RCA Engineer

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NBC's engineering role

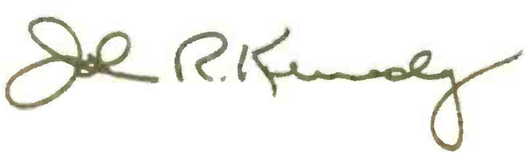
The primary task of NBC, as part of the RCA family, is to provide high quality network broadcasting service to a national audience. To support this effort, there must be a strong engineering and technical staff employing the newest and best in communications technology.

The history of NBC Engineering has been one of continuing leadership in technological improvements since the early days of radio and over the full span of television broadcasting. NBC engineers played a major role in launching monochrome television in the 1930s and 1940s, and color television in the 1950s.

NBC pioneered in the automation of television operations and developed the first completely automatic television station, WBUF-TV, Buffalo, New York, in 1956. Automation of NBC studios at WRC-TV in Washington, DC, followed. And in 1967, the first automatic, computer-controlled television network facility was completed in Burbank, California, controlling NBC's West Coast operations.

With this engineering expertise and experience, and with significant software contributions from the RCA laboratories, automation and computer control of the entire NBC Television Network was begun in 1969 and completed in 1974.

The papers in this issue describe in detail the most modern and complex switching and control television system in the Americas and are an excellent example of NBC's pioneering tradition in broadcasting.



John R. Kennedy
Vice President
Operations and Engineering
NBC Television Network
New York, N.Y.

Our Cover

. . . features Switching Central—the main operating area of NBC's new automated Television Central system at the New York studios. Various aspects of Television Central are described in several papers in this issue (pp. 2-45). Shown in the photo are Switching Central operators Dave Hubby (foreground) and Robert Waring (in booth) along with NBC Engineers Bill Howard (at keyboard) and Bob Post.

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RCA Engineer

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

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NBC Television Central—an overview

F.L. Flemming

Large television centers are becoming more common throughout the world. While the design of individual studios and associated control rooms within such centers can be dealt with based on past experience, the routing and ultimate release-to-air of numerous individual signal sources within the center take on a special dimension due to the inherently large system. Rebuilding around an ongoing operation within an existing structure strongly influences the final design. A review of existing operating practices suggests many possibilities for improvement from a human-factors viewpoint. The final scheme includes the use of a large audio-video routing apparatus, a multichannel computer-contolled release studio and numerous remote-control subsystems. Automated program schedule preparation and flexible voice communications play important roles in the completed system.

Frank L. Flemming, Vice President, Engineering NBC Television Network, New York, received the BSEE from the University of Buffalo in 1949 and spent several years with Sylvania Electric Products in production engineering work for television consumer products and designing television broadcast equipment. In 1954, he joined the CBS Television Network doing equipment and systems design work. In 1964, Mr. Flemming became Director of Plant Systems Engineering for CBS and was responsible for numerous broadcast systems engineering projects at the network and its owned stations. In 1967, he went with Visual Electronics as its Chief Engineer and was responsible for the engineering and manufacturing of a broad line of broadcast equipments. In 1969, he joined NBC in his present position and is responsible for the design and installation of all major technical systems at the network and the owned station's studio plants. Mr. Flemming is a member of the Audio Engineering Society and IEEE and a Fellow of the Society of Motion Picture and Television Engineers.

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LARGE TELEVISION CENTERS have evolved over the years to include numerous production studios, telecine equipments, video tape machines, master control for audio and video, incoming and outgoing audio and video circuits, viewing rooms, equipment rooms and other necessary television technical services. At NBC's New York plant, Television Central coordinates these relatively independent technical areas to assure smooth and efficient release of program signals to the NBC Network and to the WNBC-TV transmitter.

Since the inception of television networking in the late 1940s, this coordination need has grown by leaps and bounds, due to the pressures of a rapidly expanding industry—further complicated by the introduction of color and video tape. As production efforts have become increasingly sophisticated, the number and variety of equipment required to service them have grown at a startling rate. As an example, the original NBC video tape room at NBC New York was designed for a maximum of six video tape machines; it currently has thirty-four.

Production studios have always had dedicated live cameras, and they must be supported by video tape, telecine, and remote signals.

A kind of routing system using manual patchcords was developed over the years to feed these signals to the studios. In a large plant (like NBC) this system became very unwieldy from an operational point of view.

This problem became obvious over ten years ago, and a large capital investment would have been necessary to improve the situation strikingly. However, other capital demands caused the central plant modernization to be deferred. For example, starting in the early 1950s, NBC became the pioneer color television network and invested heavily in color image-orthicon cameras. In the 1960s, plumbicon cameras and highband video tape machines required yet another large capital investment.

Nevertheless, preliminary planning for the new NBC Television Central was going on through the 1960s. Concentrated planning began in 1969 and culminated in a new facility going on-air on October 8, 1974.

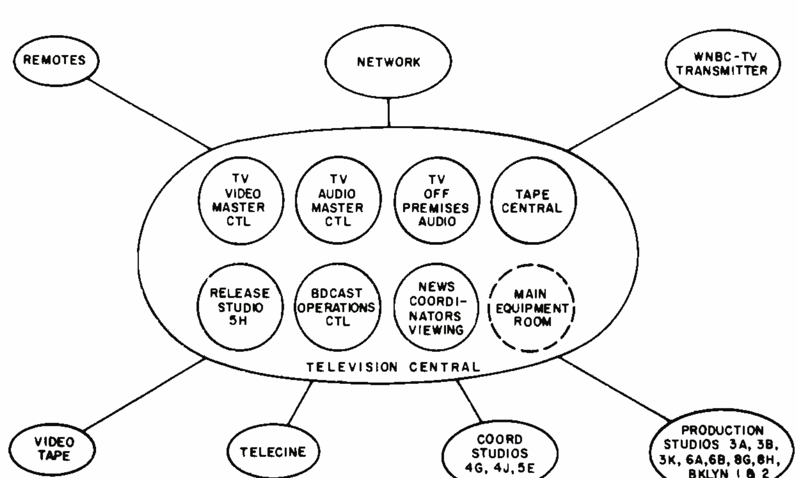


Fig. 1 — Technical area relationships in the NBC New York plant existing before the Television Central modernization.

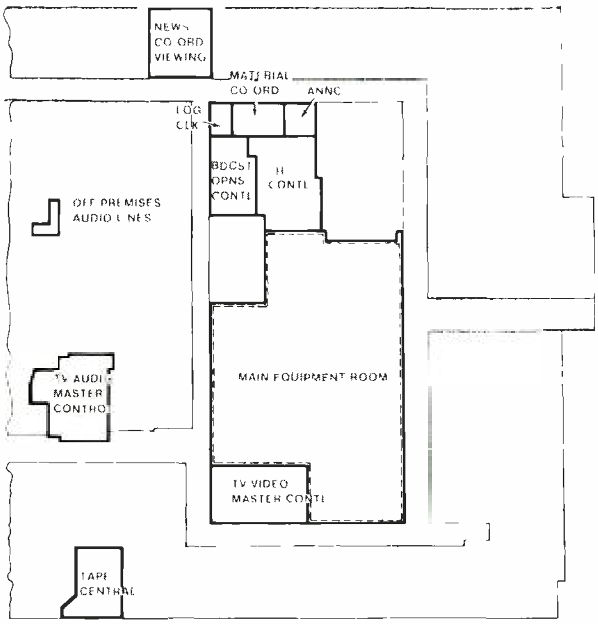


Fig. 2a — Television Central floor plan before rebuilding. This is the fifth-floor studio section, west end.

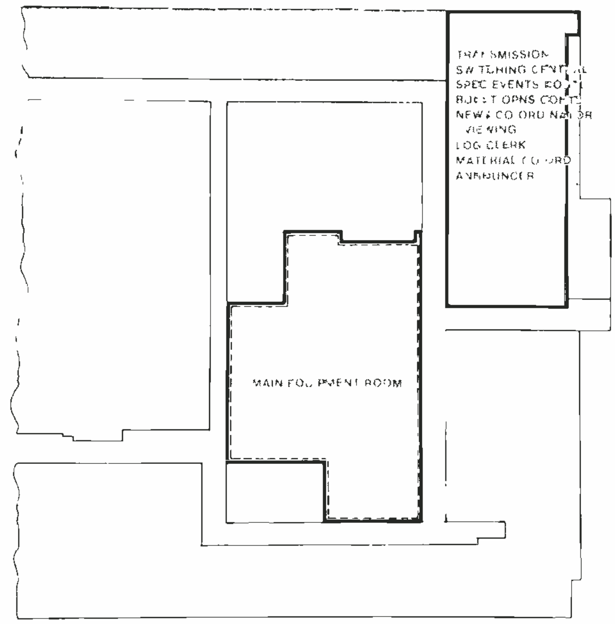


Fig. 2b — New Television Central Plan. This is also the fifth-floor studio, west end.

Previous system

As part of the planning effort, the relationships among various technical areas were analyzed. As an aid to understanding system needs, the large oval in the center of Fig. 1 was identified as Television Central. This oval contained all the functions necessary for routing signals entering and leaving the plant as well as those within the plant. Television Central is also responsible for monitoring and final release of these signals to air. At that time, essentially all of the functions inside the large oval were in separate geographical areas within the building, as shown in Fig. 2a. The outer ellipses (Fig. 1) contain free-standing functions such as production studios and video tape and telecine machines; there was no need nor plan to rebuild them.

It is interesting to note that the audio and video master controls were in separate rooms, a happenstance of early growth. In fact, the audio master control was the original radio master control of 1932, a compliment to early designers.

Both off-premise and intra-plant video and audio signal routings were accomplished by manual patching (see Fig. 3). The rapid growth of these systems unfortunately contributed to operating errors as well as inefficient use of manpower. An analysis of the previous signal-routing functions is shown in Fig. 4a; it may be charitably described as unwieldy in view of the heavy traffic demands.

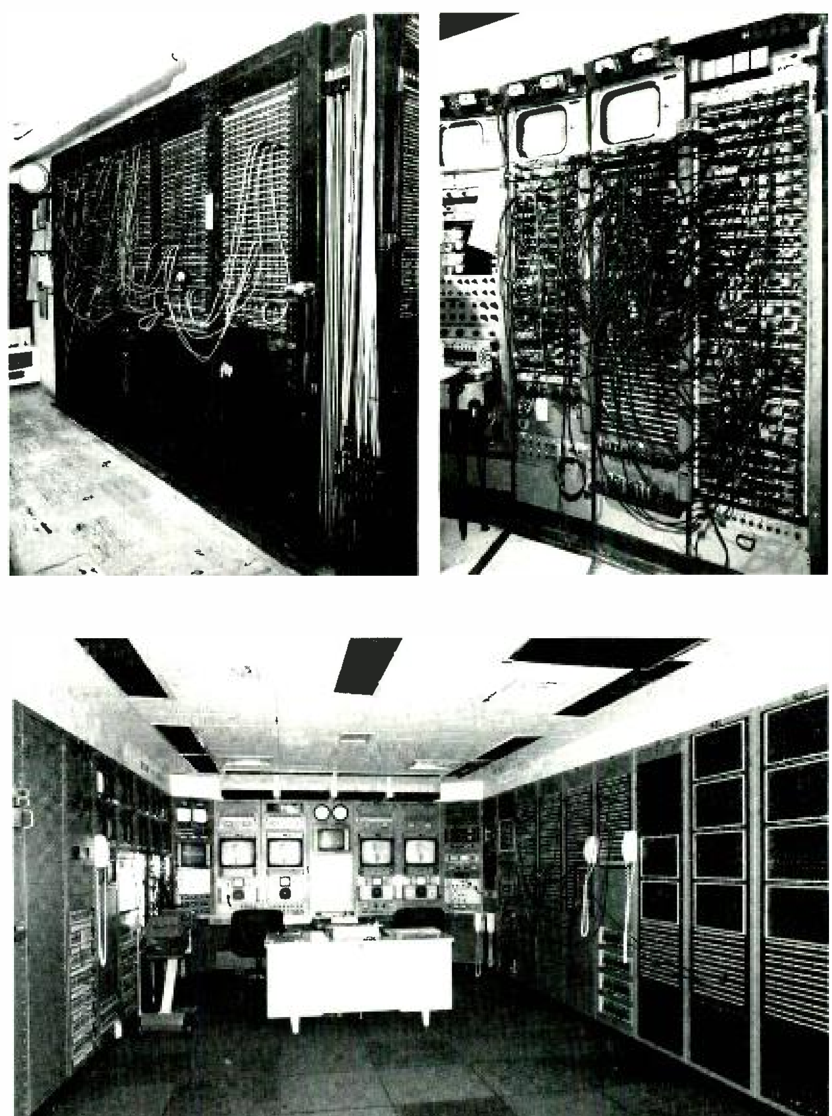


Fig. 3 — These photos compare the old master control patching bays for video (above left) and audio (above right) with the new audio and video transmission center (below).

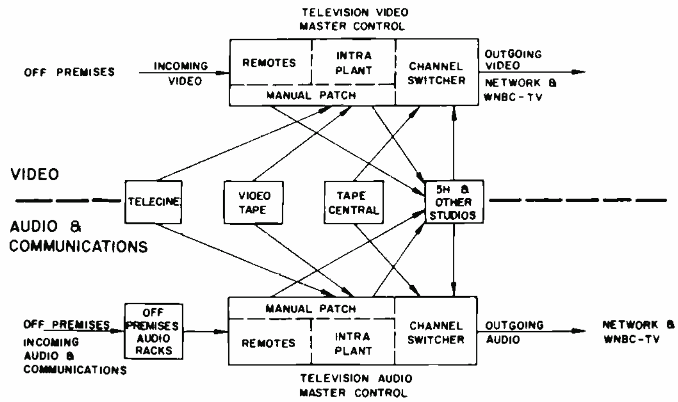


Fig. 4a — Signal-routing in Television Central before modernization.

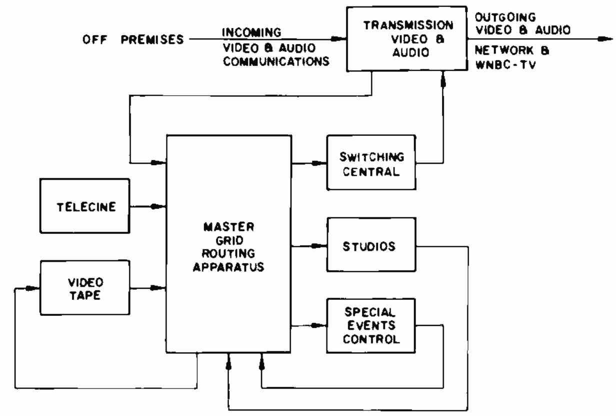


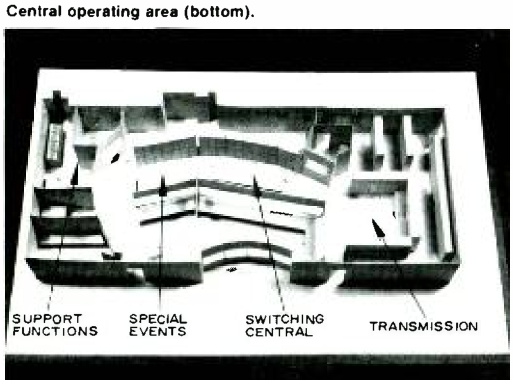
Fig. 4b — Signal routing scheme for new Television Central.

New system

After considerable study, a new signal routing scheme was developed. In this scheme (Fig. 4b), all intra-plant routing is done through a master-grid routing apparatus. The master control functions have become *transmission*, whose only concern is the routing and processing of signals entering and leaving the plant. The program release function is done by Switching Central, supported by automation.

The routing apparatus has been located in the centralized equipment room while the operating area of Television Central consists of transmission, Switching Central, and special events control (a coordinating studio). This new Television Central operating area places all of the functions shown inside the large oval of Fig. 1 (except the main equipment room) into a single facility, designed for optimum operating ease and communications. The new Television Central area layout is shown in Fig. 5; a photo of the area is shown in Fig. 6.

Fig. 5 — Television Central model (top). Fig. 6 — Switching Central operating area (bottom).



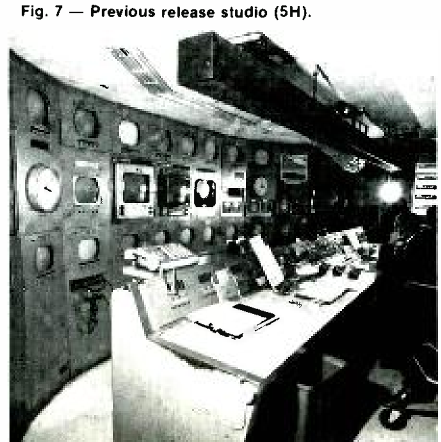
Master grid

The main body-bolt of this new approach is the large audio-video master-grid routing apparatus. This is a 100-input 320-output video device, capable of carrying four audio signals accompanying each video signal. Additionally, data and diagnostic signal paths are included for each video path.

The four channels of audio, plus the data and diagnostic signals, are placed on rf carriers using a balanced phase-modulation technique. They, and the baseband video signal, are routed through the same switch point.

Large-scale baseband audio routing switchers have been available for many years and are dependable. However, it has taken recent technology to allow a video switcher of this size to be built with truly desirable signal characteristics and dependable performance. This master grid performs not only the intra-plant signal routing function but provides the base mechanism for a most flexible, multi-channel release studio—Switching Central.

Fig. 7 — Previous release studio (5H).



Switching Central

Release studios came into being almost with the beginning of television broadcasting. Their function is the final coordination and switching of all video and audio program elements, including commercials, that make up the final complete program released to air. They have no production stage of their own.

Over the years, the switching function has been automated. NBC's first system was in Buffalo (WBUF-TV). It used mainly relay logic and went on the air in 1956.

Heretofore, release studios have had a one-output capability and, sometimes, two. Switching Central[1] has been designed with an initial capacity of six simultaneous output channels, expandable to ten. The previous release studio (5H) was a quasi two-output studio supported by very limited relay logic automation. The new operating area is shown in Fig. 6 and may be compared with the old release studio (5H) in Fig. 7.

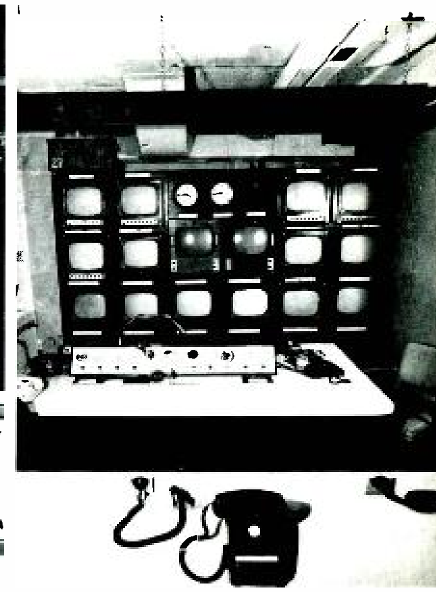
Automation

Each Switching Central channel is supported by a minicomputer with 32,000 (16-bit) word core memory supplemented by a disc of 2½ million words memory.[2] Two "steering" minicomputers can each address any of the six channel computers for information loading and data retrieval needs.

A typical output channel may have approximately 1200 switching *events* per day and is designed for a peak load of 2000 events. Each computer is loaded daily, for the switching events of that day.

Special-events control

Special-events control is a coordinating studio designed for operation by one technical person (see Fig. 8). Typically, the studio is used for the coordination of sports events such as football games and for the viewing of numerous incoming remote signals for news purposes. The old viewing area may be seen in Fig. 9.



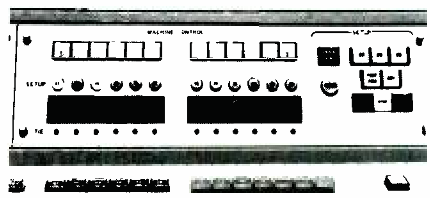


Fig. 8 — Special-events control. (above).

Fig. 9 — News coordinator's viewing room (above right).

Fig. 10 — Studio machine control panel (right).

Transmission

The transmission area monitors and processes all incoming and outgoing video, audio, and production communication circuits.[3,4] Further, it is the communication center for affiliates and common carriers that send signals to, or receive signals from, NBC New York.

Machine control

A total of over fifty video tape and telecine equipments are available to all control rooms including switching central. Remote control of the transport of these devices is routed to the Control Room so that the Technical Director may start the devices at the appropriate time to allow smooth coordination among program elements.[2,5] In the case of telecine equipments, control of the multiplexer (a mirror flipping device which routes projector optical signals to an individual television camera) is also extended to the control rooms. In the most complex case, some fifteen control and tally functions are extended for each equipment. At any one point in time, in order to avoid conflicts, only one control room may have "control" of such equipment.

"Cooper-connected" assignment of all the control and tally functions would result in a large simultaneous multi-level routing device. While this has been done successfully in the past, such a cumbersome technique is no longer necessary. Multiplexing of these commands using a data stream technique has been employed by NBC. As a result, the routing mechanism becomes much simplified.

One may be tempted to propose using the master grid as the routing apparatus for machine remote control. Upon analysis, this in not practical. The master grid is basically a one-way street, routing signal sources to end users. Further, it is a "bridging" device in that all end users may simultaneously select any single source. On the other hand, assignment of remote machine control is bidirectional (controls and tallies) and is "unique" in that only one end user is allowed to control the device at any given time.

An independent routing system has been developed for remote machine control. A selection is made at the sending end (machine end) as to which studio may control it. In the control room (the end user), a particular machine is selected and placed on a particular video switcher input. This selection is not only for remote machine control but also audio and video. Once this selection is complete, actual operation is accomplished through a machine control panel (see Fig. 10).[5]

Time-base systems

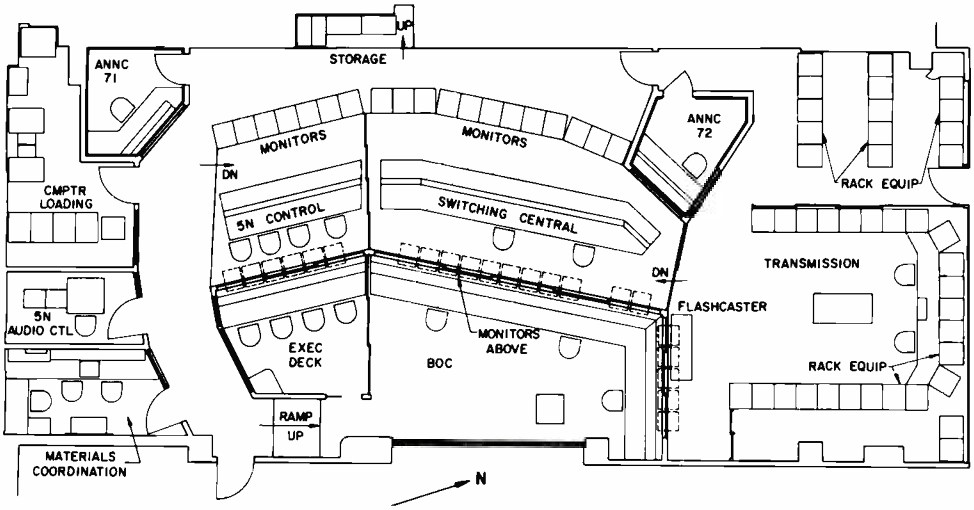
In order that dissolves, split screens, and undisturbed direct switches may be made between and among signal sources, the signal sources must be driven from the same time base. After careful consideration, a system was developed which allows this to be accomplished automatically or manually, as required. The key in allowing a simplified operating procedure was the decision to assign a sync generator to each and every program signal source. This includes all video tape, telecine and live camera equipments.

Genlocking or sync-locking of sync generators to an external source is not new. Nevertheless, care must be taken with the particular application at hand. A hard, fast lock is desirable when switching rapidly to different time-base references (external signals). Yet, any time-base errors in the external signal should not be amplified but rather, "smoothed out" if at all possible.

The foregoing has been accomplished with a special sync generator. The routing apparatus for the reference time-base signal is simply a video switcher and, in fact, the reference signal is video. By appropriate control interlock systems, when a machine assigns itself to a control room, it has the option of automatically locking to the same time base as that control room.

Communications

Despite all the sophistication of technical equipment, a television plant is still operated by people. Within the confines of individual control rooms, person to person communications have many avenues, both aural and visual. Speaking, shouting, tapping, hand signals and facial expressions all play a part. The new Television Central area layout was designed to allow optimum people-to-people communication (Fig. 11). Program element contributors remote from the control room must depend, for the most part, on aural signals over some kind of electronic communication system, and several of these are advisable for maximum effectiveness.[6]



NBC
TELEVISION CENTRAL

Fig. 11 — Layout plan showing special relationships of various areas.

Communication between the control room and cameramen is typically by an interphone system—that is, an earphone and carbon-microphone type combination. Communication from the control room to other locations may be by this same interphone type system, or a microphone-loudspeaker system, or by traditional telephone.

Often, when working with off-premise locations (remotes), a return "cue" circuit is provided to the remote location so that they may listen to the final program for continuity purposes. On command, this cue feed is interrupted for instruction information from the control room.

Yet another communication aid has been devised in the form of a "mix-minus" system. Here, with contributions from multiple off-premise sources to the program content, circuits have been devised which allow each contributor to hear all others, except himself, over a loudspeaker without unwanted acoustical feedback.

Computer-assisted maintenance procedures

In a large signal-routing apparatus such as the master grid, which is complemented by the machine-control routing system, the number of signal-path combinations approaches 196,000. Further, the command and information paths required to achieve these "connections" are numerous and must be appropriately tested. A manual approach to these combinations is unwieldy. Unique software as well as hardware testing procedures have been developed to make maintenance procedures practical. The value of these procedures cannot be underestimated. A sophisticated plant must continue to operate fully and properly if a reasonable return on investment is to be expected.

Automated program-schedule preparation

The instructions that define which devices are to be used in the composition of all programs in any 24-hour day are printed on a single document which is called a *routine*. Last-minute changes in program material and the availability of equipments make this task a demanding exercise in tactics rather than strategy. Mechanical aids play a most important part, and a logical development has been the use of a "business type" large mainframe computer as a manipulative tool to juggle the contributing pieces of information. Not unexpectedly, an important piece of information into the "main frame" is last-minute changes in sales requests. An example would be a sale one hour before air time which would preempt a non-paying insert.

Future needs

The Master Grid routing apparatus was the most expensive individual piece of equipment developed for Television Central. It was designed with a 15% spare input capacity. As of 1976, all of this spare input capacity has been used. Expansion of the system in the next two years may well be in order. The recent explosion in the area of Electronic Journalism and its requisite special video tape recorder was unexpected. This and continued video tape expansion have taken the biggest share of spare input capacity. We look at this dilemma as a positive indication of a dynamic and growing business.

The automated Switching Central release function with its attendant records of actual switching activity present a possibe opportunity to speed up the billing systems to various customers and help shorten a cash flow activity.

Conclusion

A new Television Central has been designed, constructed and is successfuly on-air. The bulk routing of video and audio signals is done by a large apparatus supported by several complementary systems that are required to make the concept practical. These include communications (with three subsystems), machine control, transmission, time base and minicomputers (including software).

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NBC Switching Central

R. Edmondson| R. Post

Switching Central is a multichannel computer-controlled facility which provides for the final monitoring, switching, and control of all Network and local television programming originating in NBC New York. The system is designed to support ten simultaneous channels and is presently equipped for six. All channels are identical and designed to be free standing and functionally independent of one another.

Robert D. Post, Senior Staff Engineer, NBC Engineering, New York, N.Y., received the BSEE in 1949 from New York University and did graduate work in digital design and computer programming at Columbia University. Following graduation, Mr. Post joined NBC as a Television Studio Engineer. In February 1951, he was appointed to the NBC Color-TV Task Group as a color video engineer. In 1957, he worked on a relay-realized computer and interface for use as a real-time control device for the first fully automated television station, NBC's WBUF in Buffalo. In 1958, he worked on a multiple-studio control television automation system, again using relay-realized computers, for NBC's WRC-TV plant in Washington. In 1961, he became Project Engineer for Burbank Switching Central, the first real-time multiple-channel television automation system with all-core-computer control, which became operational in 1966.

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Final manuscript received February 24, 1976

Richard H. Edmondson, Mgr., Communications System Planning and Operations, NBC, New York N.Y., received the BS in Physics from Yale University. Before assuming his present responsibilities, Mr. Edmondson was Senior Staff Engineer at NBC for the past two years in the Technical Development Department. He has worked for either NBC or RCA for the last 25 years. He joined NBC in 1951 as a Facilities Engineer. He moved to RCA in 1961 to work on the development of TV Automation Systems for the Broadcast Division. In 1963 he was assigned to plan, install, and operate the color television studios of the RCA Exhibit at the New York World's Fair. He joined the Staff of the Executive Vice President, Research and Engineering, in 1964, and worked with the Engineering and Marketing Departments of the Computer Systems, Memory Products & Solid State Divisions as well as RCA Ltd., Canada. He was named Consultant, Advanced Technology, by the President, Systems Development, Computer Systems, in 1971, and in 1972 became Manager, Systems Development, Broadcast Systems, a position he held until he rejoined NBC in 1974.

At NBC in New York, most of the daily programming requirements are handled by two channels, one for the NBC Network and one for WNBC-TV, our Local Station in New York City. The four remaining Switching Central channels are used for special network services or to "back up" the local or Network channels. They can also be used to provide automatically scheduled viewings of programs for clients, or as automated "pre-assembly" facilities.

The ten pages that follow cover a brief span of time at NBC in New York, showing the essence of the Switching Central operation and the structure of its system. From this brief examination, it should be clear that the designer's of Switching Central have met their design goal: to provide NBC with a modern facility where operational simplicity and flexibility are optimum.

Author's note:

Bob Post, a primary engineering force throughout the Television Central project, died on March 3, 1976.

Bob's ceep interest in science, art, and philosophy provided an excellent foundation for his strong desire to find applications for new technologies in television broadcasting and to simplify the man-machine interfaces of television switching and control systems.

Bob was a brilliant, sensitive, and unique individual. Knowing him as a friend and fellow worker for 25 years formed a very meaningful part of my life and I value the opportunity to co-author this paper.

A day at NBC Switching Central

It is 11:20:04 a.m., Tuesday, a typical weekday at NBC Studios in New York. Operational activities are underway in a variety of technical areas.

Live Studio 3K: The "Today Show" ended about an hour and a half ago, and the set has been rearranged for the "Nightly News." Rehearsals will start around 4 p.m. The program will be fed automatically to the Network by Switching Central at 6:30 p.m.

Live Studio 3A: The studio lights are *on*, the crew and cast are ready to rehearse and video tape the "Doctors." About a week later, the tape will be played to the Network automatically by Switching Central.

