity located at the RCA Technical Excellence Center in Princeton, N.J. She is responsible for publishing the *RCA Technical Abstracts* and maintaining the Technical Abstracts Database. Mrs. Moss will be working with members of the RCA library network to expand interlibrary cooperation. She will draw on her extensive experience as an information specialist with major corporations and universities. Her education includes an M.L.S. in Information Science, a B.S. in Chemistry, and an A.A. in Computer Science.

Contact her at:
RCA Technical Information Systems
Princeton, N.J.
TACNET: 226-2410

RCA elects Gordon, Vice-President, Licensing

Election of **Allan D. Gordon** as Vice-President, Licensing, for RCA Corporation, was announced by **William C. Hittinger,** Executive Vice-President, Corporate Technology, to whom he will report. In this capacity, Mr. Gordon will have overall responsibility for the company's worldwide licensing activities. He succeeds **Stephen S. Barone** who plans to retire by year-end.

During the past 11 years, Mr. Gordon has held several key posts in RCA's Licensing activity. Recently, he had been Staff Vice-President, Licensing, with responsibility for all of the company's domestic and international licensing activities.

Mr. Gordon joined RCA in 1950, and subsequently served in a series of management assignments in patents and licensing in the United States and Japan. Mr. Gordon was graduated from the University of Michigan in 1950 with a B.S. in Electrical Engineering.

Staff announcements

Consumer Electronics

James E. Carnes, Division Vice-President, Engineering, announces his organization as follows: **Tom W. Branton,** Manager, Projection Project Engineering; **Larry A. Cochran,** Director, Signal Systems and Monitor Operations; **Jack S. Fuhrer,** Director, New Products Laboratory; **Eugene Lemke,** Staff Technical Coordinator; **James A. McDonald,** Director, Display Systems Engineering; **Perry C. Olsen,** Director, Project Engineering; **Richard A. Sunshine,** Director, Mechanical Design Engineering; and **Willard M. Workman,** Director, VideoDisc Player Engineering.

Tom W. Branton, Manager, Projection Project Engineering, announces his organization as follows: **James J. Kopczynski,** Manager, Project Engineering.

Larry A. Cochran, Director, Signal Systems and Monitor Operations, announces his organization as follows: **Roger W. Fitch,** Manager, Component Engineering; **William A. Lagoni,** Manager, Signal Processing; **Ronald R. Norley,** Manager, Taiwan Coordination and Monitor Design; **Robert P. Parker,** Manager, RF Systems; **John F. Teskey,** Manager, Digital Tuning Systems; and **Robert P. Parker,** Acting Manager, Advanced Tuner Development.

Jack S. Fuhrer, Director, New Products Laboratory, announces his organization as follows: **Alfred L. Baker,** Manager, Television Digital Systems; **Billy W. Beyers, Jr.,** Manager, Digital Products Development; **Charles A. Brombaugh,** Manager, Engineering Systems; **David J. Carlson,** Manager, Signal Systems Development RF/IF; **Aaron C. Cross, Jr.,** Manager, Advanced Mechanical Engineering; **James L. Newsome,** Manager, Technology Applications; and **Donald H. Willis,** Manager, Digital Signal Processing.

Perry C. Olsen, Director, Project Engineering, announces his organization as follows: **Robert D. Altmanshofer,** Manager, Engineering-Juarez; **Eldon L. Batz,** Manager, Resident Engineering; **Elmer L. Cosgrove,** Manager, Engineering Services; **Paul E. Crookshanks,** Manager, Project Engineering; **James C. Marsh, Jr.,** Manager, Project Engineering; and **Paul C. Wilmarth,** Manager, Project Engineering.

Richard A. Sunshine, Director, Mechanical Design Engineering, announces his organization as follows: **Melvin W. Garlotte,** Manager, Mechanical Engineering-Instruments; **Roger D. Sandefer,** Manager, Design Drafting; **James B. Waldron,** Manager, Mechanical Engineering-Chassis and Sub-Assembly; and **Richard A. Sunshine,** Acting Manager, Computer-Aided Design Systems.

Gary A. Gerhold, Plant Manager, Indianapolis Components Plant, announces his organization as follows: **Elliott N. Fuldauer,** Manager, Materials; **James P. Gallagher,** Manager, Plant Financial Operations; **Aldo R. Neyman,** Manager, Operations-Components; **E. Rene Parks,** Manager, Industrial Relations, CED-Indianapolis; **Henry L. Slusher,** Manager, Facilities Services-CED Indianapolis; **JB Thomas,** Manager, Operations-Plastics; and **Gary A. Gerhold,** Acting Manager, Plant Quality Control.

Aldo R. Neyman, Manager, Manufacturing, announces his organization as follows: **Paul G. England,** Superintendent, Manufacturing Operations; **John O. Greene,** Manager, Test Engineering and Construction; **William E. Hall,** Superintendent, Manufacturing Operations; and **Donald V. Temple,** Manager, Process Engineering.