Video tape: A pair of video tape machines assigned to Switching Central are playing identical copies of "Wheel of Fortune." One is on-the-air to the NBC Network, the other is a fully redundant backup called *Protection*.

Other video tape machines are assigned to Studio 3A to provide program segments for the "Doctors" and to record the show.

Video cartridge machines: VC-33 & VC-34 are being loaded with identical copies of the next 22 commercials scheduled for the Network.

The operator is checking to be sure that their *start* controls are properly assigned and available to Switching Central so that they can be "rolled" automatically.

VC-31 is loaded with the station-break commercials required by the local station, WNBC-TV.

Telecine: The slide projector on film chain 54 is loaded with WNBC-TV's station identification slides. The **slide change** control circuit has been made available to Switching Central.

Master Grid: A problem with input 77 has been reported, and maintenance personnel in the central equipment room are checking it.

The Master Grid is a video, audio, and data switching matrix. It has 100 video inputs and 320 outputs. Four audio inputs and one data input are multiplexed with each video input. Each data input is fed by an individual code generator that repeatedly transmits an 8-bit identification code. The data code appearing at each of the 320 outputs identifies the input that is connected to it. The channel computers test these codes to **verify** that the inputs they select are properly energized. Failure to **verify** is logged by the channel computer and the Switching Central operator is alerted. Of the 320 outputs 30 are comptuer controlled, 5 for each of the 6 Switching Central channels.

Transition and effects systems: The signals now "on-air" are routed through **video and audio special effects systems,** which are awaiting computer commands to change or modify the programs.

Each Switching Central channel is equipped with a video and audio transition and effects system controlled by the Channel Computer. The **Video** transition and effects system can execute dissolves and inserts. The **Audio** transition and effects system can execute crossfades, audio-over, and audio-level selection.

Channel Computers: Second-by-second, the channel computers are checking five minutes ahead to gain control of the "rolling devices" needed for the next program segment. In the central equipment room, six identical channel computer systems are controlling events going "on-air" to the network and local station.

Each computer system's disc memory is loaded with the routine that it is scheduled to execute automatically throughout the day. The disc has sufficient capacity to store two days of **events** including two alternate sequences. The core memory contains a copy of the next 20 events. As each event goes "on-air," a new event is moved from disk to core. The software system is completely core resident, so that the channel computer can continue to operate even though its disc has failed. If the software system detects that its disc has failed, it sends a message to each of the keyboard computers. One of them will automatically replenish the core-event file as events go on the air.

MACHINE STATUS AND CONTROL

Transmission: The operator has patched video and audio signals from the Network channel into Master Grid input 90 for the local station's use, since input 77, normally used for the Network, is under test and was taken out of service.

Switching Central: When the problem with Master Grid input 77 (NETT-77) developed, the Switching Central operator used the keyboard to **modify** the *routine* for the local station. He substituted the source "REM-90" for all references to "NETT-77" by using a **special function** called **source substitution.**

The Switching Central control room permits centralized monitoring and control of all channels.

An array of television monitors, read-out displays, status indicators, waveform monitors, and audio-level meters is arranged in 12 monitor housings creating a "status display wall" in front of the operating console. The center six racks are the channel monitor housings. They are identical in layout and provide monitoring and status for each of the six channels.

Additional monitors, waveform monitors and audio vu meters are incorporated in the console along with a variety of control panels, status indicators, data displays and computer-control keyboards.

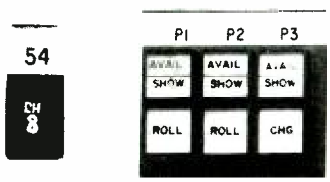
Manual control

Film and tape status and control: The film and tape status and control panels provide the operator with the capability to manually control this equipment. The panels for film and tape are located above the channel panels. They show the operator which devices are currently assigned and available to Switching Central. Only those devices that are available can be controlled automatically by the computers or manually by the operator.

VIDEO CARTRIDGE

TELECINE

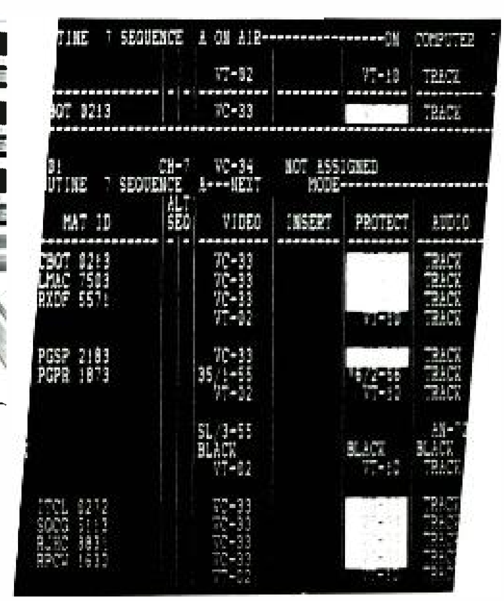
VIDEO TAPE



Status: **Roll** status is displayed at all times. **Show** status (multiplexer) is displayed at all times. **Avail** is displayed whenever a film or tape is assigned to switching central and in remote. **Computer assignment** is displayed at all times and indicates the channel computer to which status and control circuits are connected.

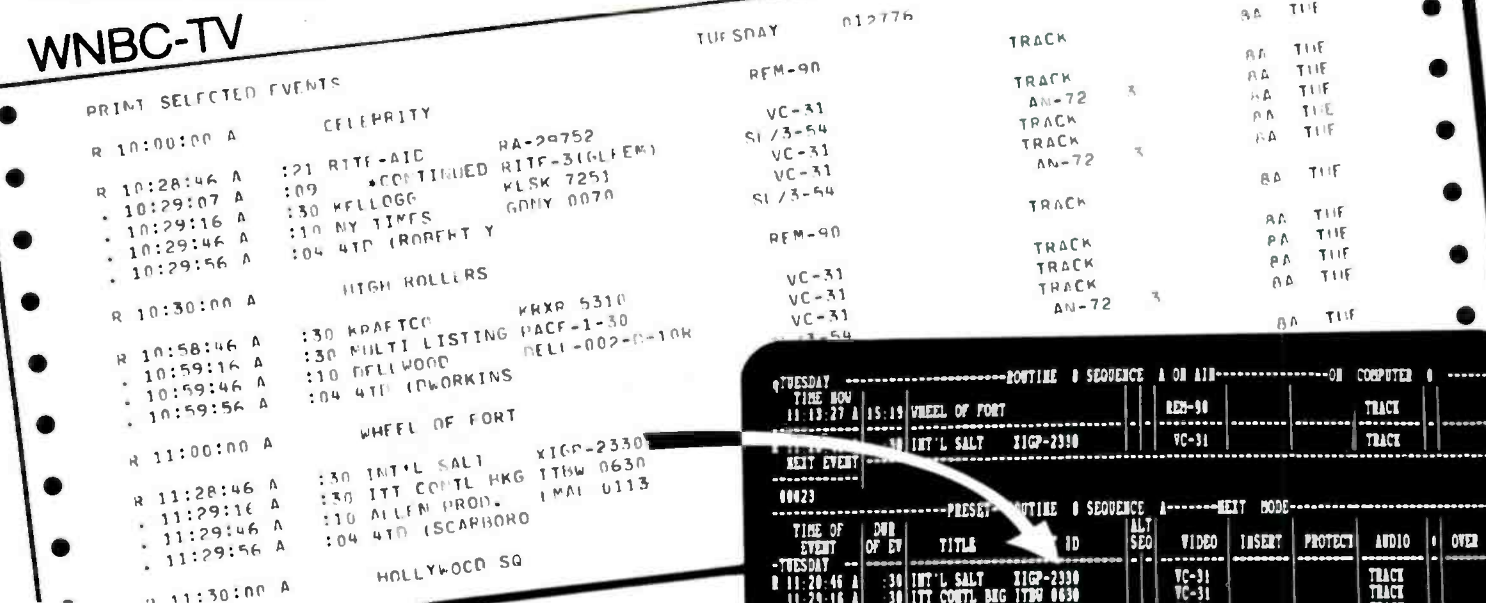
Control: **Roll** buttons are enabled when the **avail** tally is lit and may be used, in emergency situations, to manually start the film or tape. Operating the **roll** button associated with a video cartridge machine, while the current cartridge is rolling, will start a 5-second countdown after which an automatic switch to the next cartridge in the sequence will be executed. **Chg** (change) buttons are enabled when the **avail** tally is lit and may be used to manually change **slides.** The multiplexer can be controlled by the **show** buttons whenever the film chain is assigned to Switching Central and the multiplexer is in remote.

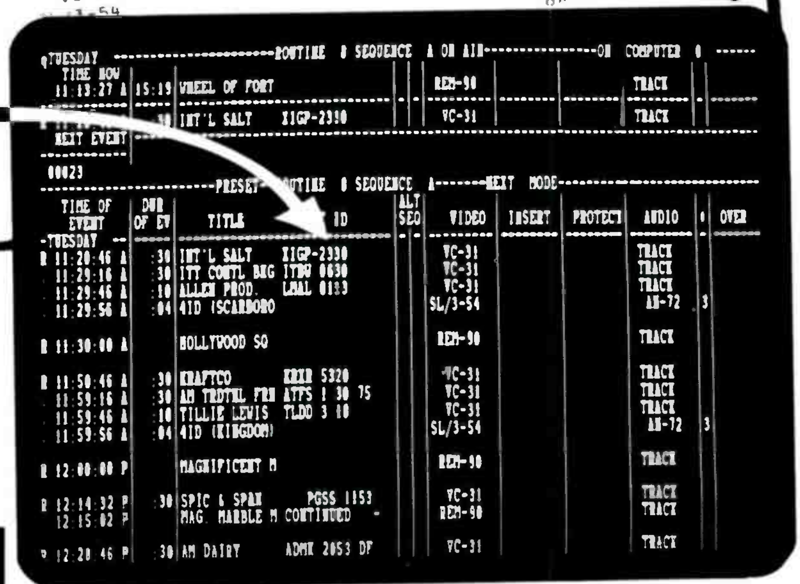
Computer assignment: May be manually controlled at all times, by pushing a computer assignment button repeatedly until the desired channel computer number is displayed. Normally computer assignment changes are automatically handled by the various channel computers.



Break-in system for manual control: News bulletins, some special events, and emergencies require manual control, independent of the computer systems. A video and audio **break-in** control control panel permits the operator to preselect one of the 100 sources feeding the master grid and switch it to one or more of the six channels.

Local routines for WNBC-TV are typical of many television stations. "Station breaks" are scheduled in between Network programs. They include commercial announcements and the station identification.





Looking at the data display for channel 8, we see that the time is 11:13:27 a.m. and we have 00:15:19 remaining of the program *Wheel of Fortune*. REM-90 indicates that the Network programs are now feeding master grid input 90. **Track** means that the source of audio comes from the same source that is supplying the video. Each second we will see the time increment and the duration decrement.

The station break is scheduled to start at 11:28:46 a.m. with a 30-second commercial for International Salt. The material identification number (MAT ID) is :XIGP-2330 and identifies the specific commercial that the sponsor wishes to have played at this time.

Video cartridge machine (VC-31) is scheduled to play this commercial. **Int'l Salt** is followed by two additional cartridges, 30 and 10 seconds each. A slide on film chain 54 will show the **channel 4** identification for 4 seconds. The audio for the slide will be provided by the live announcer on input AN-72. The station break will take 1 minute, 14 seconds and will end at 11:30:00 a.m., just in time to switch back to the Network for the program *Hollywood Squares*.

At the top of the channel-8 monitor housing the computer readout indicates that the time of day is 11:12:20 a.m. It confirms that the next event is scheduled for 11:28:46 a.m. and will be a switch to VC-31.

The top color monitor shows the program *Wheel of Fortune* which is being sent to the WNBC-TV transmitter, where it is broadcast locally. The readout below the program monitor identifies the video and audio sources.

The monitor below the program monitor has several uses. In this case, the computer has turned on the sign **PST A**, which means that the picture on the monitor is coming from the source that is "preset" to be switched on-the-air **next.**

The picture on the preset monitor includes a **source identification** as well as sponsor's **material identification** numbers for the next two commercials loaded in the cartridge machine.

The **source identification** (TCR-31) certifies that the video is coming from the proper source. These signals are inserted electronically into the video paths at each video tape, video cartridge and film source prior to feeding the inputs to the master grid.

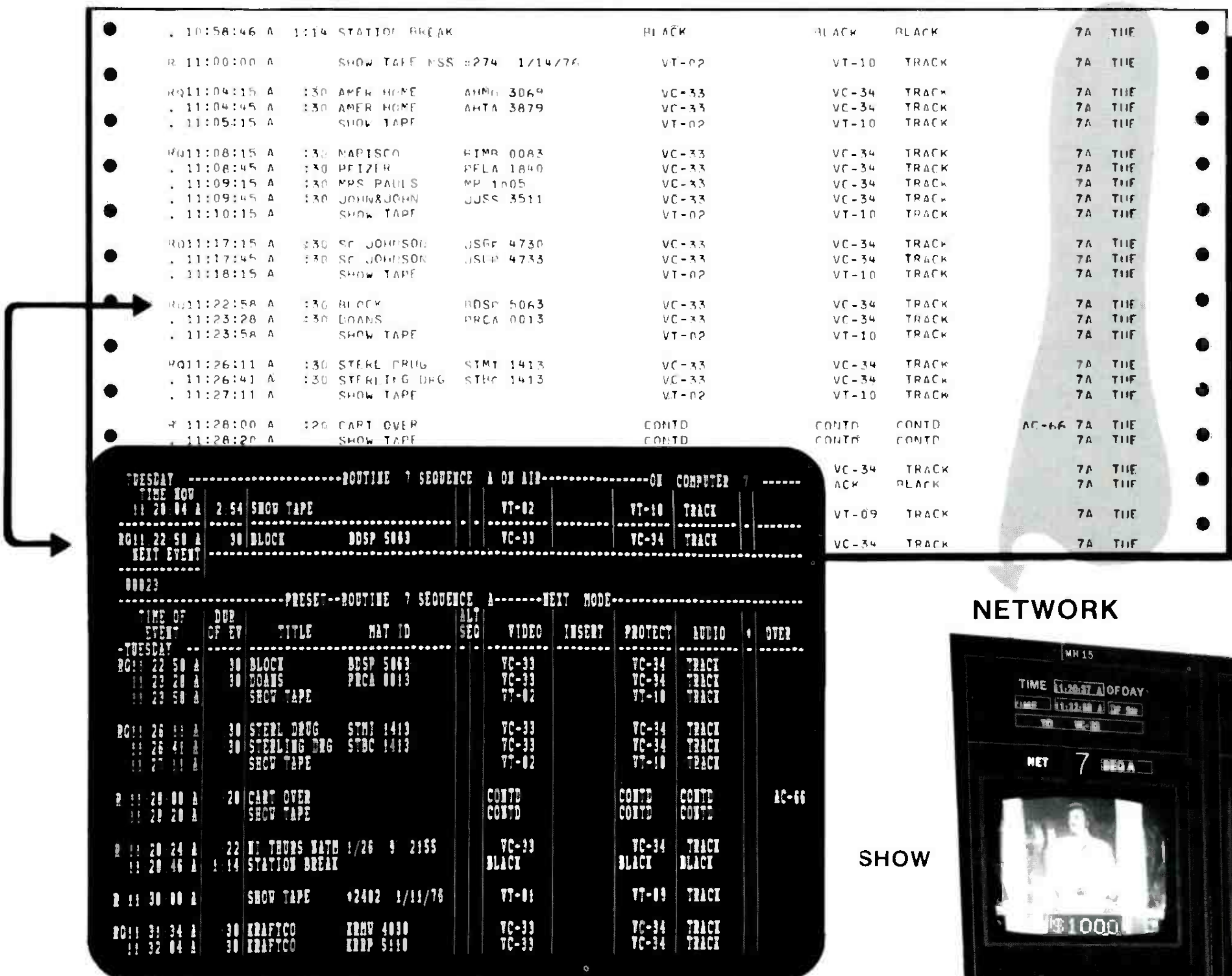
Material ID's are only generated on video cartridge machines. Prior to being started, a video cartridge machine will pre-load two cartridges and the material ID codes recorded on each are detected by an RCA device called EPIS (Electronic Program Identification System) and inserted in the video path at the source. All of these identification signals are removed from the video when the cartridge in it is rolling.

The computer readout below the preset monitor identifies the video and audio sources that will be **next** and duplicates the information displayed on the preset line of the data display.

11:20:04 a.m. — 2 minutes, 54 seconds to switching time: Separate operating routines are prepared for each day's programming requirements for the Network and local stations. The routines define the sequence of events scheduled for each channel.

Each *event* line on the routine identifies the *program segment* or commercial announcement involved, specifies the video and audio *sources* to be switched on-the-air, the *time* the switch should occur, and in many cases, the *duration* of the event.

Network routine



. 10:58:46 A	1:14	STATION BREAK		BLACK	BLACK	BLACK		7A	TUE
R 11:00:00 A		SHOW TAPE NSS #274	1/14/76	VT-02	VT-10	TRACK		7A	TUE
RO11:04:15 A	:30	AMER HOME	AHMO 3069	VC-33	VC-34	TRACK		7A	TUE
. 11:04:45 A	:30	AMER HOME	AHTA 3879	VC-33	VC-34	TRACK		7A	TUE
. 11:05:15 A		SHOW TAPE		VT-02	VT-10	TRACK		7A	TUE
RO11:08:15 A	:30	NABISCO	BIMB 0083	VC-33	VC-34	TRACK		7A	TUE
. 11:08:45 A	:30	PFIZER	PFLA 1840	VC-33	VC-34	TRACK		7A	TUE
. 11:09:15 A	:30	MRS PAULS	MP 1005	VC-33	VC-34	TRACK		7A	TUE
. 11:09:45 A	:30	JOHN&JOHN	JJSS 3511	VC-33	VC-34	TRACK		7A	TUE
. 11:10:15 A		SHOW TAPE		VT-02	VT-10	TRACK		7A	TUE
RO11:17:15 A	:30	SC JOHNSON	JSGF 4730	VC-33	VC-34	TRACK		7A	TUE
. 11:17:45 A	:30	SC JOHNSON	JSLP 4733	VC-33	VC-34	TRACK		7A	TUE
. 11:18:15 A		SHOW TAPE		VT-02	VT-10	TRACK		7A	TUE
RO11:22:58 A	:30	BLOCK	BDSP 5063	VC-33	VC-34	TRACK		7A	TUE
. 11:23:28 A	:30	DOANS	PRCA 0013	VC-33	VC-34	TRACK		7A	TUE
. 11:23:58 A		SHOW TAPE		VT-02	VT-10	TRACK		7A	TUE
RO11:26:11 A	:30	STERL DRUG	STMI 1413	VC-33	VC-34	TRACK		7A	TUE
. 11:26:41 A	:30	STERLING DRG	STBC 1413	VC-33	VC-34	TRACK		7A	TUE
. 11:27:11 A		SHOW TAPE		VT-02	VT-10	TRACK		7A	TUE
R 11:28:00 A	:20	CART OVER		CONTD	CONTD	CONTD	AC-66	7A	TUE
. 11:28:20 A		SHOW TAPE		CONTD	CONTD	CONTD		7A	TUE
					VC-34	TRACK		7A	TUE
					ACK	BLACK		7A	TUE
					VT-09	TRACK		7A	TUE
					VC-34	TRACK		7A	TUE

TUESDAY ---ROUTINE 7 SEQUENCE A ON AIR--- ON COMPUTER 7

TIME NOW									
11 20 04 A	2 54	SHOW TAPE		VT-02		VT-10	TRACK		
RO11 22 58 A	30	BLOCK	BDSP 5063	VC-33		VC-34	TRACK		

NEXT EVENT

00023

---PRESET--ROUTINE 7 SEQUENCE A---NEXT MODE---

TIME OF EVENT -TUESDAY	DUR OF EV	TITLE	MAT ID	ALT SEQ	VIDEO	INSERT	PROTECT	AUDIO	OVER
RO11 22 58 A	30	BLOCK	BDSP 5063		VC-33		VC-34	TRACK	
11 23 28 A	30	DOANS	PRCA 0013		VC-33		VC-34	TRACK	
11 23 58 A		SHOW TAPE			VT-02		VT-10	TRACK	
RO11 26 11 A	30	STERL DRUG	STMI 1413		VC-33		VC-34	TRACK	
11 26 41 A	30	STERLING DRG	STBC 1413		VC-33		VC-34	TRACK	
11 27 11 A		SHOW TAPE			VT-02		VT-10	TRACK	
R 11 28 00 A	20	CART OVER			CONTD		CONTD	CONTD	AC-66
11 28 20 A		SHOW TAPE			CONTD		CONTD	CONTD	
R 11 28 24 A	22	HI THURS NATH	1/26 9 2155		VC-33		VC-34	TRACK	
11 28 46 A	1 14	STATION BREAK			BLACK		BLACK	BLACK	
R 11 30 00 A		SHOW TAPE	#2402 1/11/76		VT-01		VT-09	TRACK	
RO11 31 34 A	30	KRAFTCO	KRMW 4030		VC-33		VC-34	TRACK	
11 32 04 A	30	KRAFTCO	KRRP 5110		VC-33		VC-34	TRACK	

NETWORK

WNBC-TV

SHOW

PROT.

The **Network** data display indicates that two 30-second commercials, **Block** and **Doans,** are scheduled to be played within the program, after which the computer is to switch back to the show tape.

Looking at the Network monitor housing (right), we see that it is 11:20:37 and the **next** switch will be to VC-33 at 11:22:58. The program monitor shows the picture that is being fed to the Network. The readouts tell us that video tape machine VT-02 is on-the-air, and that VT-10 is our **protection.**

Although the lower monitor appears to be showing the same picture, we see that the computer has lit the sign **prot** above it to tell us that we are seeing the picture from VT-10, the protect copy. The readout below tells us that the next switch will put VC-33 on-the-air and use VC-34 as a protect source.

SWITCH!

COMMERCIAL

PROT.

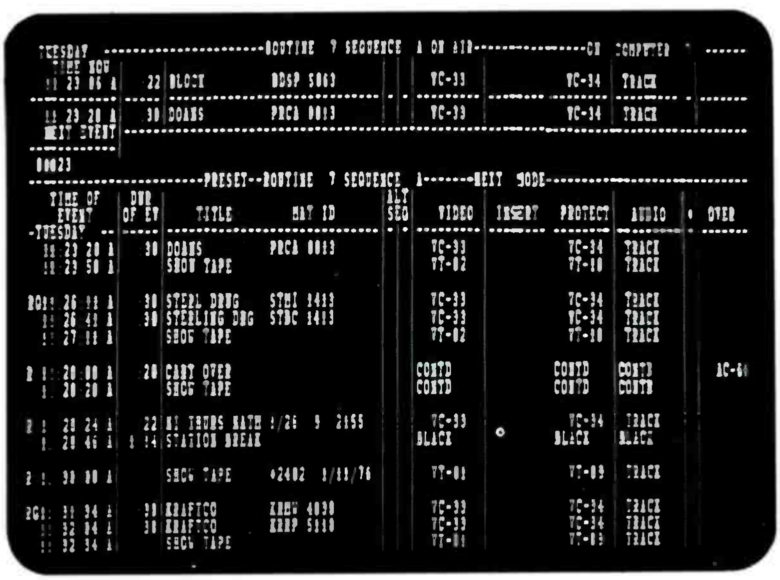
:10 SECONDS TO GO!

EXT

Film, video tape, and video cartridge machine must be **rolled** 5 seconds before they are switched on-the-air. At 10 seconds before switching time, the preset monitor is automatically switched to show the preset video to permit the operator a brief preview of the device and see that it rolls as scheduled. If the device should fail to roll, and there is a protect source scheduled, the computer will automatically switch the protect source on-air at switching time.

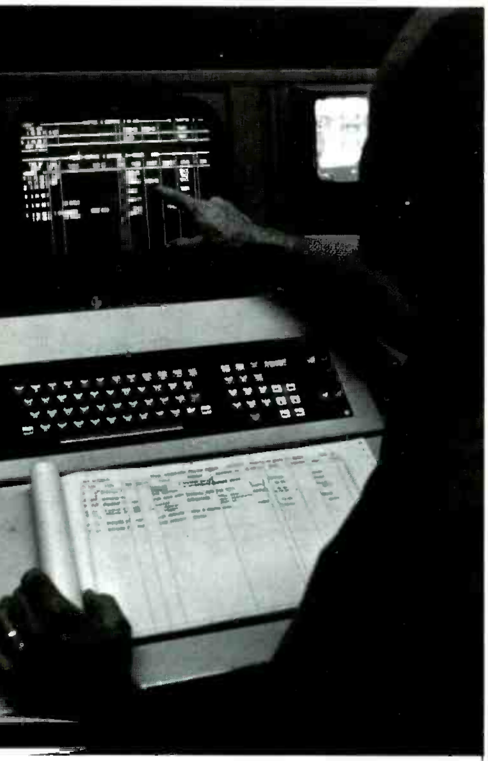
Once the switch is made, the lower monitor is automatically switched to show the new protect copy. On the data display we see that VC-33 is on-the-air with the **Block** commercial. All items on the lower section have scrolled up and a new time appears at the bottom.

It is desirable, at times, to have short announcements made, where the main audio level is reduced and the announcement is mixed with it. In this case, the main program video and audio continue with the only switching action being to roll the audio cartridge (AC-66) and reduce the level of the main audio.



Keyboard computer modes

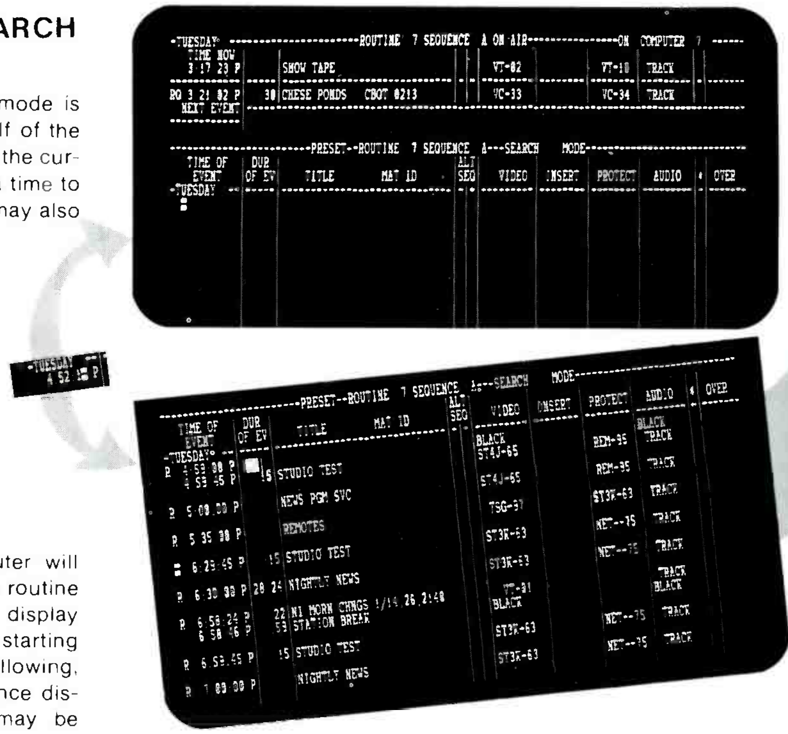
The keyboard data display can be set to operate in one of three modes: **next, search,** or **special.** The keyboard computer data display hardware is identical to the channel-computer hardware; however, the keyboard software is much more versatile.



NEXT The **next** mode is identical with the channel display, except that the keyboard can be set to display the activity of any sequence on any channel computer, not just the on-air sequences.

SEARCH

When the **search** mode is entered, the lower half of the display is cleared and the cursor is positioned for a time to be entered. The day may also be specified.

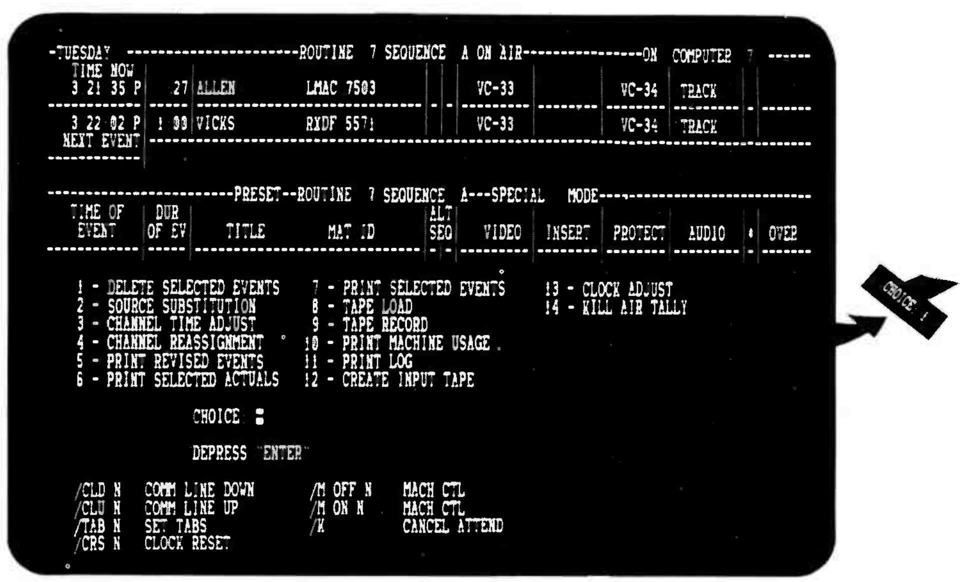


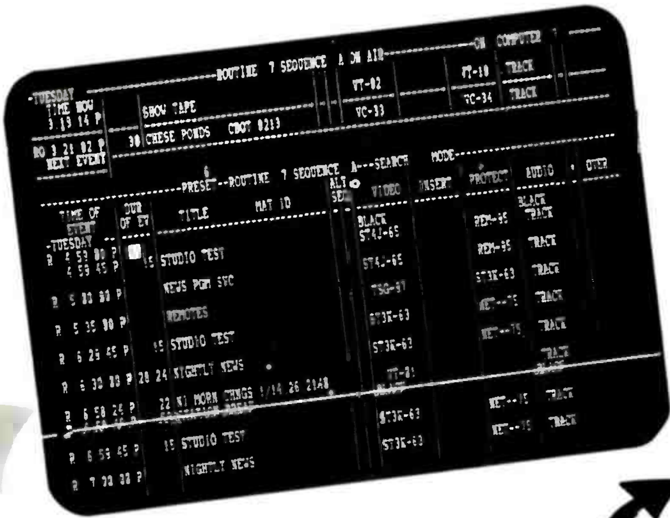
The keyboard computer will search the data of the routine being monitored and display the sequence of events starting with, or immediately following, the specified time. Once displayed, the screen may be scrolled up or down.