Henry L. Slusher, Manager, Facilities Services-CED Indianapolis, announces his organization as follows: **James C. Wood,** Manager, Facilities Engineering Projects; and **Royal E. Secor,** Manager, Facilities and Services.

JB Thomas, Manager, Operations-Plastics, announces his organization as follows: **William B. Craig,** Superintendent, Manufacturing Operations; **Hank A. Hietberg,** Manager, Plant Maintenance; **Douglas J. McGinnis,** Manager, Process Engineering; **Addison E. Wilson,** Administrator, Plastics Manufacturing Engineering; **Richard E. Molyneux,** Superintendent, Manufacturing Operations; and **Keith A. Searcy,** Manager, Process Engineering.

Gary A. Gerhold, Acting Manager, Plant Quality Control, announces his organization as follows: **Dennis W. Campbell,** Manager, Production Quality Control; **John W. Rothfuss,** Manager, Production Quality Control; and **Jill A. Lord,** Administrator, Quality Engineering.

Video Component and Display Division

Charles A. Quinn, Division Vice-President and General Manager, Video Component and Display Division, announces the appointment of **John M. Ratay** as Division Vice-President, Manufacturing.

Promotions

Matthew A. Owen was promoted from Member, Technical Staff, to Section Manager, Quality & Reliability Assurance, High Speed Bi-Polar IC at the Solid State Division.

Sheldon Gottesfeld was promoted from Member, Technical Staff, to Section Manager, Reliability Engineering.

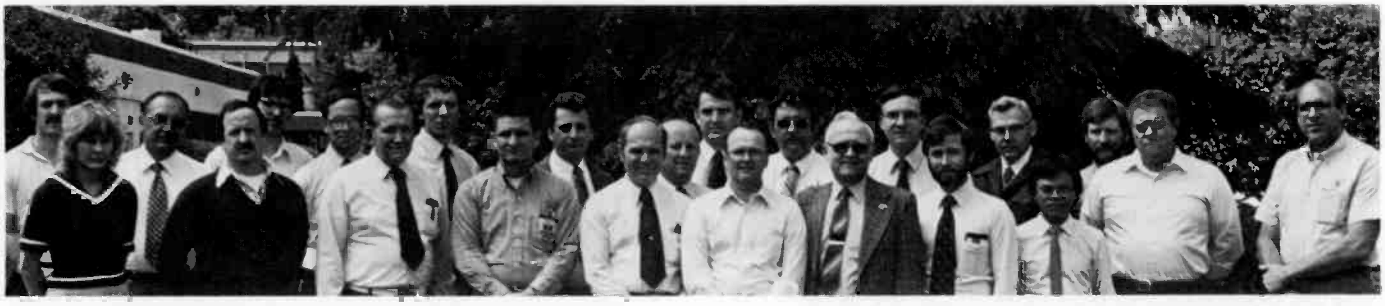
Professional activities

Inman receives ASNE Gold Medal

Inman (left) with Rear Admiral Wayne E. Meyer

Bryce D. Inman, Manager, Advanced Radar Development, Missile and Surface Radar, received the Gold Medal Award from the American Society of Naval Engineers at their annual national meeting held in Washington, D.C. on May 6, 1983.

The Gold Medal is given for a most significant engineering contribution in the field of Naval Engineering through personal effort, or through direction of others, during or culminating in the five year period ending in the current year. Mr. Inman was cited, in part, "For his visionary leadership in defining and directing the Navy's first major program in integrating the efforts of a Combat System Agent with ship designers and builders, and in integrating the first AEGIS Combat System into the first AEGIS guided missile cruiser, *USS Ticonderoga* (CG 47); for



Lancaster plant Technician of the Year Award recipients. From left to right: James R. Dowell, Mary Jane McPherson, Joseph J. Gorlaski, Dale R. Goodman, Clarence M. Weaver, Jr., John L. Leszczynski, Roy A. Erdman, Stephen C. Forberger, Robert E. Kreider, Robert Landis, Jr., David A. Landis, Donald C. Bachman, Denton L. Borry, Stewart E. Beshore, James E. Deardorff, Ivan Horning, Mark F. Trax, Bruce A. Breiner, H. Albert Walschburger, Nhu Van Dang, Ronald L. Kennard, Robert G. Sheaffer, George F. Van Cleve. Recipients not in the picture include David E. Clark, John S. Gagliano, Lee W. Horn, and Richard L. Wagner.

his perceptive efforts in promulgating the concept of a combat system 'grooming site' to control and reduce the costs, time and risks of shipboard installation and integration of a complex combat system; and for his pioneering excellence in both systems engineering and management of AEGIS Combat System development."