SPECIAL FUNCTIONS

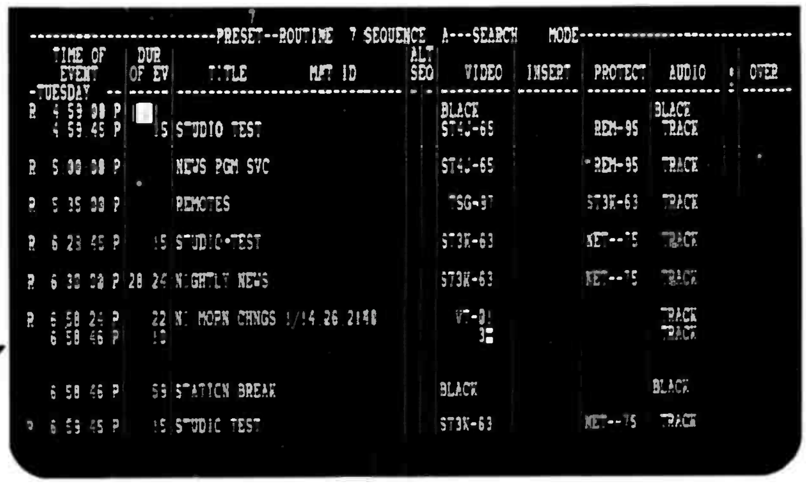
A variety of **special** functions can be performed on the keyboard computer. The list of the special functions can be displayed at any time by pushing the SPEC button on the keyboard. The desired special function is selected by typing the number of the function after the word **choice** and pushing the **enter** bar. This causes the command format for the selected special function to be displayed. Command formats are used to assist the operator in quickly and accurately entering the required parameters to permit the special function to execute properly.

The lower section of the special function menu lists simple system commands (*slash* commands). The operator can issue *slash* commands at any time. No special function format is required and the display can be in any mode. Operating the "/" key places a "/" on line 7 and positions the cursor next to it.





It is also possible to push apart the **event** lines and **insert** any number of new events. Entire routines can be manually loaded in this mode. Normally, however, routines are loaded automatically.



DELETE OR MODIFY

Events may be deleted by first pushing the **delete** button. The display then indicates the line that will be deleted if the **enter** bar is pushed.

The cursor may be positioned to any field — *source, time, duration,* or *text* — on any event line and the data modified.

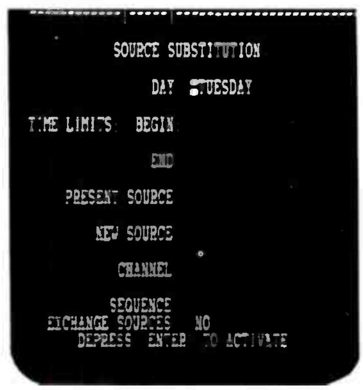
INSERT

WARNING

Delete selected events: this special function permits a range of events to be automatically deleted on one or more routines.

Source substitution was used to change all NETT-77 to REM-90 on channel routine 8. The keyboard computer logs the time each special function is executed as well as the list of parameters entered by the operator.

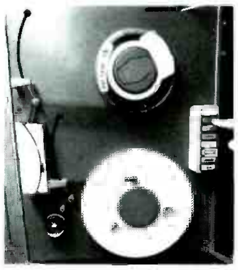
CHOICE 2



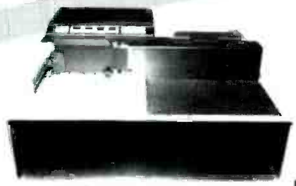
CHOICE 3

Load routines

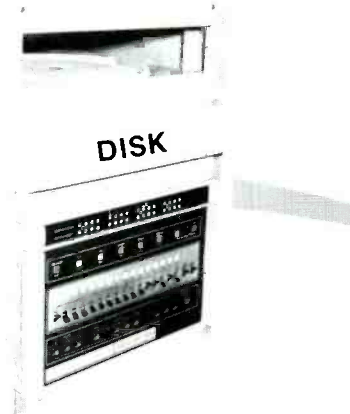
Each evening, two duplicate magnetic computer tapes containing the next day's routines and a set of hard-copy printouts are delivered to Switching Central. One of the tapes is mounted on one of the two tape transports, the **load** button is pushed, and the tape automatically positions itself at the start of data, where it waits until the operator commands the keyboard computer to execute the special function **tape load.**



MAG TAPE

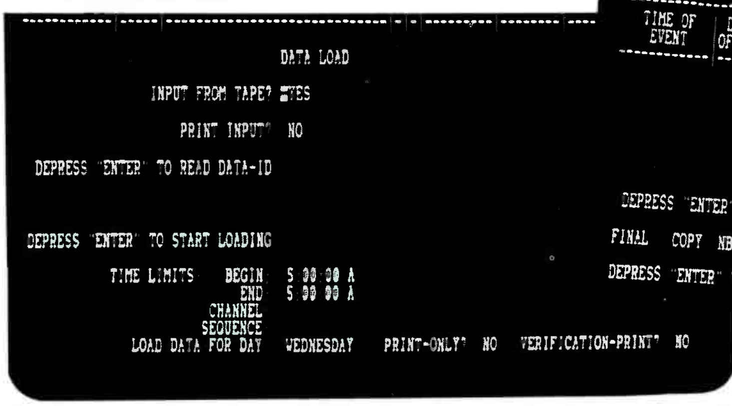


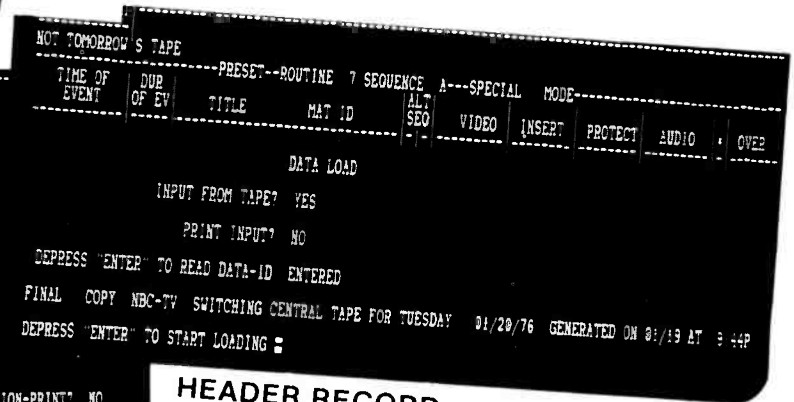
CARD READER



KEYBOARD COMPUTER

DISK





HEADER RECORD

The operator calls up the special function menu, enters 8 for his **choice,** and pushes the **enter** bar. This causes the keyboard computer to display the command format for the special function, **tape load.** The command format is arranged so that pushing the **enter** bar again is all that is required for the *normal* use of this special function. This causes the **header** record on the tape to be read and displayed. The operator compares the displayed header with the header on his printout to be sure they are identical. The header is also checked by the keyboard computer, and a warning message is sent to the operator if the day on the header is not "tomorrow."

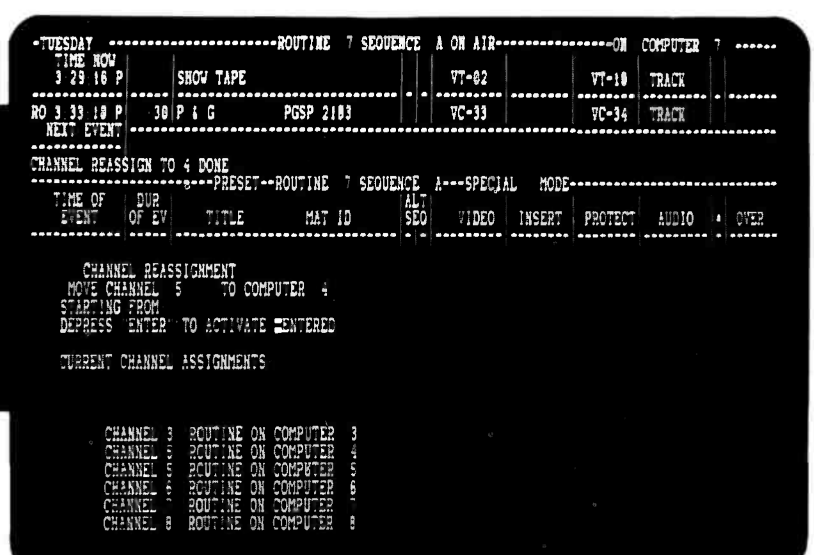
When the operator is satisfied he has the proper data tape (it need not be "tomorrow"), he pushes the **enter** bar again to initiate **data load**. The **load** function proceeds automatically in three phases:

I) The keyboard computer deletes all of "yesterday's" routines and logs on its disc and instructs the other keyboard computer to do the same.

II) The tape is read by the keyboard computer and the routines are stored (recorded) on its disc as "tomorrow's" routines. When all of the records on the tape have been read, the computer sends an **all events loaded** message to the operator.

III) The routines are then sent to their assigned channel computers where they are stored on the channel computers' discs. As each record is successfully transmitted to its assigned channel computer, it is also sent to the other keyboard computer. At the end of phase III, the message **all computers loaded** is sent to the operator.

ASSIGN ROUTINES TO CHANNEL COMPUTER



The routines stored in the keyboard computer disk memory may be reassigned at any time to a run on any channel computer by selecting choice =4 for the special function **channel reassignment.**

Log Printouts

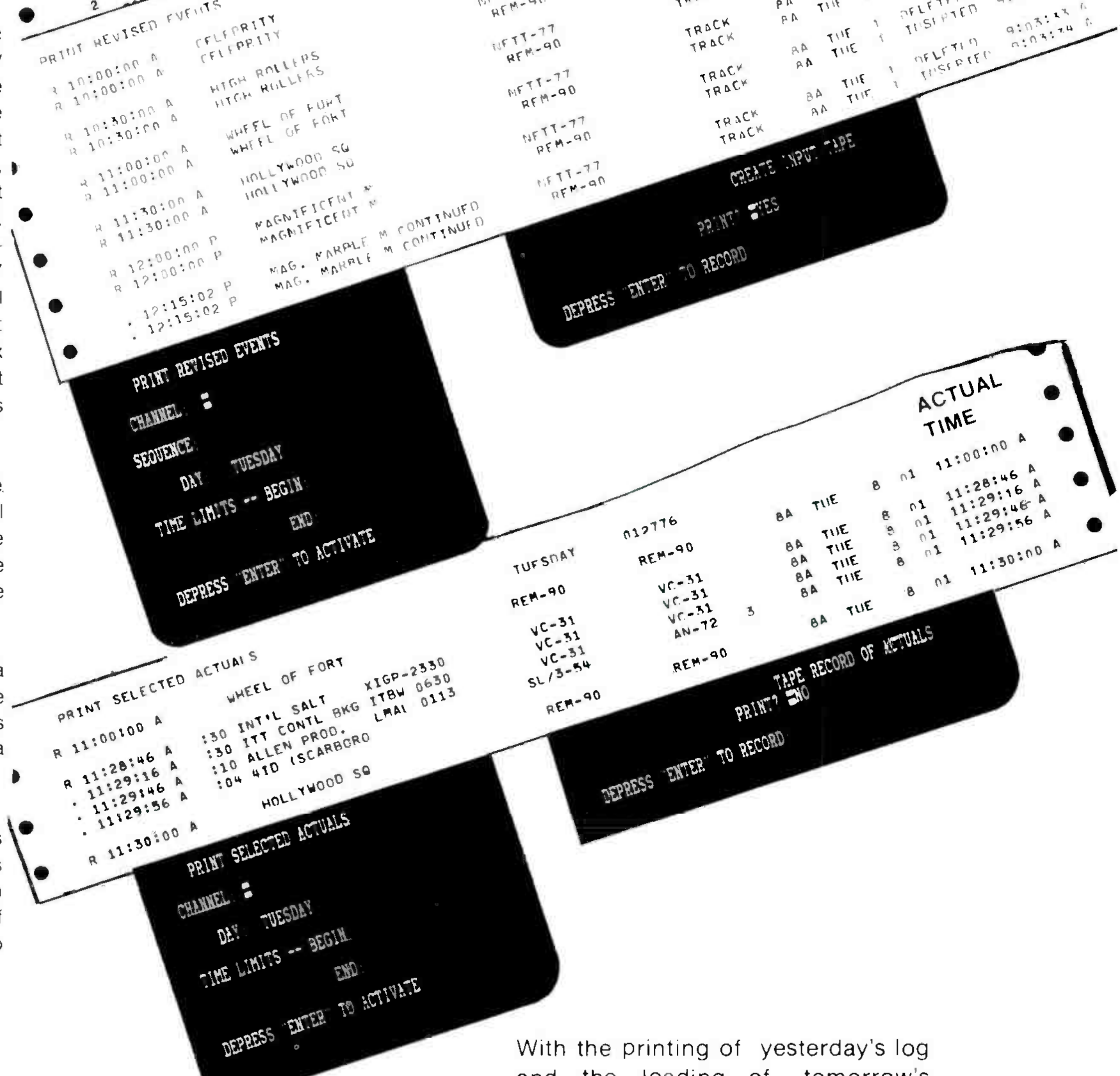
Three special functions permit a variety of log printouts to be produced.


Switching Central Log: The entire Switching Central log may be listed by time, or limited to the activities of one computer. The printout can also be restricted to only those messages that match a two-character option code (e.g., EA) or all entires that include the first character of the option (E—). Note that, along with log entries from channel computers 07 and 08, keyboard computer 17 reported that the Switching Central operator executed the special function: **source substitution** at 9:02:52 and six frames (1 frame = 1/30 s). Each **event** that is modified is logged in its original form as well as the modified version.

Print revised events: Note that the revised event printout extracts all deletions and insertions from the log file and prints them in a form similar to the routine, along with the actual time that the change was made.

If extensive revisions are made to the data base, it is possible to create an input tape which is an updated version of the day's routines and can be used for input if a data reload became necessary.

Print selected actuals: Log entries that record the actual times that events were put on-the-air can be extracted from the log file and printed. Magnetic tapes of the *actual log* can be created and used to help validate billings.



With the printing of yesterday's log and the loading of tomorrow's routines, the around-the-clock activities at NBC continue on towards another operating day.

Hardware interface considerations for multi-channel television automation

M. A. Negri

The newly automated Television Central facility at NBC's Radio City plant in New York controls ten simultaneous audio/video channels. These computer-controlled channels are independent, in that each has its own audio and video switching system as well as control of rolling devices, display systems, and manual overrides. Selection and installation of the computer systems to achieve this high level of switching control required careful consideration of the computer architecture and input/output options as well as the needs of the NBC Production and Engineering staffs.

In mid-1973, NBC Engineering in New York began the hardware phase of the Television Central modernization by bringing in computers to replace the outdated and inefficient electro-mechanical equipment (circa 1950's).

Before the implementation of this computer-controlled routing switcher, all the necessary in-plant feeds to and from the Radio City plant and outside studios had to be provided on a manual patch basis. This task alone constituted most of the daily work-load of Television Central.

The introduction of the audio/video routing switcher (also called master grid) allowed all end users of audio and video sources to obtain them by themselves. While this provided a great improvement, the new automatic facilities were also designed to control the master grid for picture and sound sources sent to the release channels. In addition these new automatic facilities would have the task of controlling all rolling devices [video-tape machines and telecine equipment] in the plant.

System architecture

One of the earliest decisions made during Television Central planning defined the architecture of the computer system. Switching Central was to be a multi-channel release studio within Television Central. Further, each channel within Switching Central would stand alone in all respects, with its own audio and video switching system, machine control, display systems, and manual overrides. Once the selection of the computer was made (General Automation SPC 16/45) the Computer Group at RCA Laboratories in Princeton was assigned the software task. NBC Engineering and RCA Laboratories then formulated all functional definitions.

As each piece of the operational package was defined, NBC Engineering proceeded to develop and implement it.

The first consideration in interfacing was to look at the input output (I, O) options supplied by the computer manufacturer. Each interfacing decision was made taking into account the nature of the equipment to be interfaced, as well as the extent of the software support that was consistent with the other tasks to be computer controlled.

Figs. 1, 2 and 3 give an overall view of one typical channel system structure. In this paper we shall concentrate primarily on the computer interfaces to the audio/video routing switcher, the machine-control system, and the channel audio video switching systems.

Routing switcher (master grid)

The master grid is a baseband-video, multiplexed-audio type switcher.[1] In its present configuration, it can switch 100 video inputs and associated 300 audio inputs into 320 possible users. It was designed to handle four different audio sources with each video source; however, for the most part, only three audios have been implemented so far.

Control of each bus is in parallel form, ten *units* and ten *tens* configuration for video. The audio subselection is accomplished by means of two additional select control bits. In addition, one extra *take* wire is used for video switching command, and another one for audio subselect. To control one typical master-grid audio/video bus, we use a total of 24 wires plus one common wire.

Each channel has five master-grid buses under its control:

1) Program video (air)

Typical channel system structure

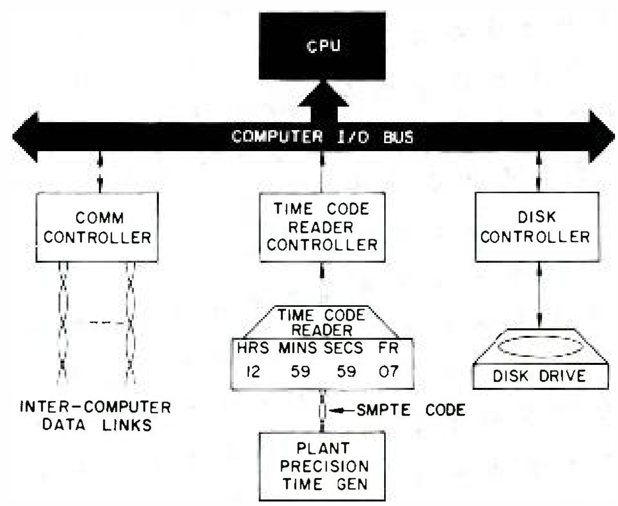


Fig. 1 — Primary software interface.

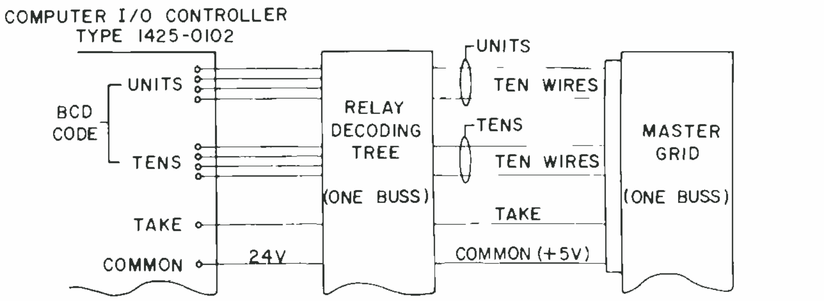


Fig. 4 — Typical master-grid video-bus control interface (one bus). The relay decoding tree also isolates the 24-V computer common from the +5-V master grid TTL logic.

2) Program audio (air)
3) Preset video
4) Preset audio
5) Effects (key) video

Five audio video buses are necessary to support a small switching system that permits limited production-type special effects at the release-channel point—such as dissolves and inserts.

Even though each video bus has associated audio sources, separate but identical buses are assigned for program and preset audio. This is to allow for the possibility of "split-audio" programming.

Controlling five master-grid buses per channel, at a count of 24 wires per bus, would mean 120 control points at the input output computer controller (I/O interface). Since each I/O controller has a maximum of 32 control lines, that would mean using four I/O controllers.

Because we did not have a relay output I/O card available at the time, and considering the recommendation of the master-grid manufacturer that their device be remotely controlled only by dry contact closures, we had to include a relay interface after the computer I/O card. In the process, we decided to BCD-encode the computer output and decode it back to decimal at the relay package (Fig. 4). This permitted a 50% savings in the number of I/O cards required, with considerable savings in I/O costs.

For computer interface to the master-grid, we selected an optically isolated digital-output I/O controller. Fig. 5 is a simplified schematic diagram of such controller.

Audio and video effects switcher

As mentioned earlier, each Switching Central channel has assigned to it five master-grid buses — three video, two audio. The output of these buses are fed into a switching system with video dissolve and key and audio "dissolve" and "over" capabilities. This switching system

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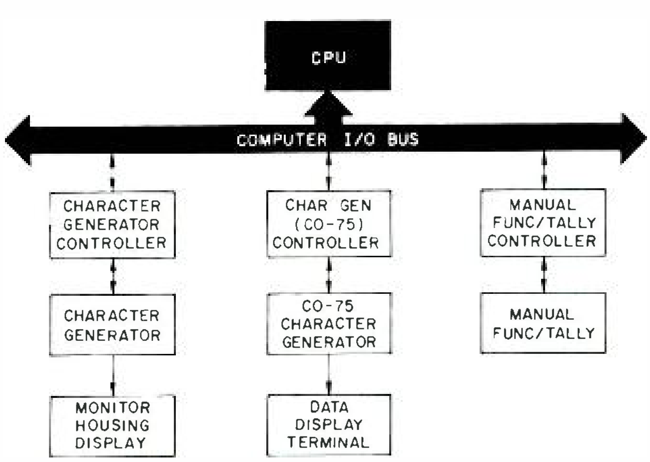

Fig. 2 — Operator-oriented interfaces.

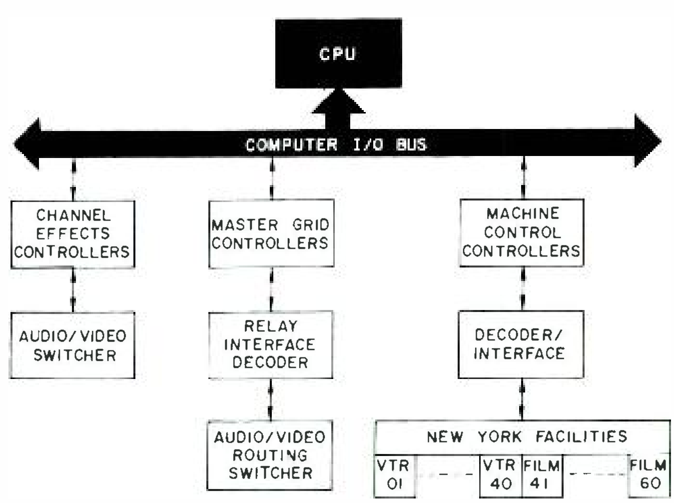

Fig. 3 — Audio/video program interfaces.

is under total computer control, as shown in Fig. 6.

Two optically isolated output controllers (Fig. 5) are used to input commands from the computer—one controller for video and one for audio. Two input controllers are used to bring the status tallies from the switcher into the computer. In addition to the switcher crosspoint control, controls are provided to start automatic dissolves; status tallies are also provided to indicate when the dissolve is completed.

The outputs of the channel switcher support the audio and video monitoring facilities[1,2] required in Switching Central and, in addition, provide the in-plant and out-going feeds.

Machine control

The Radio City plant has a complement of 34 video tape machines (VT/C). In addition, there are 14 telecine islands, each composed of a camera, two film projectors, one slide projector, and an optical multiplexer. All these facilities can be remotely controlled from any one of 24 different locations in the plant, rendering 100% flexibility in scheduling air and other type operations.

Switching Central has remote-control access to all these facilities, and all machines interface with all computers. The computer system is capable of handling up to 60 machines.[4]

To control the video-tape machines, four wires must be interfaced with Switching Central. Telecine islands require a total of 15 wires. With this information, we can consider the size of the interface task:

40 VT/C machines @ 4 wires each
= 160 wires
20 Telecine islands @ 15 wires each
= 300 wires

Since the area called Switching Central is really made up of ten possible free-standing *identical* packages (channels), for total flexibility we should be able to switch *all* wires (as machine groups) to *all* channel-computer systems. Therefore, the problem was to build some sort of 460-by-10 transfer system.

Interfacing the computers to the facilities on a wire per wire basis was discarded for

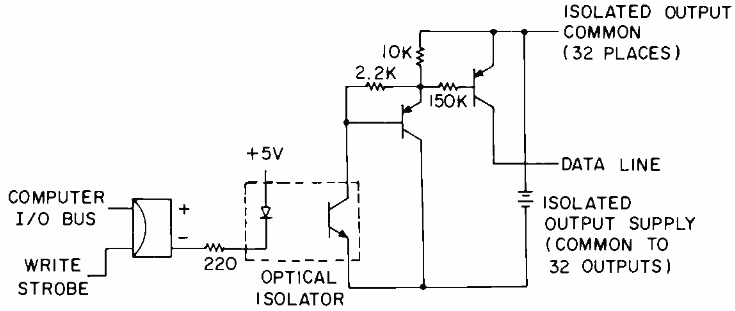

Fig. 5 — Computer output card using optical isolation.

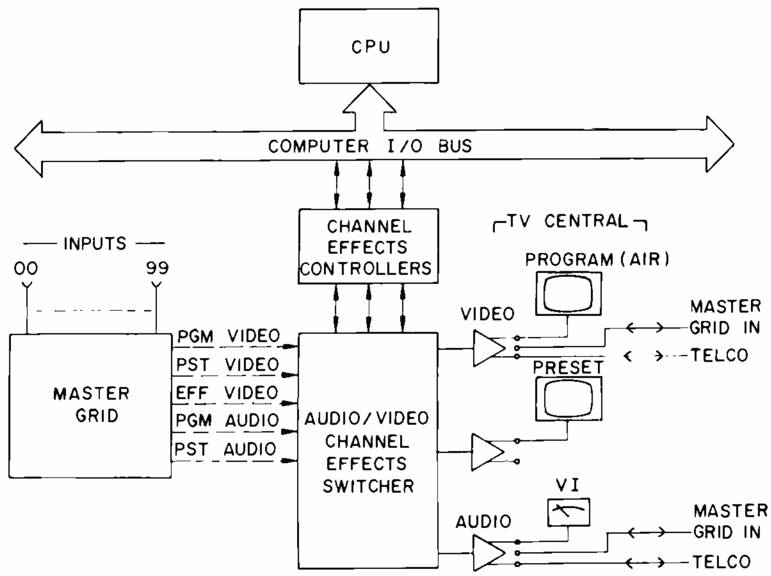

Fig. 6 — Audio-and-video-channel effects-switcher interface.

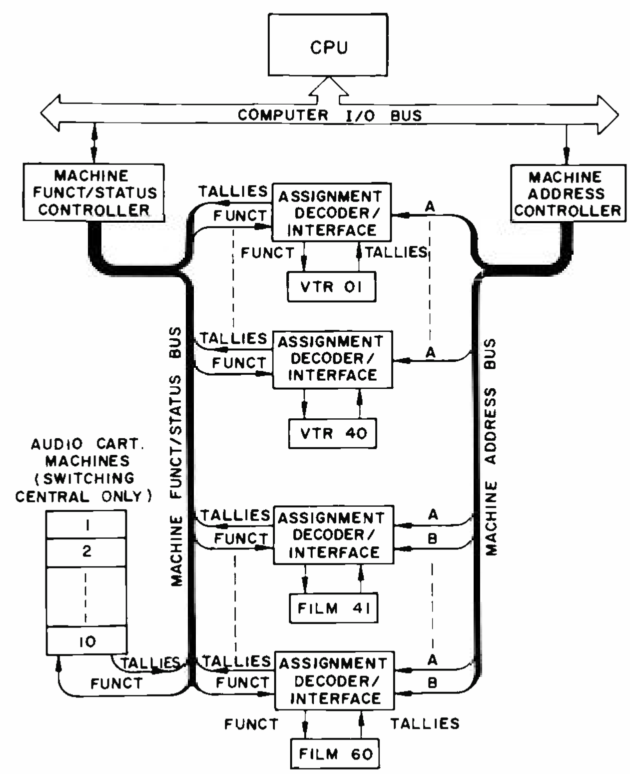

Fig. 7 — Machine-control interfaces.

economic reasons, as well as because of computer I/O limitations.

A computer-supported multiplex system was adopted, where each computer has unique buses for commands and status. Each controllable device has been assigned a unique address line that, when activated by a computer, causes the particular device interface/decoder to put itself under computer control. Fig. 7 shows the organization for one computer.

Each facility in the plant has means to delegate control (assignment) to any one of up to 24 remote locations throughout Radio City and beyond. Since this assignment system was pre-existing, we had to consider Switching Central as just one of those possible remote control places, even though Switching Central is, in reality, a generic name for up to ten control points. This problem of sub-selecting one out of ten was solved by letting the computers themselves perform the other half of the machine-assignment function. For this purpose, an assignment selector device (under computer control) was created to house the channel sub-selection and interface functions.

Referring back to Fig. 7, the system is arranged to accept only one control station computer at a time. In case two control stations request the same facility simultaneously, the system does not lockout but will give control to one of them, randomly. Once a channel gets control of a facility, the system will lock-out any other request for control. After a channel computer has decided that it no longer needs the facility, it will issue a *release* command to the system, to defeat the lock-out and allow control from other computers.

A visual indication of channel assignment for each facility is provided in the "tape-film status panel", together with means of manually changing the assignment.

The interface system will accept four commands from the channel computer and feed back three tallies along with a one-bit address for video tape machine and two-bit address for telecine chains. The machine instruction word thus formed is translated by the system into appropriate machine commands. Fig. 8 is a simplified form of the interface and assignment switcher.

Film assignment switcher

The film assignment switcher consists of a twelve-pole, ten-position stepping switch and associated control relays for homing, interlock logic (lock-out), release of lock-out, and manual stepping. The first two decks of the switch are assigned to the homing function and double as a path for the address function, once the stepper is in its *home* position. When the stepper finds *home* (by looking for a grounded line), the interlock logic latches up, thus preventing any other request for control from taking it away from the assigned channel. The lock-out can only be terminated by the channel in command. The stepper deck *release* routes the release command from the computer or from the manual release control. The deck called *tallies* feeds the channel-assignment indicator in the film-tape assignment panel, part of the Switching Central console.

Three relays are used to decode the incoming address in the form of two bits. A fourth relay (home interlock) prevents any accidental command from reaching the system while the stepper is moving towards a *home*. There is one stepper deck per function command. The purpose of these decks is to accept those commands coming from the assigned channel, uniquely. The last three decks of the stepper route the status tallies to the channel computer.

Video-tape machine-assignment switcher

The video-tape machine-assignment switcher requires a stepper with only eight decks, ten positions. Its structure follows that of the film unit, the exception being the reduced number of function and tallies required for operation of a tape machine.