Mr. Inman, a retired Navy Captain, joined RCA in 1970. While in the Navy, he directed the concept formulation of the phased array radar, the guidance system computer, and the displays for the Advanced Surface Missile System, forerunner of the AEGIS Weapon System. Upon his entry into industry, he assumed responsibility for integration of the AEGIS Weapon System into its ship and development of enhanced capability versions of the AEGIS Weapon System and AN/SPY-1 phased array radar.

Additional 1982 Technician of the Year Award recipients at the Lancaster plant. From left to right: Andrew G. Kubala, Scott Stormfeltz, and Allen G. Shappell.

Mercuri is elected

Rebecca T. Mercuri, RCA Laboratories, Princeton, N.J., was elected Vice-President of the Delaware Valley Chapter, Acoustical Society of America.

RCA Engineer honored by Society for Technical Communication

The *RCA Engineer* Staff and Editorial Representatives received a Certificate of Merit from the New York Chapter of the Society for Technical Communication "in recognition of exceptional achievement in Technical Communication." The STC recognized overall publications excellence in three consecutive *RCA Engineer* issues—March/April, May/June and July/August 1982. Authors from virtually all RCA businesses contributed to these issues.

Milley appointed Associate Editor, *PCS Transactions*

David E. Milley, of Missile and Surface Radar in Moorestown, has assumed the position of Associate Editor of *IEEE Transactions on Professional Communication.* The journal, circulated to approximately 3000 engineers, is published quarterly. Mr. Milley is an Associate Member of the Engineering Staff in the Technical and Management Documentation activity in the Naval Systems Department.

Pickus appointed Treasurer of IEEE Professional Communication Society

Leon C. Pickus, Unit Manager, Technical and Management Documentation, in the Naval Systems Department of Missile and Surface Radar, was recently appointed Treasurer of the IEEE Professional Communication Society. Mr. Pickus has been a member of the PCS Administrative Committee for the past three years and serves on their Education Committee as an instructor and workshop lecturer for the Technically Write Program. He is also a Senior Member IEEE and a member of the Society for Technical Communication.

Technical excellence

Taylor receives "SelectaVision" VideoDisc Technical Excellence Award

J.J. Brandinger (left) with Byron Taylor.

Byron K. Taylor, Member Engineering Staff, received the "SelectaVision" VideoDisc Technical Excellence Award May 23, 1983, by virtue of his outstanding creativity, resourcefulness, and proficiency in the development and design of the VDC-5 cartridge.

Byron was challenged to design a cartridge that would be rugged, tolerant of player/arm misalignment, require no adjustments, contain a portion of the time-base-correction transducer, use cost effective parts, and sacrifice no performance. Byron met the challenge and, in addition, increased the skipping range and improved the time-base correction.

Byron used developments at RCA Laboratories and many inputs and ideas from Cartridge Manufacturing Engineering to meet the cost and performance goals of the VDC-5 program. The simplification of three critical parts also offers future opportunity for competitive sourcing and assembly automation. The design of the VDC-5 cartridge brings to eleven the number of patents held by Byron and vividly demonstrates his significant and creative contributions to the VideoDisc developments.

Lysobey receives award

Jim Fayer (left) with Morris Lysobey.

The Government Communications Systems Technical Excellence Award has been made to **Morris Lysobey** of Communications Equipment Engineering for his outstanding work in the development of techniques for high-frequency (HF) antenna couplers. These units enable maximum power transfer from a transmitter to antennas whose impedance varies widely with frequency. Anti-jam considerations dictate that HF transmitters and antenna systems operate in frequency-hopping modes at rates up to several thousand frequency changes per second. Power levels of 1,000 watts and antenna Q of up to 500 make achievement of the required impedance match at each frequency a formidable task.

Morris has applied his engineering skills to this problem. He analyzed various matching configurations for several antenna types, evaluated potential switching devices, and modeled and analyzed the performance of candidate coupler configurations. He conceived and evaluated innovative solutions to the difficult problems of implementing impedance matching, fast switching of high power rf signals, bias and control signals, and power supplies. His resolution of problems such as the generation and isolation of biasing voltages up to 8,000 volts, and isolation from rf power levels up to 1,000 watts while both are applied to the *pin*-diode switching devices, exemplified highly creative and professional engineering design.

GCS is currently mounting a large effort to capitalize on the intense interest among the military services in the increased performance and use of HF communications. Mr. Lysobey's work on agile antenna couplers has contributed substantially to placing RCA in a favorable position to achieve our goals in the HF market.

Editorial Representatives

Contact your Editorial Representative at the TACNET numbers listed here to schedule technical papers and announce your professional activities.