Machine assignment

The assignment address consists of a computer I/O instruction that generates ground-level signal on the appropriate control line(s). Video-tape-machine call-ups take one address bit; film call-ups require two bits. A film chain can be called up at its I/O "address" location by specifying the projector (35 mm, 16 mm, slide) involved in the operation. The assignment address remains true for 250 ms minimum, to allow for the stepper travel. A video-tape machine is called up for assignment at its "address" I/O location (single address). The assignment address remains true for 240 ms minimum.

It is possible to call up for assignment more than one facility at a time. After the assignment function time, the computer verifies the position of the assignment switcher by looking at the assignment status line.

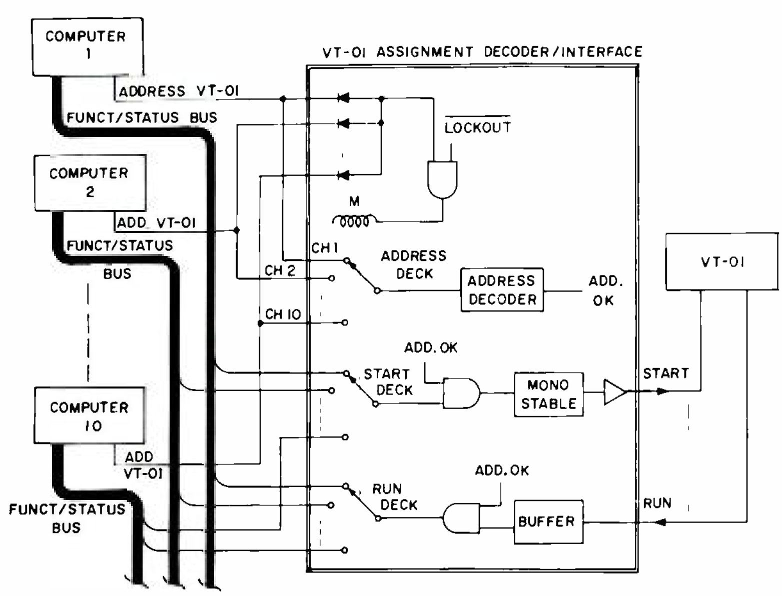

Fig. 8 — Simplified assignment, function and status switcher.

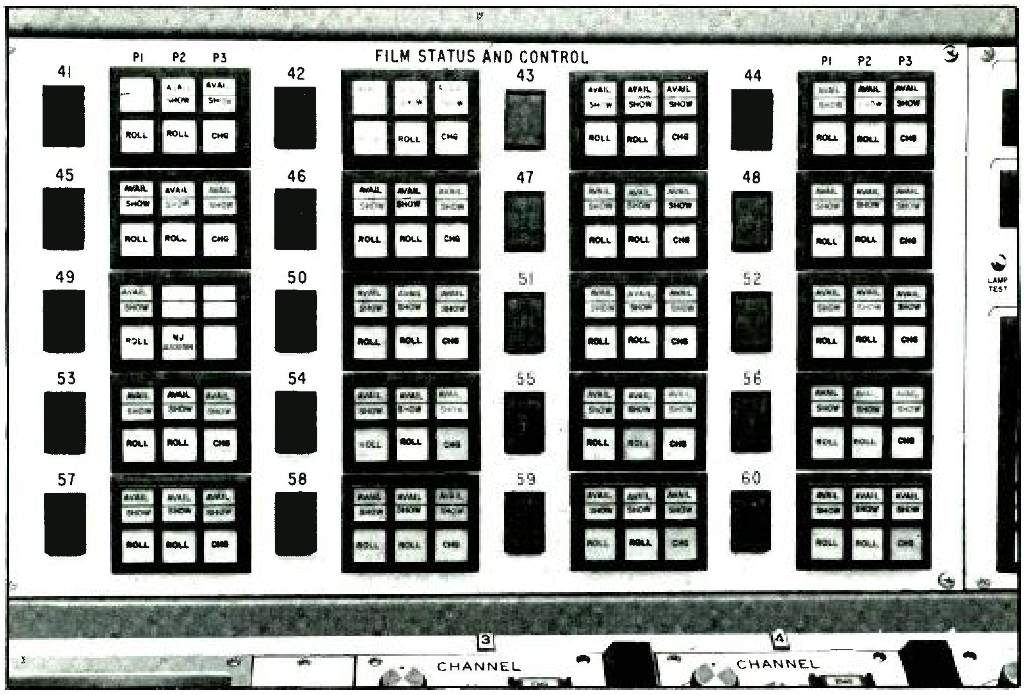

Fig. 9 — Film status and control panel.

Machine availability

After completion of the assignment operation, the computer will, when convenient, verify that it has established communications with the device(s) called up by looking for the *available* status. The procedure involves addressing one machine at a time and, while holding the address, strobe in the *available* line information from the appropriate point in the tally I/O module. There are two relay pull-up times involved in this operation. Each verification cycle will require 15 ms minimum. The *available* verification is performed several times during the normal use cycle of a device, as confirmation of status.

Machine start (change)

The purpose of the *start* command directed towards a rolling device is to initiate the action of setting the program material in motion. The same *start* command, when applied to a slide projector, will initiate the action of changing the slide shown (slide *change*). Slides are changed once per command.

The *start* (*chg*) command has a fixed location in the functions I/O card. The connecting wire to this point is externally bussed to all assignment switchers and brought into a unique point in the *start* deck of the steppers. This configuration makes it possible to simultaneously start any number of devices from a given computer, provided they are not different projectors in the same telecine island.

To *start* (*chg*) one or more devices, the computer generates the device address by grounding the appropriate control points in the address I/O cards and loading the *start* instruction on the functions I/O card. There are two relay pull-up times involved. Each *start* (*chg*) cycle requires 60 ms, minimum.

Run verification

After a *start* command has been issued to a rolling device, the system verifies that the machine has executed the order. This is done by generating the machine address as before, and while holding the address, reading in the *run* tally information that appears at the appropriate point in the tally I/O card. This operation takes 15 ms, minimum.

Film show

The *show* operation relates only to telecine islands. The complete command should include the projector that is to be put on camera; i.e., *show* 35; *show* 16; *show SL*.

To generate a *show* command to a telecine island, the computer outputs the address of the projector to be controlled and simultaneously grounds the *show* point in the functions I/O card. This operation has to be maintained for 60 ms, minimum.

Film multiplexer

After a *show* command has been given, the system verifies that the action has taken place at the telecine island. This is accomplished by the system generating the device address and strobing in the contents of the *mpxr* tally information that appears at the tally I/O card. This operation takes 15 ms, minimum.

On-air status

The *air* status of a machine is derived by the system and it feeds this status to the device involved in the form of a command. To do so, the system generates the device address and simultaneously grounds the *air* point to the function I/O card. This *air* command will set an external flip-flop that will retain the command going to the device. This output is maintained for 60 ms, minimum.

Not-air status

When a device loses its *air* status (comes off program), the system issues a *not air* command to reset the external *air* memory. The *not air* command consists of the device address and a ground on the *not air* point in the functions I/O card. This output is maintained for 60 ms. minimum.

Machine status and manual control panel

The Film/VT/C status and manual control panels (Fig. 9) provide the Swtiching Central operator with a visual indication of the complete status of all in-plant facilities, at all times, regardless of whether they are assigned to Television Central. In addition to the status, a visual indication of the Television Central channel assignment of each facility is provided.

When a facility is assigned and made *available* to Switching Central, it can be remotely controlled by means of the pertinent pushbuttons in these panels. The Film/VT/C status panels can handle up to 60 facilities: 20 film chains and 40 VT C machines.

Release

After the system has finsihed using a machine, it issues a *release* instruction to the machine control assignment system so it can be free to work with any other Switching Central channel.

This *release* instruction consists of the device address and a ground at the *rlse* point in the address I/O card. This output is maintained for 15 ms, minimum.

Film

Each film chain in the plant has a cluster of illuminated pushbuttons assigned to it in the status and control panel. The clusters are identified with the same facilities numbers in current use; i.e. 41 through 48; 51 through 56; plus 6 other clusters for future expansion.

Each cluster consists of the following:

One channel-assignment readout and pushbutton: This is a rear-projection readout with a built-in switch that indicates which Switching Central channel the chain is assigned control to. When the button is depressed, it changes the assignment, one step at a time. Assignment advances in one direction only, but it can go around continuously. There are ten channels and one *off* position. In the *off* position, the chain is disconnected from all computer controls, except assignment requests.

Three available-show pushbuttons: These are illuminated split screen momentary-type pushbuttons. They are lined up under the projector type they serve, P1, P2, P3; typically 35mm, 16mm, slide. The top half of the screen displays projector availability status to Switching Central. The bottom half indicates multiplexer (mirror) position. When the cluster is assigned to Switching Central, pushing any of these buttons will cause the multiplexer at the chain to put a projector (P1, P2 or P3) on camera. The corresponding *show* tally will light.

Video tape/cartridge machines

Each video tape/cartridge machine in the plant has two illuminated pushbuttons assigned in the status and control panel. Each group is identified with the same facilities numbers in current use; i.e.: 01 through 34. The numbering goes up to 40 for future expansion. Each group consists of the following:

Three roll-(chg) pushbuttons: These are illuminated full-screen momentary pushbuttons, lined up under the *avail-show* buttons. If a projector is *available*, depressing a *roll* button will cause that projector to start. Depressing the *change* (*chg*) button, will cause one slide change at a time. Note that these actions are independent of the mirror position, allowing for blind rolls and slide changes.

One channel-assignment readout and pushbutton: Identical to the film units, used to display Television Central channel assignment of the TV C, and to change it, as required.

One available-roll pushbutton: These are illuminated, split-screen, momentary-type pushbuttons. They line up under the corresponding channel assignment readouts. The top half of the screen displays *VT C availability* to Switching Central. The bottom half indicates run status. Depressing the button cause the video tape machine to *roll* (start).

Conclusion

All the systems described in this paper have been in service supporting daily television operations since October 1974. Thanks to the very close cooperation and mutual checks between the different groups involved in the development effort, very minor software and hardware modifications were needed. All the interfacing hardware was developed by NBC Engineering.

Acknowledgment

Considering the amount and quality of work done in such short time and with a limited budget, I feel obligated to mention the names of the unsung heroes: the late Mr. H. Bartolf and Mr. R. Yanney.

References

1. Butler, R.I.: "PCM-multiplexed audio in a large audio-video routing switcher," *this issue*
2. Mausler, R.: "New and versatile transmission video facilities," *this issue*
3. Mausler, R. and Krochmal, H., "New and versatile transmission audio facilities," *this issue*
4. Yanney, R.M. "Sixty-device remote-control system," *this issue*.

Sixty-device remote-control system

R.M. Yanney

A large remote-control system, interfacing 24 studios to 60 machines (video tape and film), was recently installed at the NBC, New York Studios as part of the Television Central Project. A time-sharing scheme was selected to circumvent the cost and complexity of a hard-wired approach. Individual buses are use for each studio—hence, eliminating common-mode failures. In this system, any machine can be assigned to any of the studios individual buses are used for each studio—hence, eliminating common-mode individual or parallel control to one or more machines. Machine status can be continuously monitored, and pulse and communications signals can be tracked.

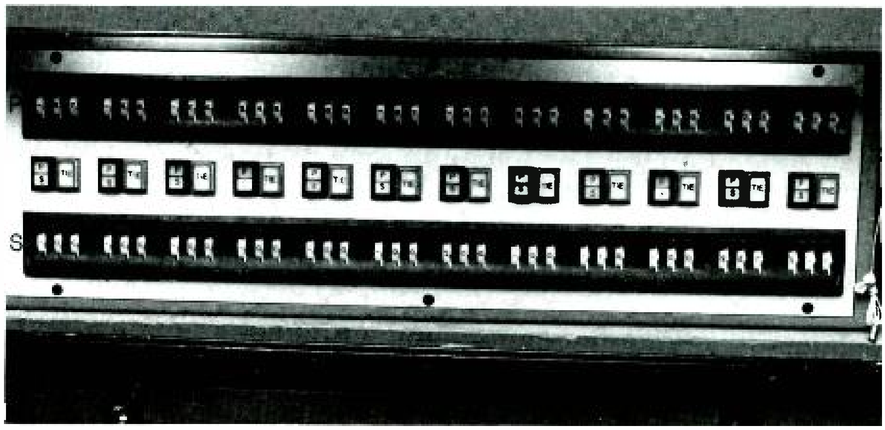

Fig. 2 — Dialing controls, located at the production studio, allow video selection as well as machine control.

IN THE process of automating the New York Studios, NBC Engineering had to develop and implement a remote control system for all rolling devices . The total number of such devices is 60 (40 video tape and cartridge machines and 20 film chains), and the total number of remote control locations (studios, editing rooms, viewing rooms, etc.) is 24. The remote control must allow any of these 24 studios to select and control any one, or several, of the rolling devices.

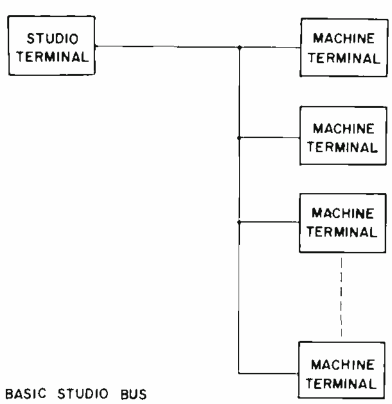

Fig. 1 — Basic machine-assignment scheme. Each studio has its own data bus, connected to various tape machines and film chains needed for studio operation.

Hard-wired approach

The first approach examined was a hard-wired system where each machine could be delegated to the studio assigned for remote control. This assignment would connect all the control wires of the machine to the corresponding control wires of the studio. The number of wires involved was about 20/machine, taking care of all commands and machine status tallies. Thus the control wires from all 60 machines would have to meet in some central location with the control wires coming from 24 remote locations where a gigantic switcher would have to take care of the assignment. This approach was too expensive, and required an excessive amount of equipment space and cables.

Time-shared system

The approach finally chosen was a time-shared control system where one pair of data wires would carry all the information (machine commands and status) serially. With this system, the total number of cables is reduced; only two wires are switched instead of 20; and the total cost was less than one-third of that projected for a hard-wired system of similary capacity.

Each studio has its own data bus, connected only to the machines assigned to that studio and separated from all other studio buses (see Fig. 1).

A switcher in a production studio usually has 12 remote inputs, expandable to 24 by allowing primary and secondary selection of input position. Therefore, the studio dialing controls (which are used for video selection as well as machine control) are arranged in two rows of 12 sets of thumbwheels with 12 primary/secondary pushbuttons. All these are mounted in a separate panel (Fig. 2) conveniently located to the Technical Director.

In the studio, a machine control terminal scans the 24 sets of thumbwheels (called "stations") sequentially at a rate of 1 ms station and comes back to the same station 24 ms later, as illustrated in Fig. 3.

The 24 sets of thumbwheels are enabled one at a time. Address codes are generated for each and carried over 9-bit address wires where they are matched with the corresponding 9-bit command wires—all shifted serially on the studio data bus.

If a machine terminal is connected to the studio data bus and recognizes its address

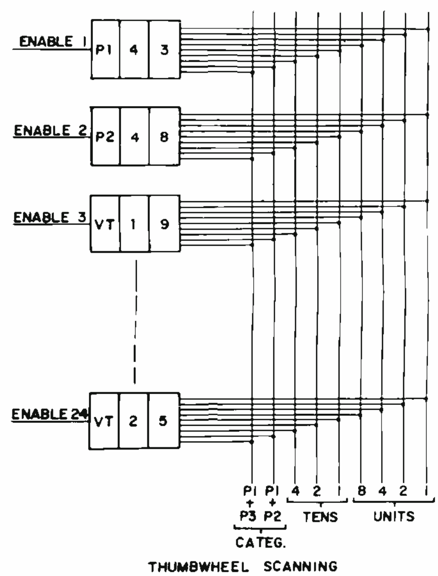

Fig. 3 — Thumbwheel scanning scheme.

code, it is allowed to "talk back" on that same data bus, sending its status and tallies to the addressing station. This complete cycle takes 1 ms. Then another address follows to communicate with another machine.

A studio control has access to 24 different stations. Therefore, 24 different addresses (machine numbers) could be selected ahead of time on the thumbwheel panel, and the system will continuously scan those 24 stations in sequence and will issue the appropriate command (if any) at the proper time.

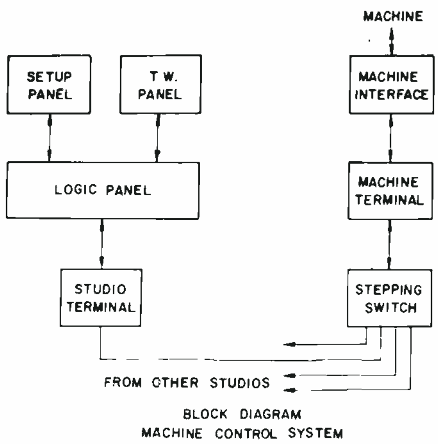

Fig. 5 — Machine control system.

Control stations

Each studio is equipped with a "setup" panel to generate commands for the different stations. This control panel (see Fig. 4) has one set of command buttons, 12 setup pushbuttons, one "clear" buttons, and 12 readout displays.

The setup buttons are latched by flip-flops and can be reset by the clear button. The 12 readouts continuously display the tallies of the 12 stations selected by the primary and secondary buttons. Also, each display is equipped with a push-button for individual starts.

A logic panel (see Fig. 5) was required to synchronize the station being scanned with the associated machine commands and the status tallies fed back from the machine addressed. Since all data are transmitted serially on the same bus where either the studio unit or only one machine unit transmits its information, the system needs only one pair of wires to be switched to the various destinations.

Since each studio has its own bus and can talk to any number of machines simply by adding the address code to the message, the studio data pair does not have to be switched, and is therefore available to every machine terminal. Therefore each studio pair is terminated at a central distribution area where it is bridged to the 60 machine selectors as illustrated in Fig. 6.

Each machine selector picks up one pair out of each studio, resulting in 24 pairs which connect to two decks of a rotary stepper controlled by the machine operator.

Ralph Yanney, Broadcast System Engineer, NBC Engineering, New York, N.Y., received the BSEE in 1953 from Cairo University, Cairo, Egypt. In 1975, he received the MSc in computer science from Stevens Institute of Technology. He joined the Egyptian State Broadcasting in 1953 and was involved in introducing tv for the first time in Egypt in 1960 and became Director in Charge of Upper Egypt Radio and Television Network and Provincial Studios in 1966. Mr. Yanney came to the United States and joined NBC Engineering in 1968, and has been primarily involved in design and testing of the remote machine control system for the NBC Studios in New York.

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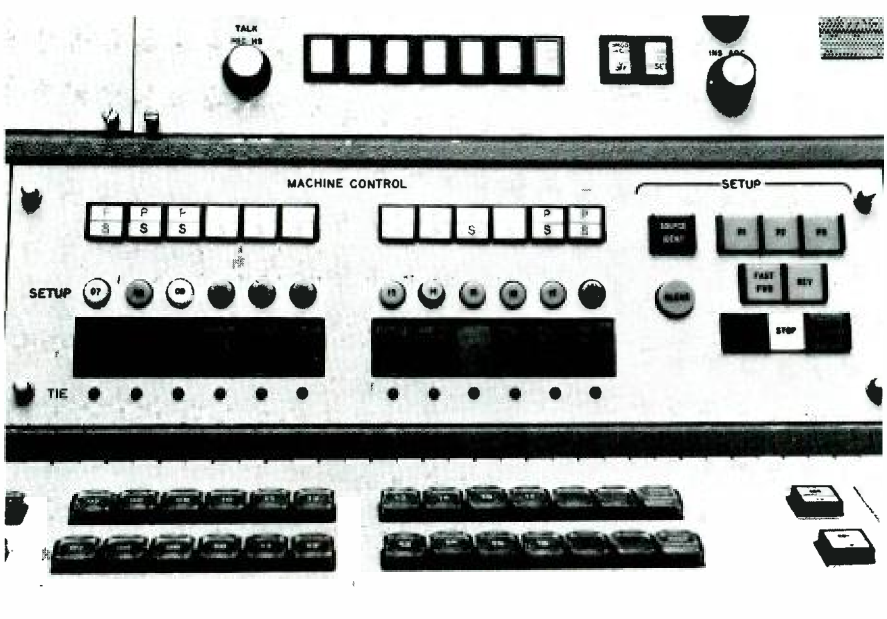

Fig. 4 — Each studio is equipped with a "setup" panel.

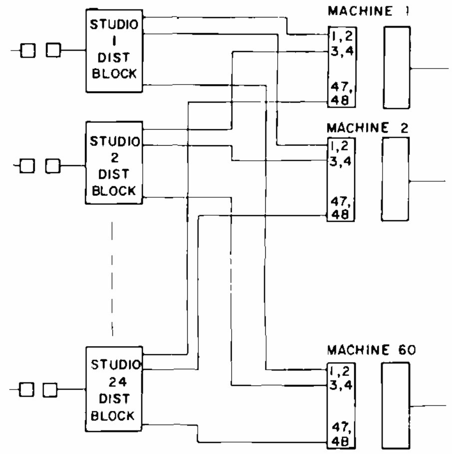

Fig. 6 — Data bus distribution scheme.

Also included in this stepper is another deck for communication where the selected studio communication line is connected to the machine communication line. Another deck is used for time-base tracking where a search line associated with each studio position will search for the sync pulses (time base) selected by that studio and will automatically switch the machine sync generator to the same pulse reference used by the studio. The remaining two decks on the stepper are used for homing and readout display at the machine to display the studio being selected.

If a studio dials a machine number on one of the 24 stations and that number is not identified by any of the machines on its data bus, a *no data* tally will be received and displayed on the corresponding readout of that station. This alerts the studio operator that there is 'no communication because of a wrong number, because the machine is not yet on the line, or because there is a failure at either end.

If an error is found by the studio unit in the message received from a machine, *fault* is displayed for that station. Meanwhile, if an error is found in the message received by a machine unit, the machine unit disregards the message completely and *no data* is displayed at the studio end.

Telecine and video tape control

A telecine (film chain) cluster usually consists of two film projectors, one slide projector, and an optical multiplexer considered as one unit, instead of three or possibly four separate units. Thus, a telecine control unit accepts four address codes derived from the machine number and the port identification. The calling station has three thumbwheels: one for the units, one for the tens, and the last for the port identification (P1, P2, P3, and F). P1, P2, and P3 relate to the projector to be controlled; F provides access to the whole chain with controls directed to the projector facing the camera. Under all four cases, multiplexer control is always available with certain restrictions.

Usually a machine is selected ahead of time on a preset bus before being taken on the program bus for preroll and cue purposes.

If a film chain is dialed with the prefix P1, P2, or P3 and taken on either the program or preset bus, automatic multiplexing will take place immediately.

To protect against multiplexer transfer for a projector on the program bus, the multiplexer command is inhibited once the "on-air" tally is received by the machine. For this purpose the program bus has first priority over control of the multiplexer by others.

When a film chain is dialed with prefix F, no automatic multiplexing takes place and all controls are manual from the setup panel.

The preset bus is also used for preset start. A machine that is selected on the thumbwheel panel, and is available for remote operation, and is taken on preset, could be started by depressing a single button called "preset start." When all the previous conditions are met, this button is illuminated.

In reference to the 12 display messages for each of the 12 stations selected by the primary/secondary buttons, two of these messages mentioned were *no data* and *fault*. Four additional messages are P1, P2, and P3, and VT/C, in amber color. When such prefixes are selected, the last one selected is for video tape or video cartridge.

Three additional messages are P1, P2, and P3 in red color. These reflect the real multiplexer status when prefix F is selected with a film machine.

Two other messages are *start* and *change*, and they are displayed when a machine satisfies all available conditions. The first display is for rolling devices which are film projectors or tape machines, and the second is used for slide change.

The last message in the readout displays is *rec* and it is received when a video tape is in the recording mode.

Another prefix "-" could be added to a machine number to inhibit machine control for that station.

Under each readout display, a small red tally is used as a tie indicator to denote simultaneous remote control of primary and secondary stations.

Conclusion

This system was first used in April 1974 and it started with one studio and a limited number of film chains. Now we have eight studios, 14 film chains, 34 video tape and video cartridge machines, all connected to the new system.

At the beginning only limited controls were used. However, as familiarity with the system continued to increase, use of the facilities continued to expand.

As far as equipment failure and maintenance problems go, they are reported to be less than any comparable sophisticated system.

Acknowledgment

Mr. Miguel Negri was the guiding light of this project, and also introduced the first solid-state logic printed circuit board used in this system.

New and versatile transmission video facilities

R. Mausler

The efficient and reliable processing of a great number of video signals originating from many diverse sources (such as extraterrestrial satellites, network land lines, microwave, and in-plant studios) is crucial to the operation of a television network. The new NBC Transmission Center provides direct monitoring access to 120 video inputs and 6 independent output channels (expandable to 10). It also provides 26 video processing amplifiers, and includes 30 source selectors for any of 100 inputs to 30 user entities; and a character generator "menu" display for supplying updated information on resource reassignment and emergency change. The use of patch cords has been greatly reduced compared to past practice.

COMMON throughout broadcasting — whether considering a large multi-million dollar major network, a small independent station, or a larger network affiliate — there exists some point in the system where video and audio signals are either received in preparation for a program, or are transmitted external to the plant as programs. At NBC these critical points, at the confluence of all the network's international and domestic activity, are generally known as the *transmission center*, or *master control*, or simply *transmission*.

Historically, these transmission centers evolved from the early days of network radio. It was network programs, remote pickups, sporting and news events, and all manner of entertainment — composed in the format of a radio program — that found its listeners through broadcasting. Hence, large areas of audio jackfields and yellow-faced volume indicators, supported by high quality audio monitoring amplifiers and speakers, were the characteristic of all audio transmission centers. The origins of television broadcasting practice may be found in radio.

Transmission organization

The plant organization and its relationship with the transmission function are shown in Fig. 1. Note that the internal workings of the plant core are independent of transmission. Transmission interacts with incoming network, satellite, and electronic news sources, and with outgoing local, network and special feeds. Fifteen processed inputs are fixed entries from transmission to the routing switcher, with another eleven to be patched as needed. The ten channel outputs are seen to link to the outside world through transmission. The studios, film chains, and video tape machines operate within the plant system, independent of transmission. Also, output channels are switched at the Switching Central control point. Thus the new transmission concept is not involved with inter-plant operations — an important departure from past practice.

Transmission centers vary somewhat from network to network, to reflect a particular operational philosophy or to satisfy the interfacing necessary for a particular plant design. For NBC, transmission is one part of a new automated broadcasting plant: a technical facility designed to monitor and process all the incoming and outgoing television audio and video signals for the network and to provide the special arrangements which are an important part of almost every overseas or remote program. Particularly, a transmission center does not originate or switch programs.

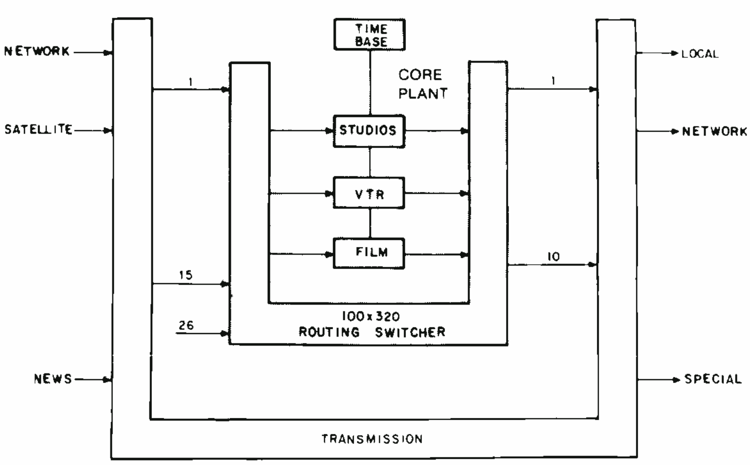

Fig. 1 — Relationship of the transmission facility with the plant organization.

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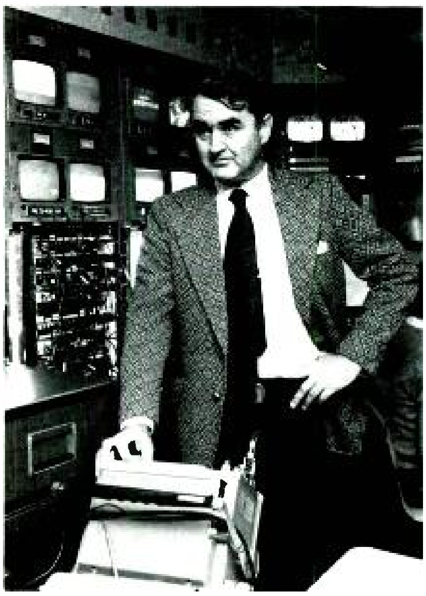


Robert Mausler, Senior Engineer, Technical Development Engineering Department, National Brodcasting Co., N.Y. graduated from the Columbia School of Engineering, where he also completed graduate work on pulse and digital circuits. Prior to appointment in his present position, Mr. Mausler worked for a number of years as an audio-video project engineer on a broad range of broadcast-related equipment and systems. His present work encompasses much of the present-day broadcast technology. Mr. Mausler represents NBC on a number of SMPTE, IEEE, and industry committees. In 1954, he received a testimonial from David Sarnoff for contributions to the development of color television.

Transmission functions

The functions of the transmission facility are diagrammed in Fig. 2; a photograph is shown in Fig. 3. The core operation of transmission involves the monitoring, video processing, audio selective mixing, audio selective interrupted feedback and testing of all input and output circuits. The dashed lines in Figs. 1 and 2 indicate the core plant.

The incoming video signal may require splitting, level adjustment, equalization, stabilization (clamping and setup adjustment), burst and chroma correction, and synchronization to the plant time base. As the outgoing video feeds have already been assembled into a program by a studio, signals merely pass through the transmission jackfield without further processing. At the jackfield, the signals are normalled to the network telephone company lines or to the studio transmitter link (STL) — a microwave connection to the local transmitter. Hence, video monitoring equipment must be provided to allow continuous monitoring of some signals and rapid-access monitoring to all signals within the plant, including those "on the air". Monitoring also includes signals of the other networks, received off the air.

Monitoring is a multi-dimensional requirement: in addition to the signal characteristics that may require processing, noted earlier, there are also picture quality, continuity, and time-base parameters to monitor. Picture quality may suffer, not only from low resolution, but also from degradation introduced in circuit links of network transmission. Therefore, linear and non-linear distortions, and the level of circuit noise become critical indicators of signal quality. Part of the facility must consist of high quality color-picture monitors, smaller high resolution monochrome monitors, and pulse-cross displays for observing the vertical interval. Waveform monitors are also needed for checking levels and some of the other parameters noted above, and Vectorscopes are used for checking color-signal encoding and differential-phase distortion. Monitoring of the subcarrier frequency is also needed to ensure adherence to the FCC rule that this frequency must be within a tolerance of ten cycles, either side of 3.57945 MHz, the color subcarrier frequency. This frequency is monitored directly by a high quality digital frequency counter.