Cablevision Systems

		TACNET
*John Ovnick	Van Nuys, California	534-3011

Commercial Communications Systems Division (CCSD)

*Bill Sepich	Camden, New Jersey	222-2156
Clinton Glenn	Meadowlands, Pennsylvania	228-6231

Consumer Electronics (CE)

*Eugene Janson	Indianapolis, Indiana	422-5208
Francis Holt	Indianapolis, Indiana	422-5217
Larry Olson	Indianapolis, Indiana	422-5117
Byron Taylor	Indianapolis, Indiana	426-3247
Don Willis	Indianapolis, Indiana	422-5883

Corporate Technology

*Hans Jenny	Princeton, New Jersey	226-2111

Government Systems Division (GSD)

Advanced Technology Laboratories

*Merle Pietz	Camden, New Jersey	222-2161
Ed Master	Camden, New Jersey	222-2731

Astro-Electronics

*Frank Yannotti	Princeton, New Jersey	229-2544
Carol Klarmann	Princeton, New Jersey	229-2919

Automated Systems

*Paul Seeley	Burlington, Massachusetts	326-3095
Dale Sherman	Burlington, Massachusetts	326-3403

Government Communications Systems

*Dan Tannenbaum	Camden, New Jersey	222-3081
Thomas Altgilbers	Camden, New Jersey	222-3351

GSD Staff

*Peter Hahn	Cherry Hill, New Jersey	222-5319

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*Don Higgs	Moorestown, New Jersey	224-2836
Graham Boose	Moorestown, New Jersey	224-3680
Jack Friedman	Moorestown, New Jersey	224-2112

National Broadcasting Company (NBC)

*Bob Mausler	New York, New York	324-4869

Patent Operations

George Haas	Princeton, New Jersey	226-2491

RCA Communications

American Communications

		TACNET
*Murray Rosenthal	Princeton, New Jersey	258-4192
Carolyn Powell	Princeton, New Jersey	258-4194

Global Communications

*Dorothy Unger	New York, New York	323-7348

RCA Inc. (Canada)

Bob McIntyre	Ste Anne de Bellevue	514-457-9000

RCA Laboratories

Eva Dukes	Princeton, New Jersey	226-2882

RCA Records

*Greg Bogantz	Indianapolis, Indiana	424-6141

RCA Service Company

*Murray Kaminsky	Cherry Hill, New Jersey	222-6247
Dick Dombrosky	Cherry Hill, New Jersey	222-4414
Ray MacWilliams	Cherry Hill, New Jersey	222-5986

"SelectaVision" VideoDisc Operations

*Nelson Crooks	Indianapolis, Indiana	426-3164

Solid State Division (SSD)

*John Schoen	Somerville, New Jersey	325-6467

Power Devices

Harold Ronan	Mountaintop, Pennsylvania	327-1633 or 327-1827

Integrated Circuits

Dick Morey	Palm Beach Gardens, Florida	722-1262
Sy Silverstein	Somerville, New Jersey	325-6168
John Young	Findlay, Ohio	425-1307

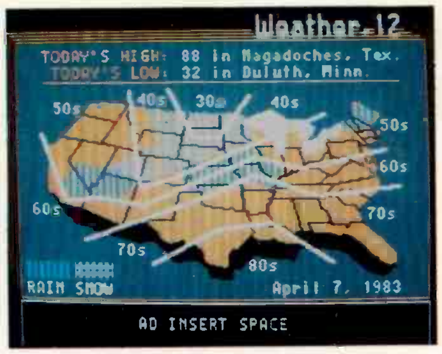
Electro-Optics and Power Devices

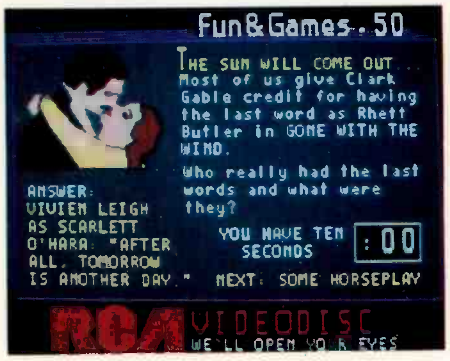
John Grosh	Lancaster, Pennsylvania	227-2077

Video Component and Display Division

*Ed Madenford	Lancaster, Pennsylvania	227-3657
Nick Meena	Circleville, Ohio	432-1228
Jack Nubani	Scranton, Pennsylvania	329-1499
J.R. Reece	Marion, Indiana	427-5566

***Technical Publications Administrators, responsible for review and approval of papers and presentations, are indicated here with asterisks before their names.**





Brian Astle's article on page 16 contains specific information about these teletext pages.

RCA Engineer

A technical journal published by
the RCA Technical Excellence Center
"by and for the RCA engineer"

13 Roszel Road, P.O. Box 432, Princeton, NJ 08540
Address correction requested

EJ NOSSEN
203 ELKINS RD
CHERRY HILL
NJ 08034
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Printed in the U.S.A.
Form No. RE-28-5