The foregoing monitoring function of the transmission center is sufficient to provide the necessary continuity of operation. But, to maintain the high standards of picture quality now accepted routinely, specialized test equipment is integrated into the transmission center (see Fig. 4). Since the test signals may be monitored with the use of waveform monitors or high quality color monitors, throughout the system, they provide a rapid means for evaluating the technical performance of the complete system, or any subordinate part thereof. The signals are available as a source to any studio or may be directly switched to outgoing channels under the control of a release studio; or, they may be patched to the telephone video circuits directly for routine monthly circuit performance evaluation.

Information on equipment or facility change is also vital to plant operation.

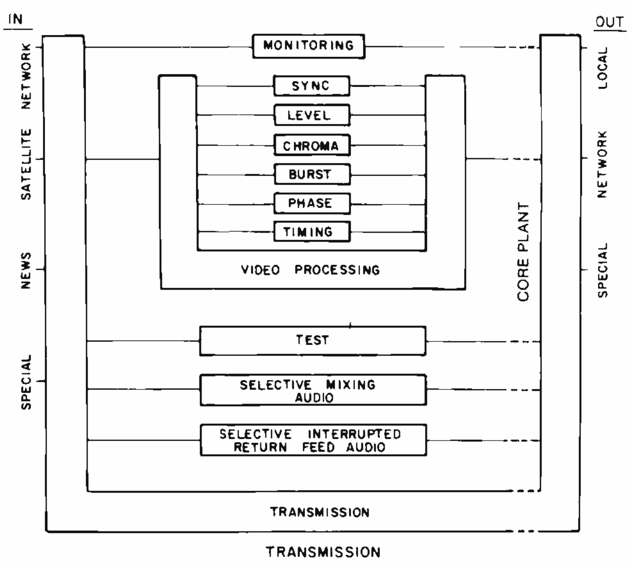


Fig. 2 (above) — Functions of the transmission facility. Fig. 3 (below) — Transmission center.

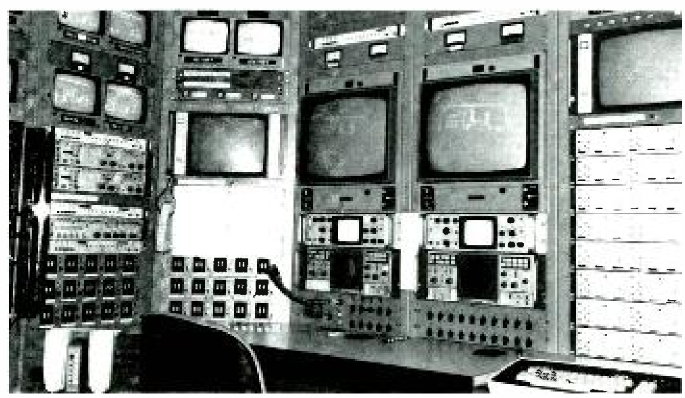
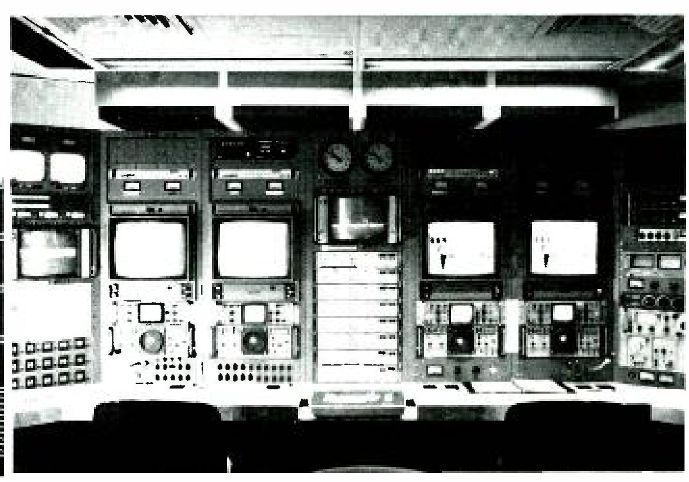


Fig. 4 (above) — Special test equipment is integrated into the transmission center. The signals generated by the test equipment include full-field color bar, window-modulated step, multiburst and grating; as well as sin² vertical-interval test signals (VITS), and the vertical interval reference signal (VIR). Fig. 5 (below) — Character generator keyboard is centrally located within transmission.



The means for disseminating this information, novel in concept and implementation, is by the use of a character generator. The character generator keyboard may be noted in Fig. 5, at the center of the operating area. The engineer on duty simply types out the "menu" (i.e., a list of changes or other actions) such as, "Washington Nemo now on MG46 in"; thus in the studio, the Technical Director will know that his Washington feed can be selected by dialing up input 46. Of course he has previously reviewed the "menu" by putting up the menu feed on input 96 of the routing switcher — its normal assignment. Note that studio personnel can determine vital information without the need to call anyone; in fact, anyone in the plant with a routing switcher output available (and there are 320 outputs) has timely facility change information available at all times.

As transmission is an interface to the outside world, so also it provides timing adjustments, when necessary, for phasing a studio source to an outside signal. Each plant source has the ability to select its time-base system; hence, 31.5 kHz phasor countdown units are used to set horizontal and vertical phasing of a time-base system by observing a special pulse-cross monitor which is referenced on one input, with the source on another input, thus displaying the mix and timing results. The pulse-cross monitors and typical displays may be noted in the center and extreme left of Fig. 5. Part of the daily transmission operation involves setting each of the network-owned and -operated stations by this technique, for phased operation with the New York plant. The timing is checked again just prior to the nightly news program, to correct for any drift or change in network path length since the early morning setup. Phasing is also necessary on "pool" broadcasts, for backup feeds, and on special sporting events. Integration of outside signals, including network, satellite, and live electronic journalism mini-camera microwave signals, may also be timed and referenced by processing through a frame synchronizer. These units, by using analog digital techniques with a one-frame memory (1/30 s), produce synchronous television signals from a nonsynchronous input. Two of these devices are part of the transmission facility and are often used in preference to the phasing method previously described. Inputs to the frame synchronizers are selected, at transmission, by means of thumbwheel control of outputs from the routing switcher. The frame synchronizer outputs are accordingly normalled back into the routing switcher whereby they become available to all studios similar to any other in-plant source. The basic circuitry for this operation and the use of test and other signals, from transmission, may be noted in Figs. 6, 7 and 8.

Video monitoring and timing system

The basic video monitoring scheme is shown in simplified form in Fig. 9. The four monitoring positions are shown in Figs. 3 and 5 as the four similar equipment racks. The four monitoring positions are designed into dual groupings to assure redundancy in case of equipment failure; they also provide extra monitoring positions required for extraordinary events, such as a national election or moon landing. Operating

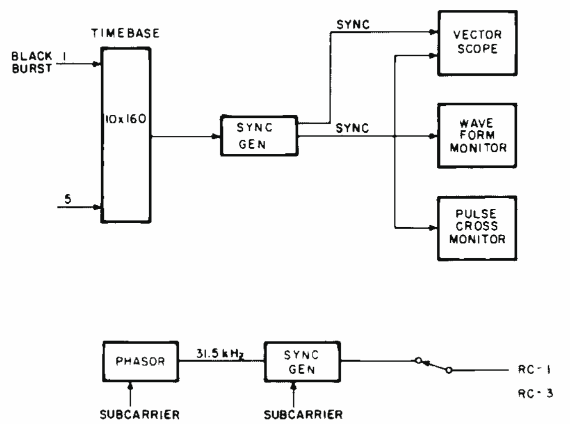


Fig. 6 — Video timing.

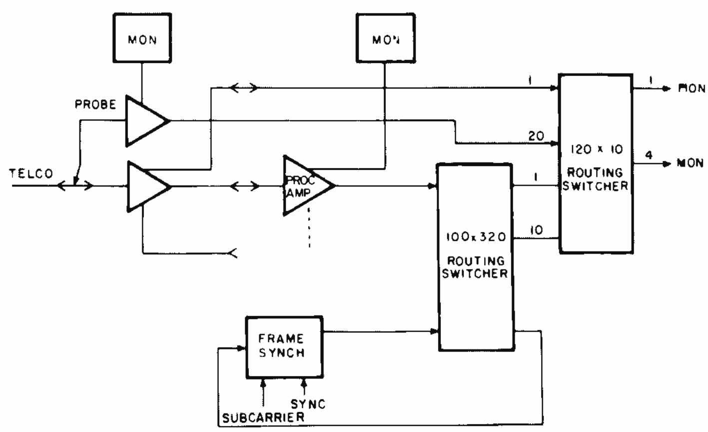


Fig. 7 — Video input.

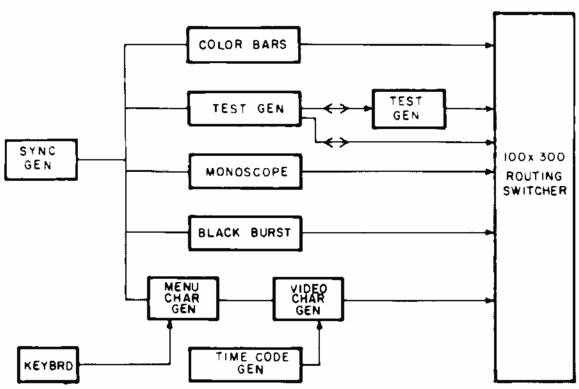


Fig. 8 — Video test facilities.

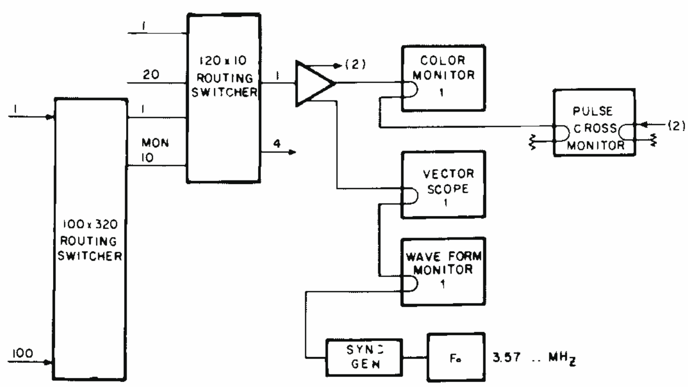


Fig. 9 — Video monitoring.

personnel are thus able to handle peak work loads without interference with each other. Note may be taken of the special 20 × 10 switcher subsystem of the master routing switcher. Transmisison has four out of ten of these special additional outputs. Therefore, transmission has an extra 20 inputs available for special monitoring, in addition to the normal 100 inputs to routing switcher. It is in this way that output channels are made available for monitoring, in addition to five patchable inputs and five of the plant time-base systems.

Further, one of the inputs is utilized as a 'probe' amplifier test position (see Fig. 7). The bridging probe, with its own monitor, serves the very practical function of giving the transmission engineer almost unlimited monitoring capability. It is, in fact, the only direct means to check an input at a jackfield test point without breaking the circuit. Vectorscopes, waveform monitors, and color monitors, are all crossfed on 'B' inputs from the other monitoring bus of the pair, thus providing redundancy on equipment as well as master-routing-switcher outputs. In fact, the four routing-switcher outputs to transmission are selected from each quadrant of the routing switcher, thus hedging against the loss of a particular quadrant of the massive routing switcher. Dual pulse-cross monitors are also provided with bus monitoring on the A and B inputs; thus timing problems may be handled by use of normal monitoring switching buses, without recourse to a special-purpose subsystem switcher otherwise necessary. Fig. 6 shows how timing reference for the monitoring devices is derived. Subcarrier and sync signals are supplied via a genlocked sync generator. This sync generator may, in turn, be referenced to any of the five plant pulse systems; thus all waveform signal monitors may be locked to any of the plant pulse buses including a genlocked system. This arrangement is particularly useful in using the pulse-cross monitor. The 31.5 kHz phasor countdown units should be noted. These units are utilized to achieve horizontal and vertical timing between a plant time-base system and a remote origination point. If the remote point has a phasor unit, that point will be "talked" into horizontal and vertical timing with the plant; however, for the pickups which do not have a phasor, the converse is true. The plant time-base system timing, instead, is adjusted to match the remote signal. When timed to the remote, the studio (or source) is then able to integrate the remote program with its signal.

As noted earlier, with the development and use of frame synchronizers, the practice of phasing is more infrequent. However, phasing horizontally and vertically to the remote, in conjunction with the normally complemented studio automatic video-delay-line remote input, is still required as emergency back-up. As indicated in Fig. 6, controls exist in transmission for the timing as well as emergency switching of the time-base buses (denoted as RC-1, RC-2, and RC-3). The time-base bus switcher permits any of the synchronized generators to act as the source for any time-base bus, thus providing redundancy for emergency back-up. Of course, the sudden loss of a time base would temporarily create a completely asynchronous condition for all equipments referenced to this bus, but only for the short time interval it takes to switch to the timed sync generator on the back-up bus.

A running check on subcarrier frequency is accomplished by using a frequency counter connected to a transmission monitor bus via a genlock sync generator. Thus the subcarrier frequency of any signal, internal or external to the plant, may be checked simply by switching to the signal on the monitoring bus with the frequency counter (see Fig. 9).

The special office monitoring needs of producer, program, management, and executive staff are also served by transmission. Two master routing-switcher outputs, controlled at transmission and dedicated as inputs to channels 6 and 12 vhf modulators, are used to provide monitoring by use of the plant off-the-air (rf) distribution system. Thus, all signal sources and the local and network outgoing channels are available on any office television receiver.

Video input system

The basic video input facilities are shown in Fig. 7. All video signals external to the plant appear at the transmission jackfield. An input distribution amplifier is used to split the signal for program and special monitoring purposes. The additional outputs provide monitoring of the incoming round-robin network feed for Broadcast Operations Control, and Switching Central (a release studio), and deliver the signal to a processing amplifier. A total of 26 processing amplifiers are available, with 15 processing amplifiers normalled to the routing switcher inputs through equalized input amplifiers. The additional 11 amplifiers are used for auxiliary purposes, such as off-the-air signal processing, or as spares when needed. One processing amplifier provides local WNBC-TV off-air monitoring for Switching Central. Continuity picture monitoring is provided from one output of the processing amplifier. The continuity monitors contінously monitor all input circuits—an important aid for rapidly diagnosing and localizing a signal problem. These monitors provide a visual reference which does not require switching action for access, but provides a rapid observation concerning signal problems. This is particularly important on input lines, since an actual circuit may not be used for significant periods of time between preliminary checkout and air use. Hence, a badly degraded picture (excessive smear, high or low level, bounce, low frequency hum, outage, noise, or ringing) will be noticed immediately by operating personnel. It is at the processing amplifier that signal corrections are made, if necessary, for establishing proper sync and video level (1 V peak to peak), burst amplitude and phase, chroma level, and setup adjustment. These adjustments are made while observing the signal waveform at one of the four monitoring positions. Therefore, the processing amplifier is a critical element in the signal transmission path, for after processing to establish signal integrity, the signal enters the plant via the routing switcher for use by any studio, or by Switching Central, for direct airing.

The increasing use of satellite communications has its counterpart in television broadcasting. The means to link an extraterrestrial signal into the plant, as a signal referenced to the local time base (hence, suitable for integration into normal studio program origination) on the effects bus, or as a camera switch, is accomplished by use of a frame synchronizer, which is shown in Fig. 6. The use of these devices is now fairly common and illustrates the role of technological advance in reducing complete problems to a simple basis. Prior to the use of frame synchronizers, transmission personnel had to conduct multiple phasing and genlock operations each day as described previously, and generally under conditions of duress. But now, the signals are directed through a frame synchronizer routinely. Frame synchronizers use digital techniques involving analog-to-digital conversion and a one-frame store memory. By reference to the plant and clocking circuitry, non-synchronous signals are outputted fully referenced to the local plant. As shown in Fig. 7, a frame synchronizer receives signals directed from the routing switcher, which is controlled at transmission, and re-enters the referenced outputs into the routing switcher for user call-up (such as a VTR for recording, or a studio for program integration). Thus, this remarkable device, nonexistant barely two years ago, is now an indispensable part of a modern transmission center. The device also corrects for satellite Doppler effect (which translates into signal path-length change) and for limited frequency offset of a source, such as a portable color camera.

Other elements of the input system include:

- Adjustable equalizers for correcting circuits on a temporary basis;
- Spare distribution amplifiers for emergency use and to cover special needs under peak load; and
- Spare equalized tie trunks each way between transmission and the main equipment room.

Video test facilities

Test equipment for checking and monitoring the technical performance of both in-plant and incoming circuits is vital to the operation of a high quality broadcasting network. Accordingly, there must exist a means to check, measure, and verify the quality of circuits. The means must be amenable to both in-service or out-of-service evaluation. Note in Fig. 8 that five inputs to the routing switcher consist of test functions.

1) A *color-bar generator* located in transmission and referenced to the plant time base through a genlocked sync generator, provides the basic full-field color signal used for the evaluation of television color reproduction in the system. The signal is basic to the setup of all color monitors and is often used to judge video tape playback quality. The color-bar signal, when decoded by a Vectorscope, will quickly identify differential phase and phase distortion. Additional outputs from the color-bar sync generator provide a black burst and grating signal, available at the jackfield. The grating signal is used for setting linearity of monitors, and indirectly, that of cameras.

2) The *full-field window signal* is widely used for a quick evaluation of circuit performance and for checking monitors, particularly at the low and medium frequency portion of the frequency spectrum. This test signal is provided by a test signal generator genlocked to a switchable time-base reference; thus, the signal may be used as a source locked to any of the several plant time bases. The pair of test signal generators together provide both full-field window and vertical-interval test signals (VITS), and any other full-field test signal that may be required. As fixed by present FCC rules, lines 17, 18 and 19 in the vertical interval may carry prescribed test signals. The VITS signal is, therefore, of great use for in-service monitoring, yielding information on circuit conditions without any interruption or adverse effect on the program portion of the video signal.

3) Line 19 contains a *vertical-interval-reference (VIR) test signal*, consisting of a color subcarrier reference burst of 40 IRE units. The VIR signal accompanies a program signal from its point of colorization throughout a transmission system. VIR is useful in evaluating possible distortion to a color signal in system transmission.

4) The *monoscope*, in use since the early days of television, generates a test pattern signal which is useful for evaluating the linearity and sharpness of monitors.

5) The *black burst* (BB) input to the routing switcher is used to continue color subcarrier synchronization on fades to 'black', and for video tape and other transmission functions. It is derived from the same genlocked sync generator which locks the color-bar generator.

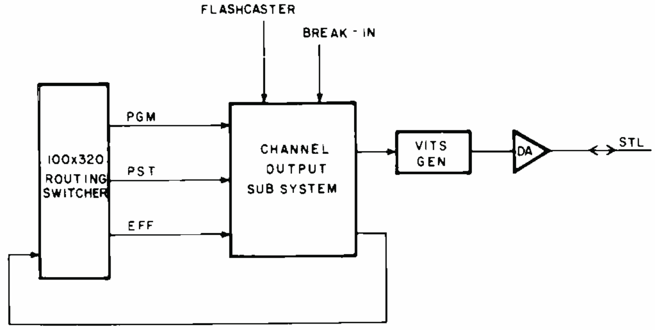


Fig. 10 — Channel output.

A video character generator is also shown in Fig. 8 as part of the test facility. The 'menu', described previously, which is used to inform users and Switching Central personnel of changes in the plant facility assignment, or other emergency information, also has a time-code generator output added to the signal format, thus supplying a valuable ancillary time service. The character generator is also put to use supplying the network with information on impending "hot" news bulletins, an important visual "alert" service.

Video-channel output

The video-channel output circuitry may be noted in Fig. 10. As noted earlier, transmission personnel do not operate or control the channel output system. These functions are automated and controlled at a separate entity—Switching Central. However, any picture or system degradation noted at Switching Central is called to transmission immediately for diagnosis and follow up. Note that an output channel consists of a subsystem switcher and effects unit; hence, program outputs may be dissolved or inserted between *program* and *preset*, and may be interrupted for flashcasting (e.g., "snow alert"). It is at this point that the vertical interval test signals (VITS) are added to the program video signal.

Final local and network channel outputs are monitored directly in transmission on continuity monitors, with an off-air feed provided at Switching Central.

Conclusion

In actual operation for several months now, the transmission facility has achieved its design goal of providing an efficient, responsive, control center, in a good working environment, using an optimum number of personnel.

The broadcasting plant core operates independently of the new transmission facility, contrary to past industry practice. The transmission center provides the one place in the system with responsibility for handling malfunctions in the interactive relationships. Under this concept, transmission is truly transparent between plant input and output.

New and versatile television transmission audio facilities

H. Krochmal| R. Mausler

Television audio must accompany the picture in television broadcasting—a fact sometimes overlooked. High quality sound is essential to network broadcasting. Thus, the new NBC transmission facility was designed and built to process, distribute, monitor, mix, and control hundreds of high quality audio signals, incoming and outgoing to the network plant.

AUDIO TRANSMISSION practice in television evolved from the experience and practices of radio transmission. Indeed, in many cases the same equipment had served both. With the growth of television network broadcasting, the old facilities were no longer adequate and often introduced problems because of conflicts in levels, impedances, and other limitations forced by the pressures of television programming for "more of everything."

NBC Engineering, in undertaking a complete plant rebuilding, was cognizant of the problems that existed with the split audio and television transmisson techniques that had evolved more as accidents of history than as planned facilities. Therefore, the new transmission center was designed to combine, in one facility, all incoming and outgoing audio and video signals of the network.

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In a significant departure from past practice, and in keeping with the new video transmission,[1] the new audio transmission is not involved in plant-core activity. Each of 100 signal sources in the plant are switched to 320 outputs within the Master Routing Switcher (100 × 320) either by local control in a studio, or by Switching Central (a release studio) under computer program control. Transmission is, accordingly, organized to concentrate on its important assignment of providing input, output, special-mixed-feed, and interrupted-return-feed supportive functions.

The audio transmission facility is designed to process, monitor, and check, easily (without special patching) some 400 input feeds and 100 output feeds which include six active channels each with a five-output fan out, special selective-mix feeds, and interrupted-return-feed circuits. The ability to monitor quickly any point in the system is crucial to maintaining a continuous high quality sound accompaniment to picture. While the basic layout planning provides four combined audio and video monitoring positions, actually, positions 3 and 4, with a fifth subsystem, provide the audio monitoring access to 75 normalled and patchable incoming line equalizers, 36 general distribution amplifiers, and 50 channel output amplifiers. The special audio monitoring and test facility is shown in Fig. 1. The jackfields, special-mix-feed matrix panel, and interrupted-return-feed priority selector panels, are shown in Fig. 2.

Audio input system

Close to 200 incoming telephone lines terminate in jacks, with 60 lines dedicated and normalled [routed through normally closed contacts on the jack panel] to equalizers; another 15 equalizers are patchable for special use. As shown in Fig. 3, the output of each equalizer is followed by a 30-dB level-setting pad which is used to set a standard −22 vu level at input to two distribution amplifiers. The outputs of the distribution amplifiers are normalled as inputs to both the master routing switcher (100 × 320) and a special mixing matrix (20 × 20) used for selective-return-feed circuit use. The outputs of the second distribution amplifier are available for special use at the jackfield, but primarily the amplifier is a backup spare to the first distribution amplifier of the pair. The volume indicator (VI) is the audio counterpart of the video continuity monitor and is dedicated to fifteen of the incoming lines. It provides a rapid, easily observable signal indication on the incoming circuit.

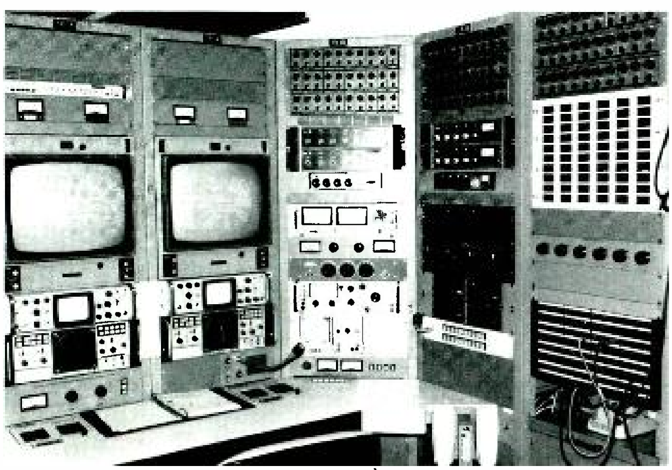


Fig. 1 — Special audio monitoring equipment (right) is conveniently located within the transmission center. The line-input monitoring selector panel may be noted at the bottom of the canted rack. The panels at the top of the three right-hand racks are input-line-level setters.

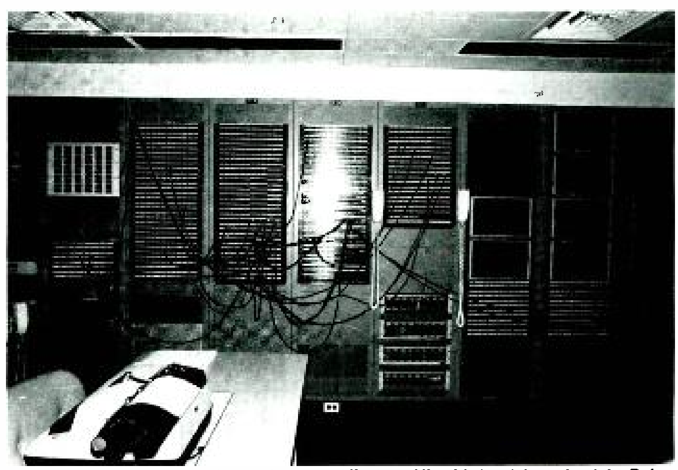


Fig. 2 — The mix-feed-matrix panel appers at the top of the third rack from the right. Below it, and in the adjacent racks to the right are several interrupted-return-feed priority selector panels. Also shown are the four audio-input jackfields.

A branch-off of the level-setting pad output is also used as an input to a special input-line-monitoring system (100 × 1).

All input levels to the three switching systems are +10 dBm at 150-Ω impedance. These are standard impedances and input and output levels throughout the audio system, with few exceptions.

Audio output system

On each of the present six outgoing channels, three outputs from the master routing switcher are processed by a channel output subsystem (Fig. 4). The subsystem is under computer control, and may be used for break-in, announce studio, or audio tape cartridge interruption or override, in addition to selection of the program, preset of effects bus outputs from the routing switcher. The channel subsystem switcher is followed by a 2 × 1 switcher which allows a full facility special-event studio interrupt of the outgoing channel feed. Output line levels are +8 dBm at 600 Ω; the levels are +10 dBm at 150 Ω for all other in-house use. Approximately 200 output lines include regular and emergency feeds to the studio transmitter link (STL) line for the aural transmitter at the Empire State Building; split television network audio for AT&T distribution to NBC-owned and -operated stations; some 35 equipped lines to AT&T for satellite and other special cirucit use; and several undedicated spare lines. In addition, there are a total of 36 patchable general distribution amplifiers for miscellaneous in-house use. These distribution amplifiers also operate at +10 dBm 150-Ω input and output with one line output of +8 dBm at 600 Ω.

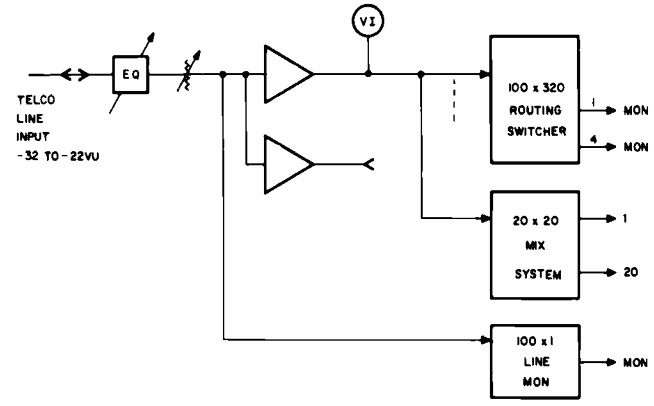


Fig. 3 — Audio input circuits.

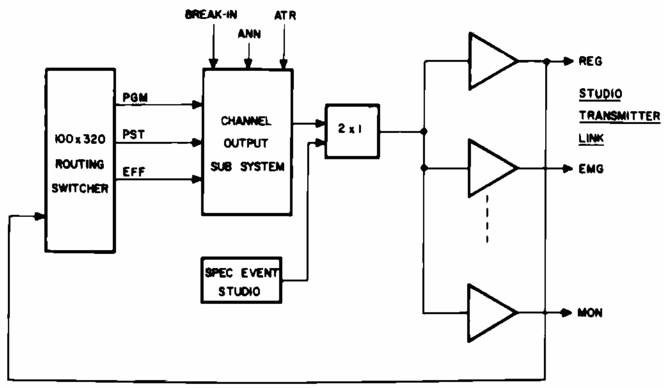


Fig. 4 — Audio output circuits.

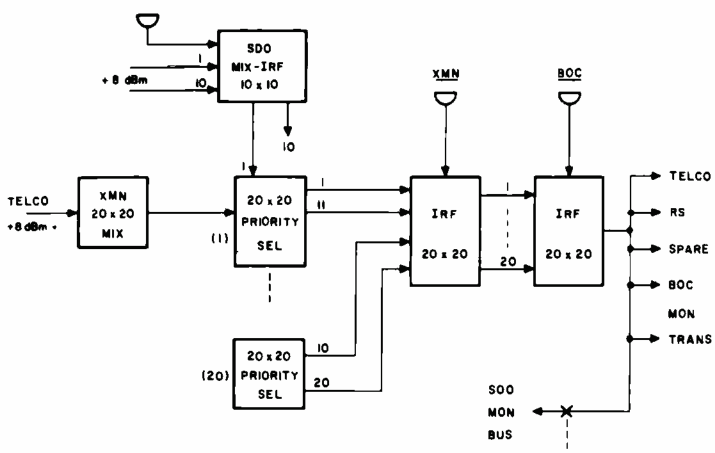


Fig. 5 — Interrupted-return-feed system, which allows selective mixing of audio signals.

Interrupted-return-feed system

A very important part of audio transmission work involves the arrangement of selected mixed-signal interrupted-return-feed circuits for combined communication, cueing, and program monitoring. This service was also a part of previous radio and aural television transmission practice but never available in a convenient, inclusive, integrated facility as now provided. The IRF system is truly noteworthy. The system (Fig. 5) uses ten 20 × 20 passive matrix-priority-selector routing panels and one 20 × 20 mix-feed-matrix panel, all located centrally in transmission (Fig. 2). Each studio control room in the plant, transmission, and broadcast operations control (BOC), is linked via the priority-select and the IRF panels to an output return-feed line. The IRF panels allow any or all of the twenty incoming circuits to be interrupted. Thus, as shown in Fig. 5, BOC has highest interrupt priority, followed by transmission (XMN), with the studios in a given arrangement also assigned a priority. Priority means, for example, that enabling at the local-IRF panel in transmission (refer to lower microphone panel in the second rack from the right, Fig. 1), on a particular line (1 of 20), would interrupt all other users from any studio attemping to speak simultaneously on that line. The order of studio priority is set up by transmission personnel at the priority selector panel.

It may be noted, from Fig. 5, that each IRF output line is also bridged to a separate set of IRF monitoring relays, which are normally enabled for the appropriate output line when making an initial crosspoint select for a studio and IRF line. When communication only is desired, free of program content, these relays are switched off at the transmisison center; hence, they become actuated only by pushbutton action when talking on the bus in the control room. These monitor lines are bridging to the IRF output line and are monitored at four positions in each control room by small panel-mounted amplifier selector units. The circuits include loudspeaker muting to prevent the acoustical feedback which would otherwise occur. Accordingly, a studio's involvement in any or all of up to ten conferencing arrangements can be monitored at each of the four positions in every studio control room, with or without program mix. In fact, quite aside from the primary IRF use, the system is commonly used for control room intercom grouping. The system also includes a "busy" tally for all control rooms on a given line. The busy tally indicates to all other users connected on the line that someone is talking. The tally does not inhibit or change the normal priority arrangement but does allow for the exercise of courtesy in the use of a circuit.

The development of the NBC IRF system once again illustrates the role of technological development in providing a better and more efficient means for handling routinely what otherwise had been a constant and difficult problem. The IRF system presently allows the routine coordination of much news, special-event, and other programming, by its ability to tie together easily and rapidly diverse elements of a production.

Producers, directors, BOC, transmission, and program coordinators, whether local or thousands of kilometers away, are conveniently grouped together by this outstanding technical development.

Audio selective mixing

An important and unique operational function of the audio-mix-feed system is the ability to mix from two to twenty program source signals. The mixing of selected program signals, without measureable crosstalk, provides the mixed feed inputs to all of the ten IRF priority-select system panels. Hence, a typical assignment might include a mix of a remote program signal from another city with an incoming satellite program signal, for input into the IRF system for a multiple-studio-interrupt loop. One or more of the remaining 18 mix circuits, in any combination, might be used to feed any of the other nine inputs to the IRF priority-select panels. Therefore, a combination of one or more selective mixes can be routed to twenty output IRF lines since there are two outputs per priority panel (ordered as 1 and 11, 2 and 12, etc) as already noted. The organization of any mix, including this example, is to provide a feedback of mixed program to a location, but excluding that location's contribution to the overall program. Hence, a mixed feed/IRF return feed, in addition to serving a cueing and communication purpose, is also used for direct studio monitoring, without acoustic feedback. In the above example, a mix between the local studio output, incoming satellite feed, and perhaps other feeds, would be selectively mixed to feed back, via the IRF system, to the remote city, without the presence of the remote city program component; and to all other locations external to the local studio, with similar selective mixing for each location.

The selective-mix system is an NBC development that is unique to transmisison facilities in this country and, with one known exception, to the world.

The system uses 20 input amplifiers, 400 alternate-action pushbuttons, a resistance matrix, and 20 operational/summing output amplifiers. The crosstalk figure, for any mix, is below system-noise level, which has been measured at better thatn 65 dB below a program level of +8 dBm.

Audio monitoring

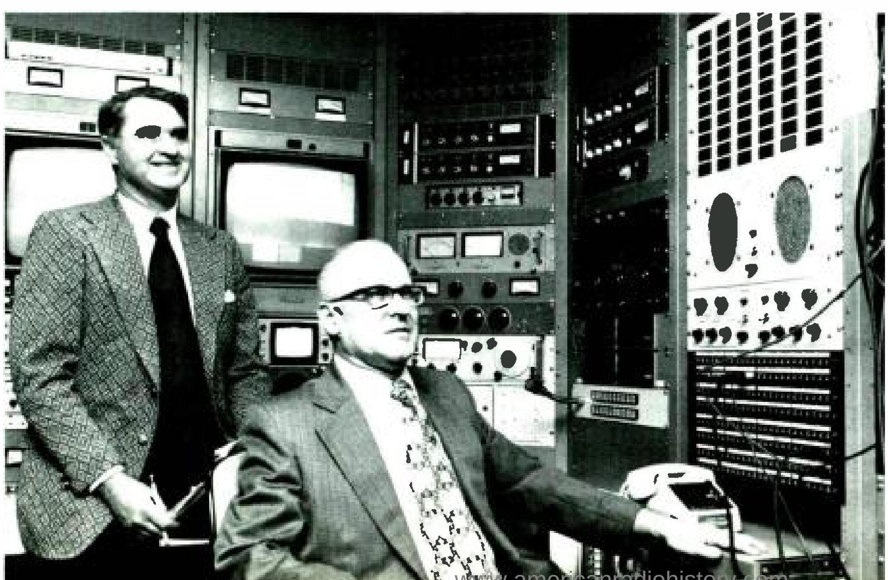
The ability to monitor quickly and easily almost 600 source, input, output, mix-IRF, and other signal points, is an important feature of the new transmission facility. The design of the transmission facility is based on the use of four independent monitoring positions, each position complete with a complement of video and audio monitoring equipment.

To provide maximum flexibility and freedom of interference between personnel under peak load or other unusual operating conditions, monitor positions 1 and 2 favor video facilities, with positions 3 and 4 (and the right-hand racks of Fig. 1) organized to serve audio needs. Position 3 also includes a sub-selector and auxiliary test 3 × 1 switch panel, which share monitor bus 3. This arrangement allows the monitoring of 60 normalled line equalizers and 15 patchable line equalizers as well as providing a rapid and practical way to test for line noise, distortion, and receive level, as well as frequency response. As shown in Fig. 6, the 4 × 1 switcher allows loudspeaker monitoring and VI indication for regular master routing switcher sources (100 circuits), for direct access to the equalized circuit outputs (75 active circuits), and for listening to the output of the special auxiliary test 3 × 1 selector. A patchable input is also available. The 3 × 1 test selector permits each of 100 incoming lines to be checked directly, or with 40 dB gain, or on an input with variable gain. The extra keyboard, 4 × 1 switches, and 3

Henry Krochmal, Broadcast Systems, NBC Engineering, New York, N.Y., graduated from Devry Institute, Chicago, Ill in 1943. From 1943 to 1950, he was engaged in the design and construction of special test equipment at RCA tube division in Harrison, N.J He joined NBC in 1950 and worked in the maintenance and operations activity until 1961. He is presently engaged in audio design and engineering. Mr. Krochmal is a member of the Audio Engineering Society.

Mr. Mausler's biography is given with his other paper in this issue.

Aurhors Mausler (standing) and Krochmal.



× 1 switch panel with VI, may be noted at position 3 (left-hand operating position) of Fig. 1. The regular and peak reading volume indicators for monitor bus 3 are above the color monitor.

Monitor position 4 is also designed to provide the special monitoring access particularly needed to maintain aural equality and continuity. In Fig. 1, at desk position 4, the additional keyboard for channel output selection and the switches for 4 × 1 sub-selection may be noted. The pair of regular and peak-reading volume indicators normal to position 4 may be seen above the color monitor. The circuit for position 4 is shown in Fig. 7. The addition of a 100 × 1 channel monitor selector and 4 × 1 sub-selector allow the monitoring of all present and future output channels and general distribution amplifiers, some 86 monitoring points, as well as providing a patchable and test signal input.

Additional monitoring for the 20 special-mix input feeds, and for the 20 IRF-output line feeds, is provided by the group of four small bridging amplifier units in the second rack to the right of position 4, as shown in Fig. 1. Each of these monitors units has built-in ten-input selector switch. Therefore, when necessary, transmission personnel can conveniently listen to any of the IRF lines without disruption to the mix or priority selection arrangements.

The final quality arbiter on all aural monitoring is, of course, the human ear. In transmission, the quality of sound monitoring is judged by four RCA LC1C high quality loudspeakers at the monitoring positions, with a separate stand-alone JBL high quality loudspeaker at a fifth position for special use.

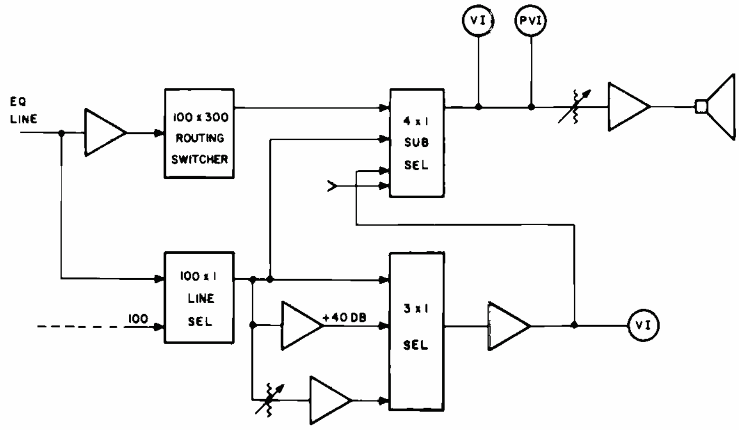


Fig. 6 — Monitoring position 3.

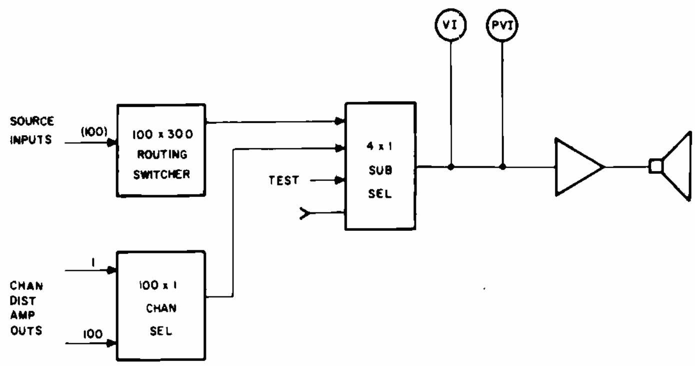


Fig. 7 — Monitoring position 4.

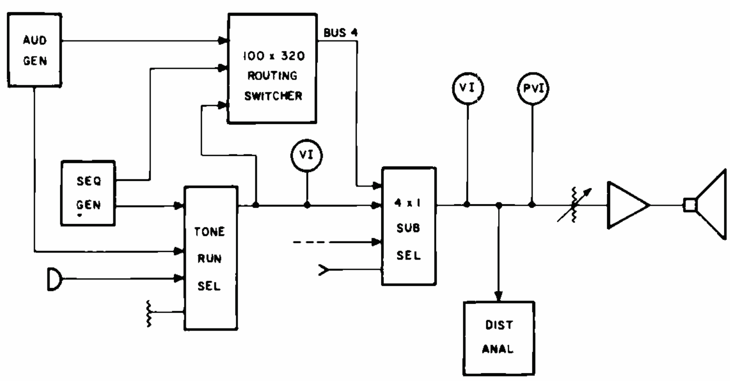


Fig. 8 — Test facilities.

Audio test facilities

A transmission facility must include adequate means for testing and measuring harmonic distortion, noise level, and frequency response, on the incoming lines as well as through the system. These facilities must be readily available and an integral part of the facility. Test and measurement procedures, in addition to the human ear, are the ultimate basis for maintaining high quality aural performance.

The built-in test equipment circuitry may be noted with reference to Figs. 6 and 8. Fig. 6 shows the procedure for testing incoming lines by use of the 3 × 1 subsystem portion of monitor position 3. This easily available means of checking the incoming lines is of special importance because the makeup of circuits is constantly changed, and by contrast to video circuit use, where visibility of performance is generally available, the audio line may not be listened to or used for a long period of time after initial checkout. The simplified circuitry of Fig. 8 shows that a distortion and noise meter is part of the monitor bus 4 system; hence, distortion and noise readings may be readily taken at any time.

Conclusion

The new television audio transmission facility provides an efficient operating system in support of stringent network requirements. This new facility can process a very large number of audio inputs and outputs, and provide the very important ancillary services of mixed program monitoring and interrupted return feedback. Signal processing, monitoring, and test systems are integral to the design and provide effective support for programming and operational needs. Some novel and original NBC developments contributed to the success of this audio transmission facility.

Communications in NBC Television Central

O.S. Paganuzzi

Improved communications for NBC's entire New York plant was a major goal of the recent NBC Television Central project. Throughout the planning, design, and installation phases, the operating modes of the existing communications subsystems provided a baseline for technical and operational improvements. Among subsystems discussed in this paper are production interphone, interrupt-of-return feed, engineering interphone, and intercom. Also discussed are specific problems of telephone interfacing, telecine and video-tape machine communications, and communication with remote areas.

O. Stephen Paganuzzi, Dir Broadcast Systems Engineering, NBC Television Network, New York, received the AB in Physics from Columbia University in 1949 and the MBA in Organizational Behavior and Finance from Iona in 1970. After two years experience in the design and production of electronic equipment, Mr Paganuzzi joined NBC in 1951 as Maintenance Engineer. During this period he assisted in the original installations of monochrome and color vidicon systems and early developments in video tape In 1960, he became a Facilities Design Engineer and worked on the systems design of telecine, video tape, radio, news, and audio facilities, and the total design of New York TV Studios 3A, 3B and 8G In 1968 he was made a Project Engineer and in 1970 became Director of the Broadcast Systems Engineering Department Mr Paganuzzi currently has the responsibility for Technical Capital Projects installed by the Network in New York.

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FROM THE INCEPTION of the NBC Television Central concept, the modernization of all intra-plant communications was handled as a separate, unique project with its own objective: an effective, reliable communications system throughout the Radio City plant.

At the start of the project, a design concept was developed which emphasized the operational interrelationships for each of the needed communications systems. Among the tradeoffs considered were system cost *vs.* installation costs; available installation resources; operating costs (including maintenance and staffing); space required for installation; interfacing equipment required, if any; availability; "newness" of the equipment; and environmental requirements.

After much deliberation, the telephone company was assigned to manage communications for production personnel. However, primarily because of its many unique requirements, the communications used by technical (engineering) personnel was designed and implemented by NBC Engineering. Of course, to achieve a "built-in" custom look and provide proper interfacing, NBC had to work very closely with the Telephone Company for both systems (Figs. 1 and 2).

Production interphone system

The majority of the communications equipment in the production interphone system is standard telephone type. This system is primarily concerned with communications for two production areas: Broadcast Operations Coordination, the supervisory hub of day-of-air operations; and the Executive Deck, a coordination area for the Studio 5N (ad-lib) Production Control Room.

Both the broadcast operations coordination (BOC) and executive areas can amplify telephone conversations on Telephone Company loudspeaker packages. However, when not used on-air, incoming program lines must also be amplified and used for talk-back communications.

Interrupted-return feed

Accompanying each of the twenty lines coming into NBC Television Central is an outgoing line which provides program monitoring to remote locations, usually for cueing purposes; these lines can be interrupted momentarily without causing incoming program discontinuities. Both BOC and the executive deck (as well as the transmission area) have the ability to directly interrupt these return-feed lines and thus talk back to the remote areas.

Not only do Television Central areas have this "interrupt-of-return-feed" (IRF) capability, but transmission can delegate control to any studio in the building to interrupt ten previously chosen positions of the twenty possible. The system used to perform the many simultaneous functions necessary (subselect control, tally return, monitoring, etc.) to produce this capability is quite extensive.[1]

Fig. 1 — This photo of the Broadcast Operations Coordination (BOC) office shows what can be done to achieve a "built-in" custom look with standard telephone equipment. In addition to standard make-up hardware ("broker" phones and call directors), a patch bay (right) has been assembled with standard parts and centralized within the console area. All Telephone Company instruments within the Television Central complex (as well as selected peripheral instruments in other operating areas) may be interconnected from this patch bay. Thus, allowance has been made for the expansion and flexibility required under heavy traffic conditions.

Fig. 2 — The Executive Deck is adjacent to the BOC area. This is used as a coordination area for the Studio 5N (ad-lib) Production Control Room. Communication facilities provided for the Executive Deck are of the same type as those provided for BOC; however, no patchfield is provided. A number of loudspeaker panels (shown on the upper turret) are capable of assignment by the transmission center to amplify any of twenty incoming lines. This system is an NBC program monitoring system, not concerned with Telephone Company equipment.

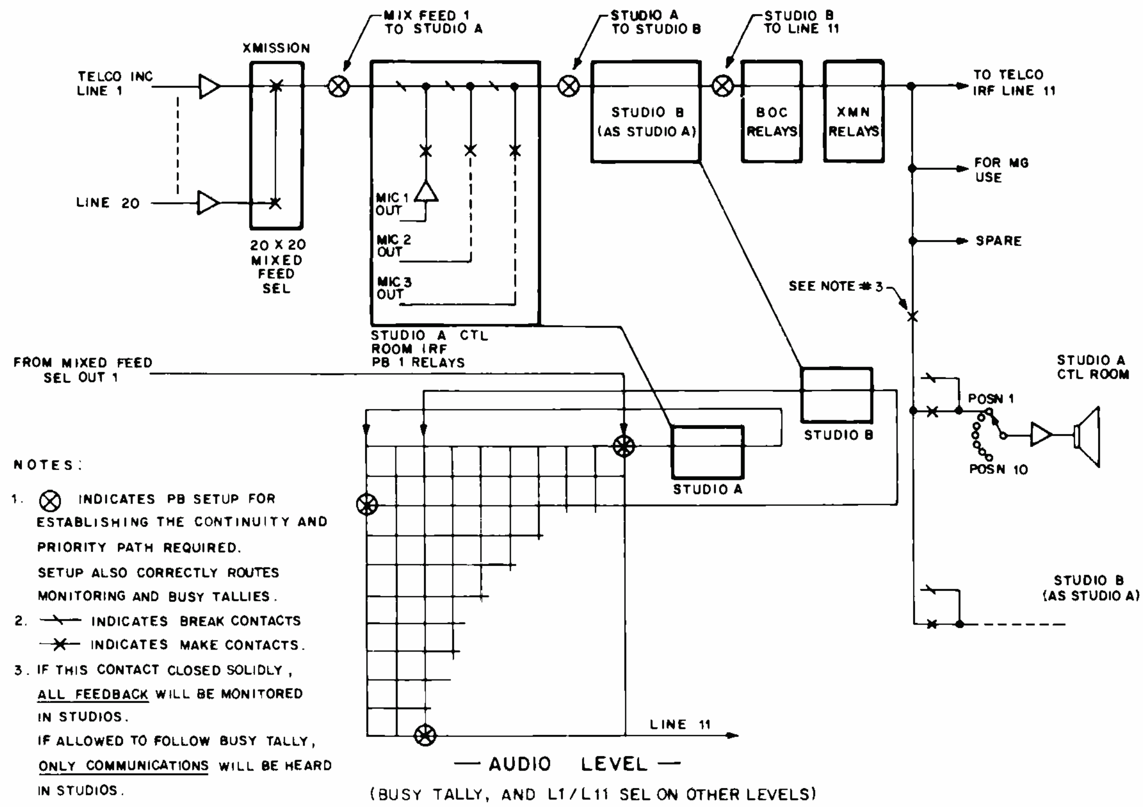

Fig. 3 — Interrupted-return feed system.

Since the IRF system is designed primarily for use by the Production Staff, when an outgoing line is not assigned, the system may be used as a studio-to-studio production intercom. It is also possible to set up a number of these communications subgroups for operation simultaneously within the main structure. Further, the delegation of control for mobile unit transmission is provided within the system. Assignment of these lines to any location provides transmitter keying control as well as proper modulation return monitoring.

Any standard studio audio console has the ability to make up a composite program return feed—the one that is interrupted during IRF talk-back. This might be a complete program feed, but more than likely it is specially made up of all sources except the remote location to which it is to be fed. This composite is sometimes known as foldback (or Music Feedback), but is commonly referred to as "mix-minus" audio by NBC. To provide greater flexibility than that provided by the studios, transmission is also supplied a mix-minus make-up panel (twenty patchable sources on the twenty IRF lines). These transmission make-ups can be substituted for normal sources, mixed with normal sources, or used for special monitoring/communications requirements. Figure 3 illustrates the interrelations of the system components.

Engineering interphone

The main body of the present NBC private system is concentrated within the technical (engineering) interphone system. This communications system starts at the cameraman's headset and extends out from the studio floor, through the control room, to finally fan out and encompass technical communications in video tape, telecine, remotes, and other studios.

Each studio has its own communications subsystem[2] (Fig. 4). Note that each of the studio stations incorporates an NBC-designed headset amplifier which performs an effective two- to four-wire conversion with transmit-receive amplification as well as sidetone rejection[3].

After carefully evaluating the existing studio interphone system, the following design philosophies for the new system were formulated.

1) The NBC intra-source house routing grid would be a two-wire, NBC-designed system. This was a result of three main considerations: total cost, interfacing required, and special performance characteristics desired.

2) The PLX switchboard, interfacing the NBC house system to outside phone lines, must have extensive conferencing capability and should be cordless (pushbutton setup). The switchboard system was obtained from a private-communications interconnect-system vendor. Such a system would cover the many outside-world interconnect contingencies (two-wire, four-wire, private lines, exhange line, dial pulse, signalling systems, etc.).

3) Each station location unit was to be completely self-contained with pushbuttons, amplifiers, loudspeakers, etc. and be capable of "push-to-talk" (momentary pushbutton or footswitch) transmission. When using a headset, the switch must be energized to maintain continuous two-way communication. Thus, the system will always return to a listen-only (disconnect) condition unless the transmit switch is

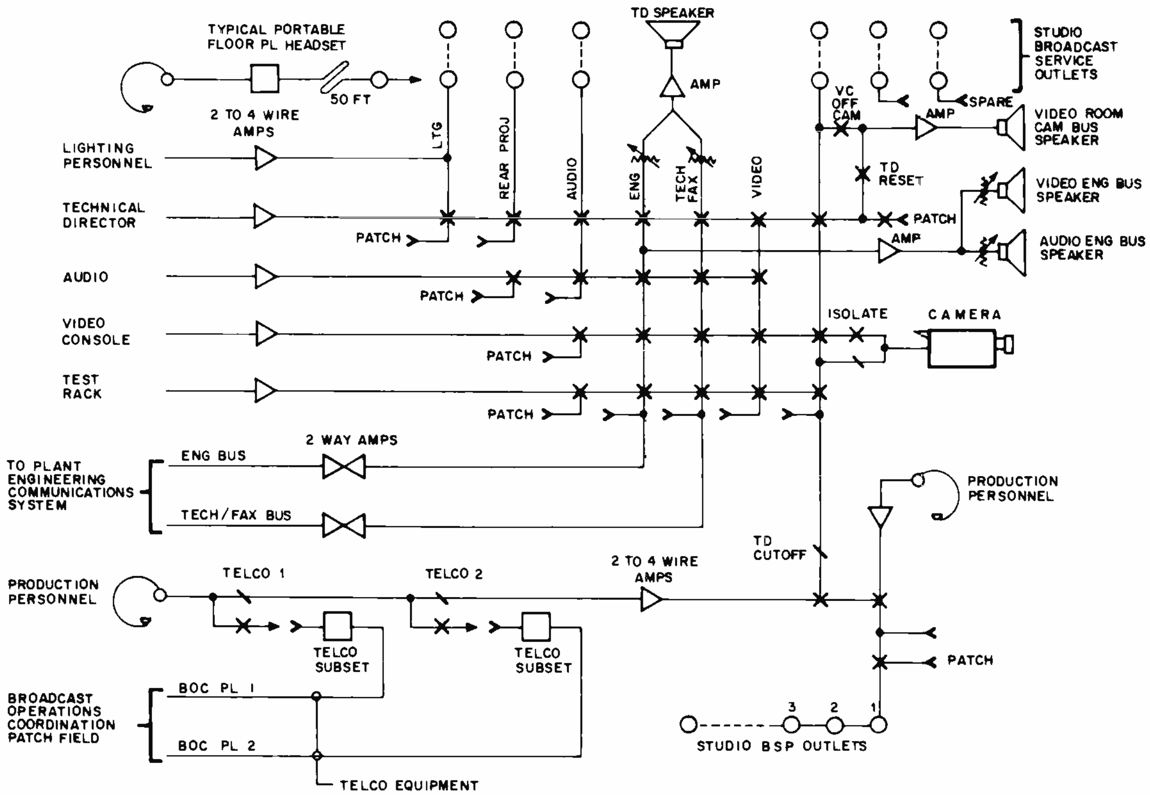

Fig. 4 — Studio engineering interphone system—simplified diagram.

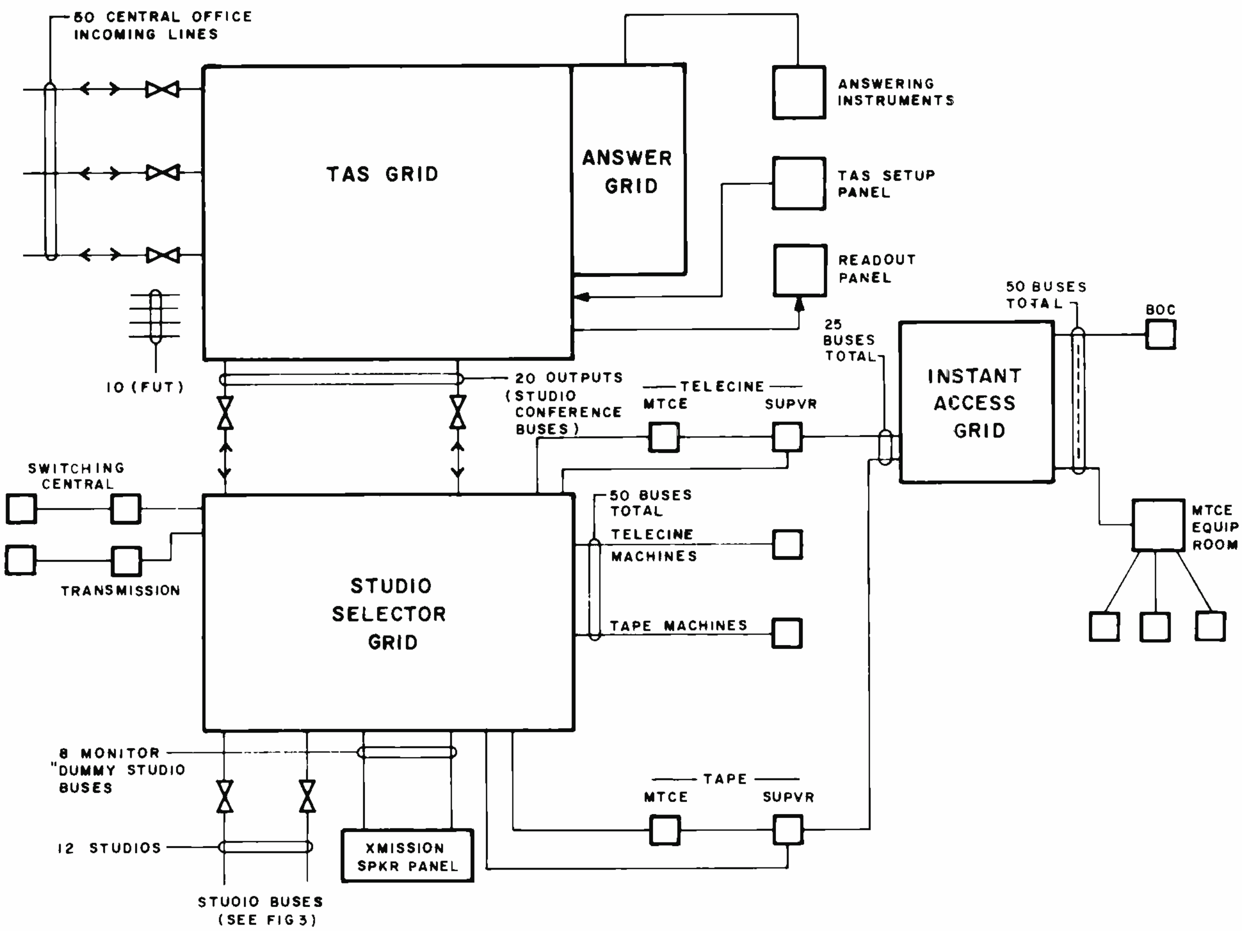

Fig. 5 — Technical interphone system. Note that many subsystems contribute to the major system.

deliberately operated. These stations economically provide in out gain adjustment (without elaborate anti-sidetone control systems) while solving the "off-hook" problem. At specially designated positions, voice operated switching can be provided to perform the push-to-talk function (transmission and Switching Central).

4) Because one amplifier is used to talk or listen within each station unit, automatic gain control is considered unnecessary. It might be useful for listening, but because of the high ambient noise existing in some areas, it was rejected in most talk cases—rapid in out switching of the AGC action would itself create problems. Further, empirical tests on a standard purchased system (installed elsewhere) have substantiated this position.

With these guidelines, the system was blocked out to include the interphone system and its major subsystems. The result is shown in Fig. 5. Note the various subsystems defined.

Instant-access intercom

The instant-access portion of the interphone diagram (Fig. 5) utilizes the same hardware as any other position; however, it differs in two outstanding areas:

1) A number of pushbuttons are provided on each station so that both the push-to-talk and sub-select routing (directing) of the call are done with individual single momentary buttons. Thus, although the equipment is like that of other Interphone stations, these stations operate as if they were fast-access push-to-talk intercoms—because of the directing action of the talk buttons. Additionally, the many buttons allow simultaneous talk to more than one location if more than one button is depressed.

2) Although instant access is a part of the engineering interphone system, a number of production positions are included; thus, it services a mixed group. This combination, however, adequately complements the immediacy of the day-of-air operation.

The instant-access intercom subsystem is really integrated within the main interphone system, but re-labeled to differentiate its special functional capabilities.

Video-tape and telecine supervisory

The supervisory subsystems shown in Fig. 5 are also functional re-definitions of the interphone system group. They are meant for technical use as a special category of the instant-access intercom. Both the telecine and video-tape supervisory desks have the ability to call any film island or video tape machine directly. Their calls, however, are mixed into the machine listen bus (only) and are not heard by the bus position with which the machine is working.

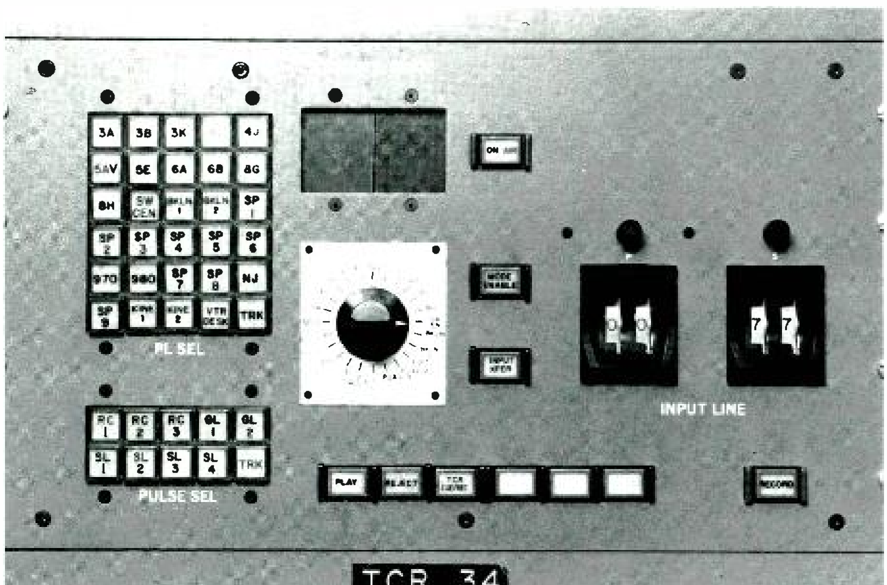

Fig. 6 — Machine assignment panel. Although this panel controls a video-tape cartridge machine, it is typical of any remote position.

There is also a direct-call position provided so that maintenance personnel in tape or telecine might be called in their respective local area shops. Thus, it is immediately apparent that the supervisory systems exist only on bus systems local to the tape and telecine area. The supervisors, however, are also part of the instant-access system.

Interconnect assignment

Returning to the interphone diagram (Fig. 5), note that each of the studio subsystems are separate entities (as are source machines such as telecine or tape). For operational reasons, the responsibility of machine-to-studio control interconnect has been delegated to the machine. Communications will either automatically follow (track) this interconnect assignment or assignment of communications may be made independently of control status. Assignments are made at the source machines on panels much like that shown in Fig. 6.

When a machine is assigned to a studio, communication is established on that studio's tech/fax bus (refer to Fig. 4 and 5); in fact, any machine assigned to a specific studio will appear on a tech/fax bus. Therefore, all assigned source machines are conferenced to each other as well as to the studio. This is an operational advantage because sub-selection by the technical director is not necessary; i.e., within the studio, one footswitch originates communications with *all* service machines. In actuality, with direct machine transport control, little on-air conversation is necessary, and most conversations are limited to pre-show directives and discussions.

The technical director has been given one other footswitch to originate communications to external areas. This switch activates "talk-out" on the engineering bus, and is primarily used to contact the Switching Central areas. Note that it is possible to patch through the transmission area—thus incoming sources may be split (machines on tech/fax, remotes on engineering, for example). Normally, unless a very large number of inputs is involved, the studio operates the show production on the tech fax-conferenced bus, with Switching Central conversations on the engineering bus.

Trunk assignment switchboard

When a remote area wants to establish communications with any in-house production area, his first action is to call in to the transmission area. With proper identification, the transmission man would then address the trunk-assignment switcher with two numbers: incoming-trunk number and studio-bus assignment. Appropriate busy lights and status readouts are maintained in transmission, but from that point on, the remote location will maintain communication only with the assigned control studio.

The TAS (Trunk Assignment Switcher) makes possible the direct conferencing of any grouping of sixty incoming lines (combinations of private lines, normal telephones, leased lines, etc.) to any of the studio buses, or to a group of "dummy" monitoring buses. In number, the switcher is a 60-input × 20-(conference bus)-output four-wire grid. The system will allow the full input complement to be assigned and conferenced simultaneously on any studio bus without perceptible loading. No input trunk may be simultaneously assigned to more than one conference bus unless special splitting operations are performed. The capability for fast reassignment of trunks makes it highly unlikely that multiplexed operation would ever be required; but if it were, the stuido buses involved would be tied together unless special bus conferencing configurations were used.

The monitoring buses are each outfitted with a bus "riding" loudspeaker. If communication to transmission were originated by normal telephone or ring-down private line, signaling would be normal. If no ring circuit is involved (the majority of cases), the expected incoming circuit would be set up on a monitoring bus and the loudspeaker left open. When connection is made at the remote-end, immediate aural contact is made with transmission, and further routine procedures may be continued.

All TAS levels are maintained constant by the use of hybrid amplifiers. This is in keeping with our general philosophy of "constant-level" adjustments, and amplifiers exist at various system points for this purpose. Although not continually adjusted, level-set controls are presently necessary for ease of subsystem interfacing within a dynamically improving plant.

Other subsystems

In addition to the production and engineering systems described, there is also provided for each technical area a TOE (technical operations and engineering) telephone terminal, an SOS phone (emergency alert), a production private-line (PL) terminal, and a standard telephone instrument. The standard telephone instruments are normally multi-button types, and the terminal positions are made to appear on these buttons along with the central exchange lines.

The TOE is a Telephone-Company-supplied in-house phone system, primarily for technical use—two-digit, non-blocking dial-in. The production PL is also Telephone Company supplied, and includes the other end of the BOC patch-bay trunks previously discussed.

These systems provide extra convenience under normal conditions, operations expansion under full-load conditions, and redundancy under emergency conditions; they are very necessary to the entire operation.

On the other hand, with the updating of plant communications, the NBC-designed SOS system is less important today than in the past. The system provides a special red-colored handset in each of the technical positions. Should any of these handsets be raised "off-hook," an alarm is operated in transmission and in maintenance and an annunciator in transmission identifies the instrument location. A loudspeaker in transmission and maintenance allows aural monitoring as well. An answer by either location drops the alarm but maintains two-way communication. Disconnect of all handsets resets the system for the next operation.

Future considerations

The private systems that have been installed have been operationally accepted. Their positive acceptance is primarily the result of the custom-fit to operational needs. System return and savings (alone) certainly justify the original installation expenditures, but there is always room for improvement. The stations as designed are relay-operated. We are working on future units that will be totally solid-state and compatible with our present units. The studio two-way amplifiers are NBC-designed hybrid types, and although quite stable, subject to the eccentricities of hybrid feedback cancellation. We are working on more innovative approaches with which great immunity to line-impedance variations might be gained. Of course, there are continuing analyses to determine the feasibility of building other private systems and upgrading the present system.

It must be remembered that little more than a year ago, much of the engineering for Television Central was not committed to paper. Because of the short turn-over time imposed, it was necessary to produce "fail-safe" systems — systems which, although in many cases "brute-force", were suprisingly adaptive, possibly innovative in application, but certainly dependable. With the completion of the project, and more time to breathe, we can refine and produce more sophisticated products, especially those products which will have repeated demands in every new project installation.

We are also learning a great deal about the operation of the new installation: what was previously absolute is possibly no longer necessary. Push-to-talk communications produce more disciplined conversations, short and to the point (diversity possibilities?); requests for more one-direction, non-mixed bus conversations are being expressed; etc. These new considerations will certainly influence further designs and, as always, be taken in stride.

Acknowledgments

In the accomplishment of this major system in a remarkably short time frame, I should like to thank the TCM Communications Subcommittee for their rapid conclusions, and for the implementation of same; the Broadcast Systems Staff, especially Mr. M. Negri, Manager, and Mr. F. Snell, who spearheaded the engineering of this project.

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PCM-multiplexed audio in a large audio-video routing switcher

R.J. Butler

Broadcast quality audio signals are now supplied to the NBC Television Network after pulse-code-modulation (PCM) processing. The 12-bit PCM system and the biphase modulation techniques described in this paper allow six multiplexed signals (video, four audio, and data) to use a common crosspoint while maintaining exceptional isolation among all signals. The heart of the system is a 32-thousand crosspoint (100 X 320) routing switcher which supplies the audio and video signals required for network services and supports all in-house production and recording needs for the NBC New York plant.

Robert J. Butler, Director, Technical Development, NBC Engineering, New York, N.Y., studied electrical engineering at New York University and joined RCA Service Company in February 1947. He was transferred to the National Broadcasting Company in March of 1952 and has worked in all phases of color-studio development. Mr. Butler was appointed Project Engineer in the NBC Engineering Planning and Equipment Development Group in October of 1966. He was named Director of the Group in 1969.

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LATE in April 1974, NBC put a large audio-video routing switcher into operation at its NYC plant. This new facility is unique in many ways. Of particular interest in this paper is the manner of processing audio signals (Fig. 1). Four high-quality audio channels complement each video channel and are encoded into 12-bit PCM digital signals and then biphase modulated on a 24-MHz subcarrier. The resulting rf envelope is mixed with the baseband video signal and routed as a multiplexed signal through the switching system.

Encoded audio

Each video signal is allowed a full 10-MHz bandwidth while the four audio signals occupy a 12-MHz band centered at the 24-MHz subcarrier (Fig. 2). After switching and routing, the two multiplexed components are separated by simple high- and low-pass filter circuits.

The energy extracted by the low-pass filters (below 10 MHz) is amplified and is the video output of the system. The rf energy between 18 and 30 MHz is demodulated to recover the original digital modulation. The digital train is then decoded into the four baseband audio signals by further processing.

One of the primary reasons for considering a multiplexed method of switching was the planned size of the switcher. 100 inputs were to be independently switched to any of 320 outputs. Also, experience has shown that each video input should be complemented by two or more audio counterparts. For example, when one video-tape recorder is dubbing the output of another VTR, both program and cue

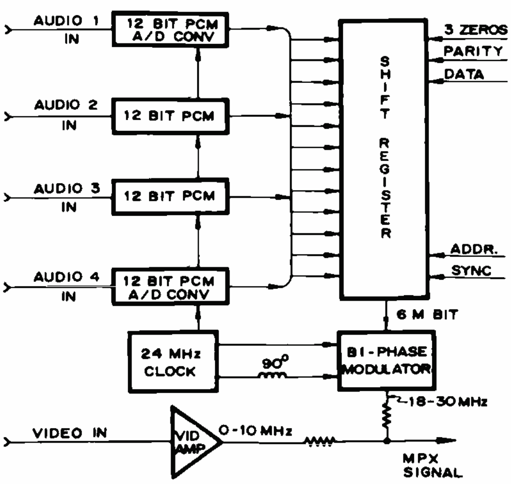


Fig. 1 — Multiplexing scheme for four PCM-encoded audio channels and one video channel.

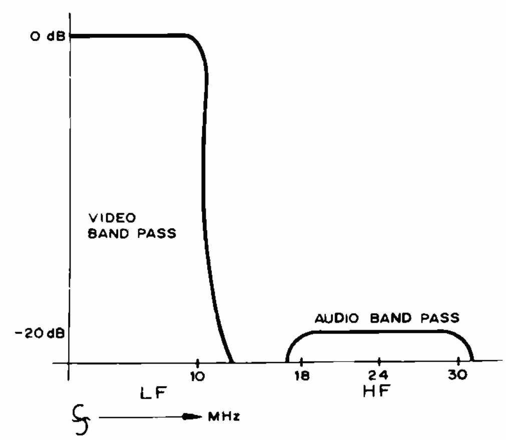


Fig. 2 — Spectrum used by the multiplexed signals.

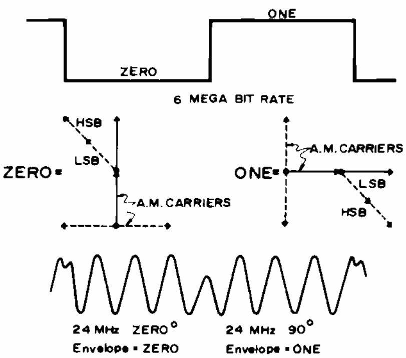


Fig. 3 — Zeros and ones are modulated as 90° quadrature components of the 24-MHz subcarrier.

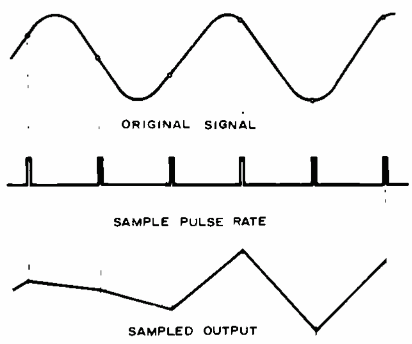


Fig. 4 — Sampling is too low resulting in intermodulation distortion.

Table I — Actual modulation excursion as a function of IM order.

30-kHz samples			*75-kHz samples*		
Sig. freq. (kHz)	*IM order*	*dB level*	*Sig. freq. (kHz)*	*IM order*	*dB level*
15	1	0	15	4	−41.2
13	2	−11.7	9.375	6	−58.5
10	2	−20.6			
7.5	2	−22.5			
6.0	3	−35.1			
3.75	4	−46.5			

audio channels must be delivered from the playback machine to the record machine. Video-tape and special requirements, plus many other plant operations, predicted the need for at least three audio channels for each video channel into the switcher. If independent crosspoints had been used for both the audio and video signals, the number of crosspoints required would have exceeded 120,000.

Many methods of multiplexing were investigated, but only one system demonstrated the ability to maintain high isolation between the video and audio signals when multiplexed. The isolation had to be high enough so that it did not degrade the 75-dB audio signal-to-noise specification. Appropriate filtering was sufficient to provide a 60-dB video signal-to-noise specification but only pulse-code-modulation (PCM) of the audio signals complemented by biphase modulation could sustain the audio signal-to-noise specification.

Zeros and ones within the PCM code were modulated as quadrature components of the 24-MHz subcarrier (Fig. 3). This 90° phase modulation of the subcarrier gave it virtual immunity to the differential gain and phase of the system.

PCM system

The quality of a PCM audio signal depends primarily on two factors:

1) The number of samples per second, and
2) The number of bits describing each sample.

Sampling rate

Fig. 4 illustrates what happens in a sampling system when too few samples are taken. The output waveform shows severe distortion and a level reduction. If this signal were the highest frequency of interest in a sampled system, the harmonic distortion could be limited by the use of filters. However, the modulation of the sampled signal falls in-band and cannot be eliminated by filtering. The modulation impressed on the sampled signal is the result of intermodulation (IM) between the sampling rate and sampled signal. The first IM order of distortion is the difference frequency between the sampling rate and the sampled signal. This IM product usually falls out-of-band and is of no consequence. However, the second order and the higher IM orders which result from harmonics of the sampled signal can fall in-band and result in a discordant sound. These unwanted IM products result in subjective comments such as: "strident," "harsh," and "too bright" etc., depending upon the subject audio and the listener.

It is interesting to note that this modulation effect falls off rapidly as the number of samples per audio frequency is increased. For a system in which residual measured distortion is to be less than 1%, this product must be at least 40 dB down. This condition is not likely to be achieved with less than five samples per audio frequency. In fact, because these IM products are the result of asynchronous sampling, and therefore not harmonically related they create a new discordant component more readily detected. For this reason such products should probably be at least 55 dB down.

Table I gives the actual modulation excursion as a function of the IM order for two sampling rates (30 and 75 kHz) used for a 15-kHz audio system. Only IM products which fall in band are shown.

Consider the case of the 30-kHz sampling rate with a 13-kHz input signal where there are 2.3 samples per audio frequency. The first order IM product will occur out of band and be filtered; however, the second order IM product will occur at 3.96 kHz at 11.7 dB below the original signal. This is a significant contribution, particularly when white noise may be present and pre-emphasis may be used. This projection assumes a flat response; if pre-emphasis is employed, the degradation will worsen in direct proportion to the degree of the pre-emphasis because the spectrum is down shifted by hetrodyning and is not removed by de-emphasis techniques.

It can also be seen, from Table I that if only two samples are taken during the period of one cycle of information, the amplitude of the sampled output will vary between zero and 100%. This is the case for a 15-kHz signal sampled at a 30-kHz rate. This is true since, in an asynchronous sampling system, the two samples will alternately be at the 0° and 180° sampling points and then be at the 90° and 270° phase sampling points. This sampling condition produces an output whose average value is one-half the original signal level and is 100% modulated by the first IM-order product.

Number of bits

The dynamic range and signal-to-noise ratio (S/N) of a PCM system are determined primarily by the number of quantizing levels the system can resolve. The least significant bit in the PCM binary code represents two quantizing levels: "zero" for the lowest level and "one" representing the lowest resolvable level. Each more significant bit added to the code doubles the number of quantiz-

Table II — Effect of number of bits on S/N and dynamic range.

No. of bits	*Quantizing levels*	*S/N dynamic range (dB)*
8	256	48.16
9	512	54.18
10	1024	60.2
11	2048	66.23
12	4096	72.25
13	8192	78.26

ing levels that can be resolved. The ratio between the highest and lowest level that can be resolved is the dynamic range of the system. Since the dynamic range of a PCM system is not a continuum, there may be signals sampled which have amplitudes that fall in between the quantized levels prescribed by the PCM code. These levels are always modified by the coding process to the next closest quantizing level. This distortion of the PCM process is called the "quantizing error" and is given as ± ½ the least significant bit. In other words, harmonic distortion is added to all sampled frequencies as a function of the quantizing error. Since many of the harmonics generated fall in-band, they represent noise and can limit the ultimate signal-to-noise ratio. Table II shows the relationship between the number of bits, quantizing levels, dynamic range, and theoretical signal-to-noise.

NBC system

To provide a flat frequency response to 15 kHz with a signal-to-noise ratio of at least 75 dB, the NBC system used a sampling rate of 75 kHz and 12 bits to describe each sample. The improvement in the theoretical signal-to-noise as given in Table II was realized as a result of the sampling frequency chosen, plus filtering, which limited the audio band to 15 kHz.

Originally, only three audio signals were required for each video input. Four audio channels were provided since four is a more logical divisor than three in most counting systems.

Fig. 1 shows, in single-line form, how the signals are multiplexed in the routing switcher. An amplifier limits the input video signal to twice its nominal amplitude and filters out any energy that may exist in the 18- to 30-MHz region. Four analog-to-digital (A/D) converters sample and convert four audio input signals to four separate 12-bit PCM codes. Each code is sequentially loaded into the parallel-to-serial shift register to make the digital train which will modulate the biphase modulator. Within the shift register one sync bit, two address bits, one data bit, a parity bit, and three zero bits are added to each audio sample of 12 bits to make one 20-bit audio word. Fig. 5 shows the bit pattern for the four successive audio words. There are four 20-bit audio words, 75,000 times a second, or six million bits per second.

The biphase modulator operating at the primary clock frequency of 24 MHz produces an envelope of rf energy from 18 to 30 MHz. This envelope is added to the video signal 20 dB down. The combined signal is multiplied by elements not shown in Fig. 1 so that it can supply 320 discrete crosspoints, one for each of the 320 outputs the switcher contains.

After switching, the combined signal is split by filters into two parts (Fig. 6). The low-pass filter allows all the energy below 10 MHz to be routed to the video output port. The high-pass filter allows the rf envelope from the biphase modulator to reach the phase-lock loop (PLL). The phase-lock loop locks to the 24-MHz carrier and responds to the quadrature phase shifts through its automatic frequency control (AFC) circuits. The AFC voltage variation is processed to reconstitute the original data train of ones and zeros. The data train enters the serial-to-parallel shift register and sequentially loads the digital to analog (D/A) converters. The output of the D/A converters is band limited to 15 kHz and becomes the four audio outputs of the system.

Just as a tv signal must be synchronized when it is received, the audio word needs to be synchronized when it reaches the serial-to-parallel shift register. In digital terminology, this process is called framing and is accomplished as follows. When a one reaches the end of the shift register (which is only 17 bits long) a clock-reset pulse is generated. The reset pulse clears the register to zeros and inhibits the 6-MHz clock used for shifting data in the register for a period of three clock pulses or 3 bits. If the signal is properly framed, this will occur every twentieth bit when the first bit or sync one reaches the end of the register. If the data word is not framed within the 17-bit register, there will only be a 50% chance that the twentieth bit after reset will be a one. If the twentieth bit after reset is a zero, a new reset pulse will not be generated and the twenty-first bit will reach the end of the register. The twenty-first bit may or may not be a one, and if it is a zero the twenty-second pulse will reach the end of the register. Eventually, the sync bit will be the twentieth bit after reset and framing will be established. This method of synchronization depends on the fact that only the first bit position in each audio word can continuously be a one. All bit positions other than the first must never continually be ones; otherwise false framing may occur.

System installation and test

After final test at the vendor's plant, the entire system was delivered to NBC in New York in October of 1973. The complete system for 100 inputs by 320 outputs is housed in 29 racks. Five identical racks house the input multiplexing cards, 16 identical racks house the 32,000 crosspoints contained on 20×1 crosspoint cards, and eight identical racks house the audio-output cards. There are approximately 5,000 printed-circuit cards used in the system of 13 different types. Each card is directly interchangeable with a card of the same type. Each input is powered by a separate plug-in power supply; each output is also powered by a separate plug-in power supply. The input and output power supplies are identical. Each card is only related to either one input or one output function. This means that removal of any single card of power supply can only affect one input or one output.

The "data" bit

To do a complete continuity check of the system by manual means is really out of the question and for this reason the "data" bit was added to the audio word. Each of the 100 data-bit inputs to the system is uniquely coded to identify which input reaches each output at any instant in time. The data bit was used to test continuity through all 32,000 crosspoints with the aid of a computer at the time of final test. Presently, the data bit is used to verify computer-activated crosspoints in our channel switching system.

Input assignments

The 100-input capacity of the system is presently assigned as follows:

Inputs	*Source*	*No. of inputs*
1-44	Video tape	44
45-56	Telecine	12
57-58	Character generators	2
59-60	Special cameras	2
61-72	Studio outputs	12
73-80	Channel outputs	8
81-95	Remote inputs	15
96-100	Test signals	5
	Total	100

Output assignments

The 320-output capacity of the system is presently assigned as follows:

Use point	*No. of outputs*
Video tape	44
Production studio inputs	168
Special technical monitoring	20
Special production monitoring	20
Channel switching	50
Not yet assigned	18
Total	320

At present, the switcher is used in all phases of the New York plant operation. Fig. 7 shows a typical processing path. Studio outputs are sent to video tape via the routing switcher for pre-recording.

At the playback time, the original recording video-tape machine, or a different one, will be the source of the program signal. These signals enter the routing switcher for the second time and are delivered to the Network channel facilities. For operational convenience, the Network signals re-enter the switcher so that they may be selected for use on the local station WNBC-TV. The audio signals at this point have gone through three complete analog-to-digital and digital-to-analog translations. The local channel output is also re-entered into the switcher so that the local signal may be monitored.

Technical monitoring has access to all steps within the process so that faults or distortions may be isolated. In the audio signal path, it is safe to say that the audio signals suffer less by the PCM processing than they do by a first generation video-tape recording.

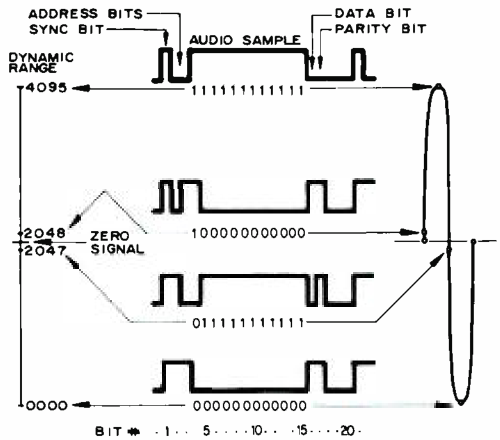


Fig. 5 — Bit pattern for four audio words. Non-return-to-zero (NRZ) code is used at a rate of 6 Mb/s.

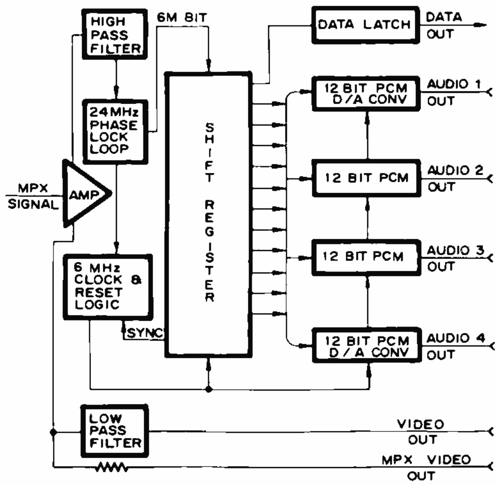


Fig. 6 — Video and audio processing after switching.

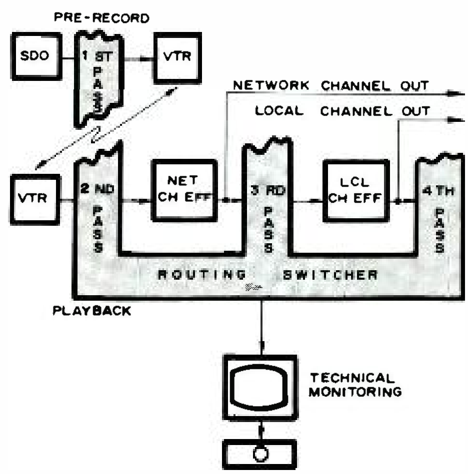


Fig. 7 — Typical signal processing through the routing switcher.

The 1976 David Sarnoff Awards for Outstanding Technical Achievement

RCA's highest technical honors, the annual David Sarnoff Awards for Outstanding Technical Achievement, have been announced for 1976. Each award consists of a gold medal and a bronze replica, a framed citation, and a cash prize. Awards for individual accomplishment were established in 1956 to commemorate the fiftieth anniversary in radio, television and electronics of David Sarnoff; awards for team performance were initiated in 1961. All engineering and research activities of RCA divisions and subsidiary companies are eligible for the awards. Chief Engineers and/or Laboratory Directors in each location present nominations annually. Final selections are made by a committee of RCA executives, of which the Executive Vice President, Research and Engineering, serves as chairman.


J. Weisbecker


R. Winder

Joseph A. Weisbecker
Dr. Robert O. Winder

For excellence of team effort leading to the development and marketing of an advanced microprocessor.

Mr. Weisbecker and Dr. Winder, RCA Laboratories, Princeton, N.J., are the team responsible for the COSMAC microprocessor, from research, through basic concept, to marketed product. Mr. Weisbecker foresaw the need for such a product, and began work on it in 1971. He then developed the microtutor, which is presently used as a sales tool as well as an aid in teaching microprocessor concepts throughout the corporation. Dr. Winder, as group head, promoted applications studies and contributed to the microprocessor's acceptance and practical application. He made further technical contributions, among them the development of software and training courses. He also led the team that developed an improved single-chip microprocessor.

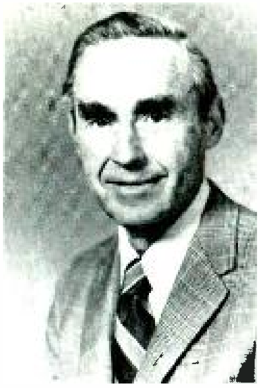

J. Keigler


L. Keyes

John E. Keigler
Lorne Keyes

For outstanding contributions to the development of a highly cost-effective communications satellite.

Dr. Keigler of Astro Electronics Division, Princeton, N.J., and Mr. Keyes of Government and Commercial Systems, RCA Limited, Montreal, in their respective roles as spacecraft and communications systems engineers have been the principal architects of RCA Satcom for over five years—from initial system concept to successful operation in space. They synthesized key RCA developments in spacecraft and communication technology into a communications satellite design which has significantly greater communications capacity per pound, thus lower cost per channel, than any other spacecraft now in service. Timely delivery and successful operation of Satcom reflect the accuracy and realism of their system definition.



J. Avins

P. Bingham

W. Gibson

M. Norman

C. Patel

Jack Avins, J. Peter Bingham, Walter G. Gibson, Marvin N. Norman, Chandrakant B. Patel, Robert L. Shanley II, Bernard Yorkanis

For outstanding team cooperation in bringing certain revolutionary video concepts from research to commercial product in the ColorTrak system.

Messrs Avins, Gibson, and Dr. Patel, of RCA Laboratories, Princeton, N.J.; Dr. Bingham, Shanley, and Norman, of Consumer Electronics, Indianapolis, Ind.; and Yorkanis of Consumer Electronics, Somerville, N.J., played key roles in the design, development and implementation of a unique "Transversal" filter to improve picture sharpness for RCA's new ColorTrak television receiver. This circuitry provides symmetrical peaking of picture detail with a "sharpness" control that symmetrically changes the amount of peaking without broadening or smearing picture edges. The key challenge was to achieve performance similar to that of broadcast studio equipment at a fraction of the cost. This was accomplished through the cooperative efforts of Consumer Electronics and the Labs.

R. Shanley

B. Yorkanis

Eugene O. Keizer

For inventiveness, technical contributions and leadership in video systems research.

Mr. Keizer of RCA Laboratories, Princeton, N.J., has a 36-year record of outstanding leadership, technical contribution, and achievement in areas of color television and video disc. He was involved in research on color television and is considered to be one of the world's experts on the subject. Among his 51 issued patents are two used in all commercial color television sets worldwide. A pioneer of the video disc system, Mr. Keizer has been a major contributor to all phases of this program since its 1965 inception.

E. Keizer

Albert M. Morrell

For continuing outstanding technical contributions to the design of color picture tubes.

Mr. Morrell of the Picture Tube Division, Lancaster, Pa., has, since joininged RCA in 1951, provided leadership in implementing picture tube design concepts of exceptional merit. Most recently, he conceived and implemented into product design a new, highly practical concept of color picture tube geometry. Mr. Morrell has a number of patents to his credit and, throughout his career, has made many important contributions to the development of the shadow-mask design and screen application techniques which ensured commercial success of the RCA color picture tube.

A. Morrell

hobby column

Most engineers have the unique ability to apply the talents and training of their profession to advantage in just about everything they do—from designing and building complex products to fixing lawn mowers. Engineers' hobby interests, likewise, often bear the stamp of their professional training.

Many times, an engineer's hobby is clearly an extension of his professional interests. For example, a list of RCA engineers in the South Jersey area who are ham-radio operators occupies several pages, and their activities could take several more—ranging from straightforward two-way communications to slow-scan television to complex repeater systems. We have reports that many engineers are applying microprocessors in unique and interesting ways outside of the work environment; we plan to cover this topic in subsequent issues. Lou Follet's satellite weather station (our inaugural hobby paper in this issue) is another example. Several years ago, Wendell Anderson of G&CS staff also built a satellite weather station.

Even hobbies that are not typically technical often benefit from the application of engineering skill. Model builders push for increased precision, efficiency and originality. Auto racing buffs develop electronic engine control equipment and timing devices.

In a general sense, the ideas and gadgets that engineers produce off-the-job are sometimes as clever and interesting as those they produce on-the-job. It is our hope, in starting this hobby column, to report on some of this interesting and stimulating work, and possibly create an interchange of ideas among RCA engineers who have similar interests.

The title of the column—"on-the-job/off-the-job"—implies the only limit (besides length, originality, and interest) on the material we will publish. Information—in the form of notes, letters, or full-length papers— should be related to technology and be of general interest to engineers.

We are waiting to hear from you. Address correspondence to

Editor
RCA Engineer
Bldg. 204-2
Cherry Hill, N.J. 08101

—J.C.P.

on the job / off the job: Weather satellite ground station

Weather satellite ground station

Home project yields high-quality cloud photos

L.H. Follet, Jr.

Lou Follet producing a photographic image from data transmitted from a NOAA-4 satellite pass. Cloud-cover photo (8 x 10-inch) is made on TXC-1 facsimile unit in foreground.

Polar-orbiting weather satellites equipped with a scanning radiometer (SR) gather radiated energy which is converted into photographic images of the earth's surface and cloud cover. Inexpensively equipped ground stations throughout the world receive direct transmissions from these satellites, day and night, in both visual and infrared ranges. The system is called Automatic Picture Transmission (APT). It is a source of valuable data for environmental study and weather forecasting. This article describes the technical operation of a typical APT receiving ground station. It emphasizes some of the practical considerations in system design and construction. The author has included several cloud-cover photographs produced by his own APT weather satellite tracking station in Mt. Laurel, N.J.

Ed. Note: Hobbies are usually pursued singlemindedly. But Lou Follet of the RCA Service Company has found an unusual hobby that marries at least three activities — meteorology, photography, and communications. Everybody talks about the weather, but Lou can probably speak with more authority than most people. You might say he is a cloud watcher. But he doesn't look up at clouds, he looks down at them via pictures received at his ground station from a National Oceanic and Atmospheric Administration weather satellite (NOAA-4) orbiting the earth at an altitude of 750 nautical miles. And what he sees at his home in Mt. Laurel, N.J., is the daily cloud-cover pattern of continental North America.

Lou's interest in cloud watching was sparked at a demonstration by NASA scientists of the Automatic Picture Transmission (APT) subsystem. The APT subsystem was conceived as a means of obtaining relatively good high-resolution cloud-cover pictures without a great deal of expenditure and without a lot of complicated tracking and receiving equipment. Lou contacted NASA and obtained the technical information for starting an APT ground station.

The next step was to find the parts to put the system together. However, Lou found that there are no manufacturers *per se* who make a complete APT system or even portions of the system. He then scoured the surplus equipment market and built his own printed circuit boards where there were none readily available. It took almost 8 months of Lou's spare time to construct the system at a cost of approximately $600. That was for the first time around. Lou feels he could do it again with less expenditure and much less time.

Although this article is intended primarily as a guide for those interested in the design and technical operation of an APT weather station, it should appeal to anyone interested in weather forecasting, photography, and radio communications. And for those readers who would like to construct an APT ground station, Lou invites inquiries and will be glad to share his experiences. Contact Lou at his home, 117 Berkshire Drive, Mt. Laurel, N.J. 08057. Lou is also listed in the *Radio Amateurs Callbook* under WA2BOG.

A SERIES OF Improved TIROS Operational Satellites (ITOS), designed and built by Astro-Electronics Division and operated by the National Oceanic and Atmospheric Administration, are furnishing environmental data useful in atmospheric research and weather forecasting. Aboard these meteorological satellites are a number of important sensors, including a vertical temperature profile radiometer (VTPR) which provides measurements of the vertical temperature structure of the atmosphere; a very high resolution radiometer (VHRR) which produces high-resolution imagery; and a solar proton monitor which detects and counts solar proton and electron emission.

ITOS satellites are equipped with an Automatic Picture Transmission (APT) subsystem which requires no command signals in order to function. Operation is completely automatic and data may be obtained by relatively inexpensive ground station equipment. The current operational ITOS satellite containing the APT subsystem is NOAA-4.

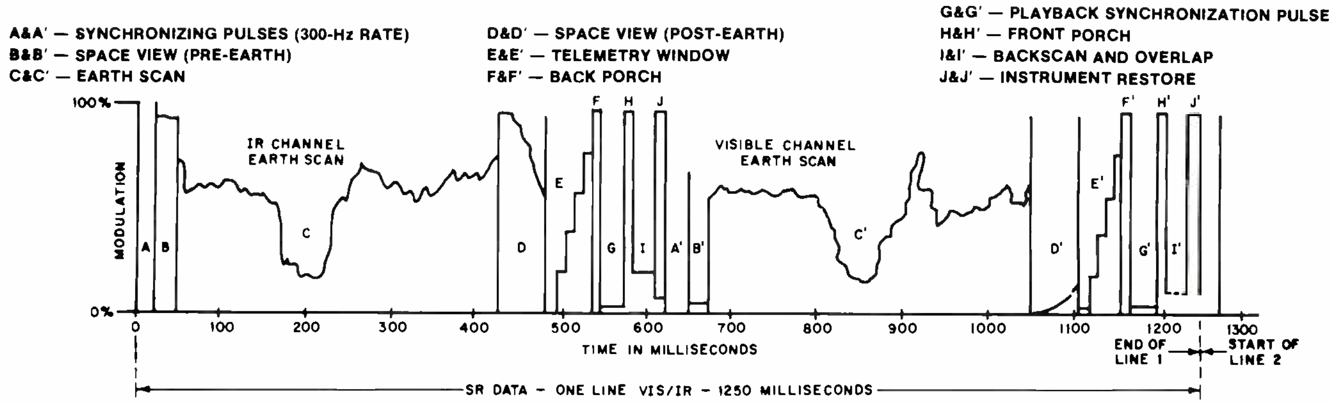


Fig. 1 — Scanning radiometer data output.

The APT subsystem aboard the NOAA-4 satellite uses a two-channel scanning radiometer (SR) sensitive to energy in the visible spectrum (0.5 to 0.7μm) and in the infrared window (10.5 to 12.5μm). Future spacecraft starting with the next ITOS series will fly with at least one radiometer whose visible channel spectrum will range from 0.49 to 0.94μm. In the radiometer, gathered energy is focused through a dichroic beam splitter which separates the energy into two data channels. The visual energy (VIS) is detected by a silicon photodetector. The infrared energy (IR) is detected by a thermister bolometer. The two data channels are time multiplexed over a vhf radio link to APT ground stations for direct readout.

The NOAA-4 weather satellite travels in a sun-synchronous orbit at an altitude of approximately 790 nmi. Global coverage is provided with descending north-to-south orbits occurring in the morning and ascending south-to-north orbits occurring in the evening.

Presently there are 119 countries throughout the world utilizing the services of APT. Of the approximately 200 APT stations operational in the United States, only a handful are manned by non-professionals.

Louis H. Follet, Jr., Mgr., Instructional Sales, RCA Service Company Commercial Products, Cherry Hill, New Jersey, joined RCA in 1954. Prior to his joining RCA, Mr Follet attended Syracuse University, Syracuse, N.Y. His military service during the Korean War included specialized training in broadband telecommunications systems at the Lorenz Company in Berlin and Stuttgart, Germany. Between 1954 and 1958, he served as a Mobile and Microwave Communications Field Engineer for the RCA Service Company and received assignments with RCA International Division in Caracas, Venezuela, and in Havana, Cuba. He also participated in the installation of numerous domestic microwave and mobile telecommunications systems for industrial pipelines, railroads, turnpikes, and utilities in the United States for the Engineering Products Division, Camden, N.J. In 1958, Mr Follet joined the Broadcast Division in Camden as Microwave Product Analyst and took part in the development of TVM-6 and TVM-13 television microwave relay systems. He was engaged also in the development of RCA's Instructional Television Fixed Service (ITFS) 2500-MHz relay equipment and served on the National Committee for the Full Development of Instructional Television. In 1968, Mr Follet became manager of Microwave Systems Engineering for Microwave Associates, Inc., Burlington, Mass. Mr Follet rejoined RCA in 1970 and is presently responsible for sales administration and market development of products used for closed circuit tv systems in industry and education. Mr Follet is the author of several technical articles and brochures relating to television products and communications systems design.

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Satellite transmission system

Data is gathered by the scanning radiometer on the satellite and combined with synchronizing and telemetry signals. The information is transmitted on an amplitude modulated subcarrier by the spacecraft's fm transmitter. This transmitter operates at a nominal power output of 5 watts in the 136.0- to 137.0-MHz Space Research band. The transmitter frequency tolerance is ±0.005%.

Time multiplexing of VIS/IR data is accomplished by feeding the output of the IR channel directly, and in real-time, to the satellite transmitter during the first half (180°) rotation of the SR. The visual data is also recorded during this time for playback during the second half of the SR rotation. The entire scanning process and readout is accomplished in 1.25 s (48 r/min), the IR and VIS channels each occupying a time interval of 625 ms.

The full data produced by one complete 360° rotation of the scanning radiometer is shown in Fig. 1.[1] Each complete rotation of the scanning radiometer produces one line of picture information in the APT readout system.

In addition to the telemetry window used for grey-scale calibration, a burst of seven synchronizing pulses (300-Hz square wave) is transmitted immediately preceding each of the two data channels. These synchronizing pulses occur in the space view preceding earth scan and are used by ground displays to help eliminate Doppler[2] and to minimize jitter produced in the visual channel by the magnetic recorder. They are also used to set the timing for horizontal sweep for displays using an oscilloscope and to facilitate drum phasing on mechanical/photographic displays.

Ground station RF system

Receiving antenna

The NOAA-4 satellite transmits a linearly polarized rf signal; however, the receiving antenna should be designed for circular polarization. Signals propagated through the ionosphere undergo a polarization change with energy vectors rotating with time through a plane perpendicular to the axis of transmission. This effect, known as Faraday rotation,[2] can be minimized by a receiving antenna designed for circular polarization. A common type of circularly polarized antenna for satellite reception is the helical antenna. This antenna exhibits excellent gain and polarization characteristics. For APT service, however, its chief drawbacks are a comparatively large bandwidth, an awkward input impedance (140 ohms), and the difficulty encountered in supporting it on a lightweight tracking pedestal.

Another antenna suitable for satellite reception is the cross-polarized yagi, or "criss-cross" antenna. This antenna is constructed of lightweight aluminum elements, making it ideally suited for use with light-duty tracking devices. Readers interested in the construction of an APT station are advised not to overdesign the receiving antenna. As forward gain is increased, antenna beamwidth is correspondingly decreased. Exceptionally high-gain antennas produce a sharp lobe but create difficulty in manually tracking the satellite, particularly on overhead passes where the rate of angular change is greatest. The following design parameters are given as a guideline for APT tracking antennas:

Antenna gain	10.0 dB (isotropic)
Antenna beamwidth	40.0° ± 5.0° (3-dB power point)
Frequency	130-140 MHz (optimized to 137.0 MHz)
Polarization	Circular right-hand
Circularity	± 2.0 dB

The author uses a modified criss-cross antenna with two separate eleven-element yagi antennas mounted 5/8 λ apart. (see Fig. 2). Separating the two antennas reduces interaction between elements and results in a balanced array with the center of gravity equally distributed between the two booms. This permits simplified mounting on the tracking pedestal. Circularity is achieved by inserting a 1/4 λ section of 50-ohm transmission line in series with one of the 75-ohm phasing lines and by turning the axis of each boom so that the yagi elements are at right angles to each other. The input impedance of the antenna at the "T" connector is approximately 52 ohms, and easily matched to readily available coaxial transmission line.

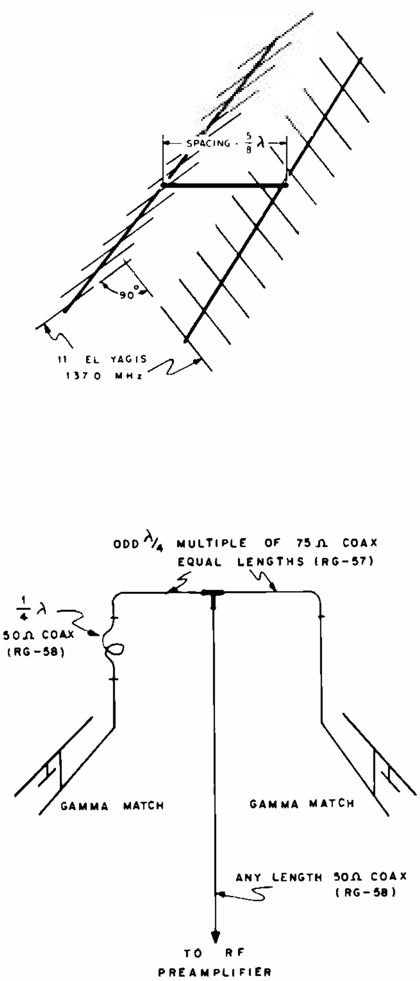


Fig. 2 — Antenna configuration of APT ground station.

Tracking pedestal

The combined weight of the entire tracking antenna including phasing harness and hardware is about 20 lb. It can easily be rotated by a heavy-duty tv rotator such as the RCA model 10W707. Two such rotor motors can be adjoined to form an azimuth and elevation (AZ/EL) pedestal. The pedestal can be mounted on any lightweight tv tower on a rooftop, using suitable mast guying, or at ground level with a simple vertical mast.

The antenna should have sufficient clearance to allow full orientation of azimuth and elevation without obstruction from trees or other obstacles. Clearance of at least 2λ is recommended to insure optimum resonant performance.

The rotor control units must be modified slightly to provide tracking scales which correspond to NOAA satellite orbits. To do this, the azimuth scale should be redrawn with two 360-degree scales, each a reciprocal of the other. North (N) and south (S) must be positioned at the top and midway between the two extremes of the rotator control. This permits continuous tracking through north or south without returning the antenna positioner to the opposite end of the scale.

To allow use of either the center north or center south scales, the elevation scale must encompass a total of 180 degrees (0°-90°-0°). Since direct overhead passes are tracked from horizon-to-horizon by the elevation control alone, no adjustment is required in the initial azimuth setting during these passes. Any pass with less than 90° elevation angle must be tracked in both azimuth and elevation.

VHF receiving equipment

Transmission characteristics of vhf signals propagated through the ionosphere and the troposphere include a number of harmful fading mechanisms including angular changes in wave polarization (Faraday rotation), absorption, refraction, scintillation, and scattering. These deterents become quite critical when tracking the satellite at low elevation angles where path losses can approach −150.0 dB (see Fig. 3). Under these conditions, the signal-to-noise (S/N) ratio may fall below acceptable levels, and noise will be introduced resulting in poor quality images. Additional path transmission characteristics are shown in Table I.

A low receiver noise figure is essential so that acceptable S/N can be maintained during portions of the orbit when the signal strength is minimum. Highly acceptable rf preamplifiers incorporating J-FET transistors are available on the market. Typically, they yield approximately 15.0 dB gain with a noise figure less than 2.0 dB. It is important to keep the input and output terminations carefully matched and to physically mount the preamplifier as close as possible to the antenna. Bandwidth filtering of ±2.0 MHz is recommended.

The fm receiver is designed to receive operational satellite signals in the Space Research band. Receiver sensitivity on the order of 0.5μV/20-dB quieting is generally adequate, although every effort

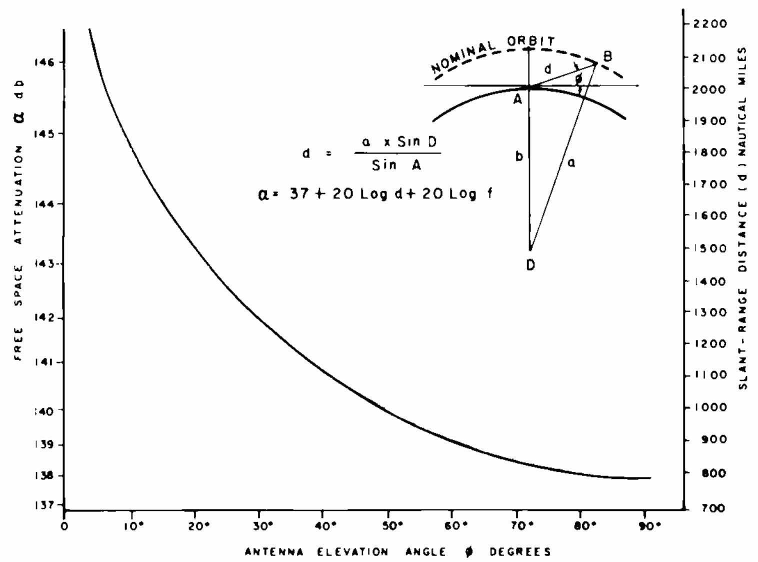


Fig. 3 — Free space loss as a function of path distance and antenna elevation.

Table I — Summary of path transmission characteristics.

Satellite	NOAA-4
Carrier frequency	137.50/137.62 MHz
Orbital altitude	790 nmi
Free space loss* (=37 + 20 log d + 20 log f where d is distance in miles, f is frequency in MHz)	142.0 dB
Miscellaneous losses	3.0 dB
Total rf losses	145.0 dB
Receiver antenna gain **	10.5 dB
Net path loss	134.5 dB
Transmitter power gain, (nominal 5 W)	37.0 dB
RF carrier power input to receiver	−97.5 dBm
Equivalent noise input from:	−108.7 dBm
Receiver noise factor	2.0 dB
Noise bandwidth	2.0 MHz
Noise temperature	490 K
C/N ratio	11.2 dB
S/N ratio pp/rms (1.2 KHz)	40.0 dB

*Nominal values for 1300-nmi path (antenna elevation angle 30°)
**Includes nominal 3.0-dB polarization loss

should be made to obtain better sensitivity.

The fm peak carrier deviation of the satellite APT transmitter is 9.0 kHz ± 1.0 kHz. The occupied bandwidth of the rf carrier is approximatley 27.0 kHz, requiring the fm receiver to be designed for a linear i.f. response of approximately ±15.0 kHz minimum. Full fm detection is essential. Slope detection should be avoided.

An important consideration is the effect of Doppler shift in the fm carrier. Unless automatic frequency control is incorporated, doppler shift may cause nonlinear i.f. response, clipping, and possibly loss of subcarrier level. Increasing the bandwidth of the i.f. amplifier is not always recommended due to the resultant exponential increase in system noise. If automatic frequency control is not provided, it may be necessary to monitor the dc output of the discriminator and make periodic zeroing adjustments of the local oscillator during the orbital pass.

A means should also be provided in the receiver to monitor relative signal strength. A dc voltage can usually be obtained from the second fm limiter stage that is roughly proportional to the rf signal strength. Most fm receivers designed for operation at satellite frequencies have at least two stages of fm limiting before the discriminator. Generally, the second stage provides the best indication of relative signal strength as the first stage reaches saturation under comparatively low input signal levels. Any good dc milliammeter may be used to monitor relative signal strength provided precautions are taken to decouple the meter movement from the ac signal component. Modifications can also be made to a number of fm industrial band mobile or base station receivers that operate in the 148-MHz to 172-MHz frequency range.

The wideband RCA industrial "Carfone" base station receiver, no longer produced but available on the surplus market, makes an excellent APT satellite receiver with minor modification. Solid state receivers specifically designed for APT satellite reception can also be purchased fairly inexpensively.

Control and monitoring system

Motor control

The output of the fm receiver is applied to the channel 1 input of the stereo tape recorder (see Fig. 4). The 2400-Hz amplitude modulated subcarrier containing earth scan and synchronizing and telemetry data is recorded on magnetic tape and fed to the channel 1 distribution amplifier.

Channel 2 input to the stereo recorder receives a precision ac sine wave at 1440 Hz. This signal is generated locally by a crystal oscillator operating at 1.440 MHz. Three IC decade counters in series reduce the crystal reference frequency by a factor of 1000 to produce a square-wave output of 1440 Hz. Wave shaping is then applied to the square-wave output. The precision 1440-Hz signal is needed to drive the ac synchronous motor in the TXC-1 facsimile recorder. Although the drum in the TXC-1 normally rotates at 60 r/min, the motor drive circuitry can be altered easily to operate the drum at 48 r/min by applying the external 1440-Hz signal through a phone jack provided on the facsimile unit.

An alternate method for obtaining the motor drive signal is with a phase-locked oscillator. The oscillator is set to operate at a free-running frequency of 1440 Hz. The loop between the oscillator and the phase comparator is broken and a divide-by-3 counter is inserted in series. The resulting 480-Hz signal is compared to a reference frequency of 480-Hz derived from the APT satellite subcarrier through a separate divide-by-5 counter circuit. The phase-locked-loop oscillator is particularly effective in removing the characteristic horizontal skewing of the photograph caused by Doppler shift.

The output signal from channel 2 (the control channel) is amplified and fed to the input of the motor drive circuit of the

TXC-1 recorder. The distribution amplifier output of channel 1 (the data channel) is set for 0 Vu. This level is fairly critical as it establishes the operating points for the a.m. subcarrier detector, sync detector, and lamp driver.

The satellite subcarrier signal is transformer-coupled to a full-wave bridge rectifier. Following detection, the 4800-Hz signal component is removed by a low-pass filter. The resultant video signal is then applied to the lamp driver circuit. The unfiltered output of the detector is also ac-coupled directly to the Z-axis of the oscilloscope producing intensity modulation for the photo-oscilloscope system.

Synchronization

To distinguish between visual and infrared channels, logic circuitry in the ground station samples the video signal during the period when the scanning radiometer is looking at space. The calibrated outputs from the visual and infrared detectors aboard the spacecraft differ in relative amplitude, resulting in higher (96%) modulation of the 2400-Hz subcarrier in the IR channel, and lower (4%) modulation of the VIS channel. The ground station logic circuitry differentiates the two levels and generates corresponding synchronizing pulses for either the VIS and IR channels.

Proper timing of the ground station sync generator is established by the burst of seven pre-earth synchronizing pulses inserted into the data stream by the satellite ahead of earth scan.[3,4] After demodulation, the sync information is passed through a 300-Hz filter and Schmitt trigger which separates and squares the pulses. The burst is applied to a binary counter which initiates a trigger for the sync generator on the 4th pulse. The demodulated video is also passed through a 30-Hz low-pass filter which establishes the presence of VIS or IR video occurring during the space-scan interval. The two analog signals are fed in alternate sequence to the data input line of the sync generator. A sync pulse is generated when the data input is "one" at the time of a clock pulse from the counter. Additional circuitry locks out false counts arising from noise components at 300-Hz.

Baseband filtering

The video information bandwidth of the scanning radiometer used aboard the current operational satellite NOAA-4 is 1200-Hz for the visible channel and 600-Hz for the infrared channel. Ground station filtering is recommended to optimize signal-to-noise ratios and provide best picture quality.[5]

If the data is to be used for synoptic evaluation, care should be taken not to restrict the high-frequency response of the visual channel. The frequency response characteristics of the filter provide approximately 6-dB attenuation at 1500-Hz and 20-dB attenuation at the subcarrier frequency of 2400 Hz. The low-pass filter is designed to provide maximum attenuation at 4.8 kHz at the output of the full-wave detector. Only a single filter for both channels is used since data are intermingled when received by the ground station.

Image display

Several techniques can be employed to display APT imagery. These include facsimile recorders using wet or dry electrolytic paper; photo-facsimile equipment which produces an image on photosensitive paper; and photo-oscilloscope systems. Laser scanning systems are new and generally employed only in the more advanced systems requiring high-resolution photographs. The present cost may be prohibitive for inexpensive APT ground station use. Still other advanced systems produce image displays on conventional 525-line, high-resolution television monitors using storage display tubes. This information can be computer processed to produce time-lapse imagery. Such techniques are particularly well suited for the display of global data produced by the high-resolution subsystems aboard the synchronous meterological satellite (SMS), sometimes called Geostationary Environmental Operational Satellite (GEOS). This satellite orbits the earth at an altitude of approximately 22,500 miles. The angular velocity of the satellite coincides with the earth's rotation; hence its position is stationary with respect to a given subpoint.

Photo-oscilloscope recording

High-quality APT photographs can be produced with an oscilloscope and a Polaroid camera. Using this method, images are produced line-by-line as the

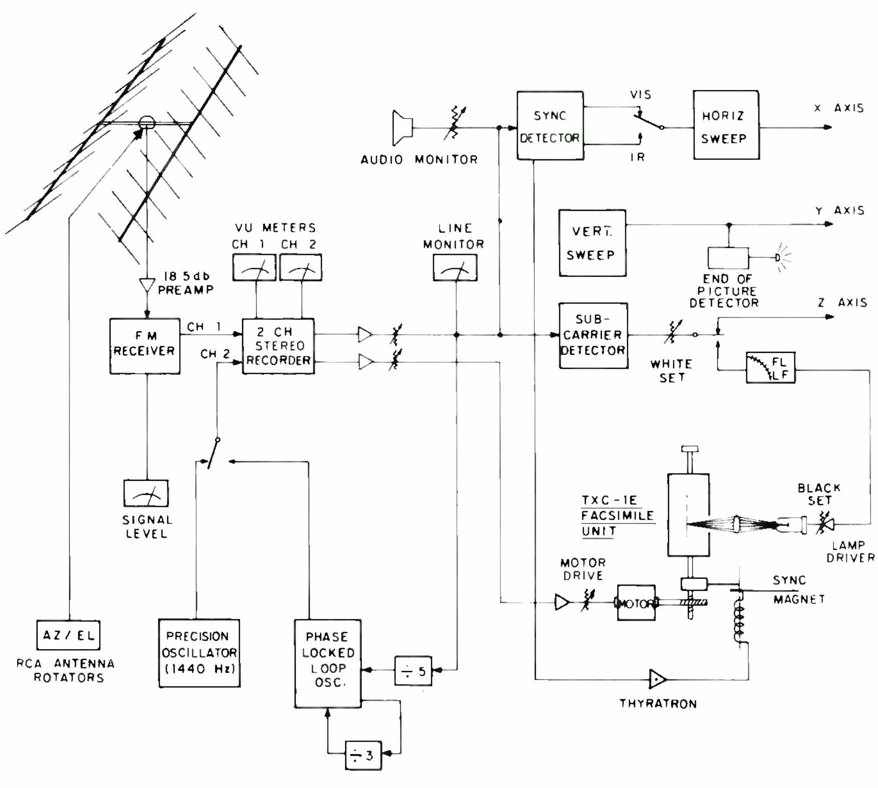
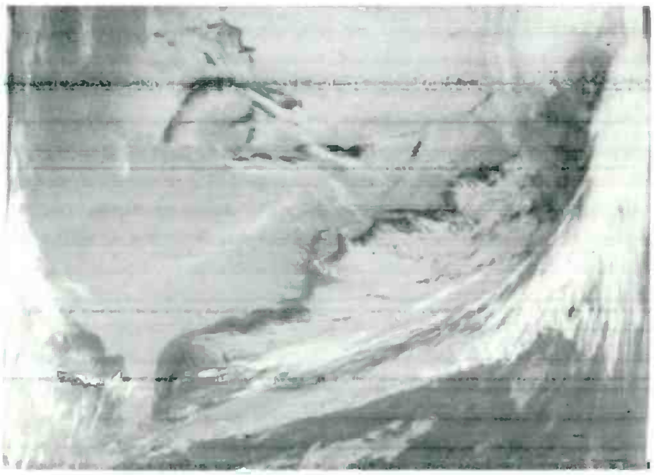


Fig. 4 — APT ground station, system block diagram.

Weather satellite photos received at Mt. Laurel, N.J., APT ground station

Nighttime Infrared

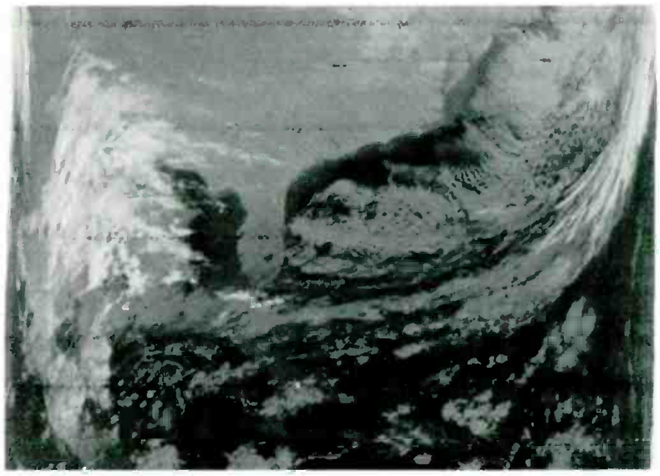
NOAA-4 Orbit No. 4988, December 18, 1975.



Deep low-pressure system near Newfoundland with trailing cold front southwestward along the Atlantic coast to the southern tip of Florida. Strong flow of northwest winds producing considerable off-shore cloudiness and precipitation in the form of snow to the lee side of the Great Lakes.

Nighttime Infrared

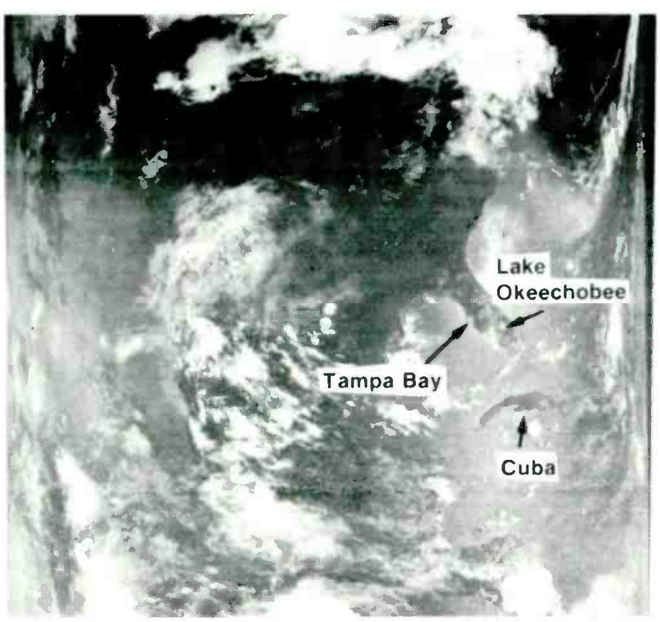
NOAA-3 Orbit No. 9685, December 19, 1975.



Cold front weakening with low-pressure area forming in the Gulf of Mexico. Gulf stream visible along southeast coast of the United States branching off near Cape Hatteras, N.C. Off-shore cloudiness persists due to continued northwesterly flow of cold, unstable air.

Daytime Visual

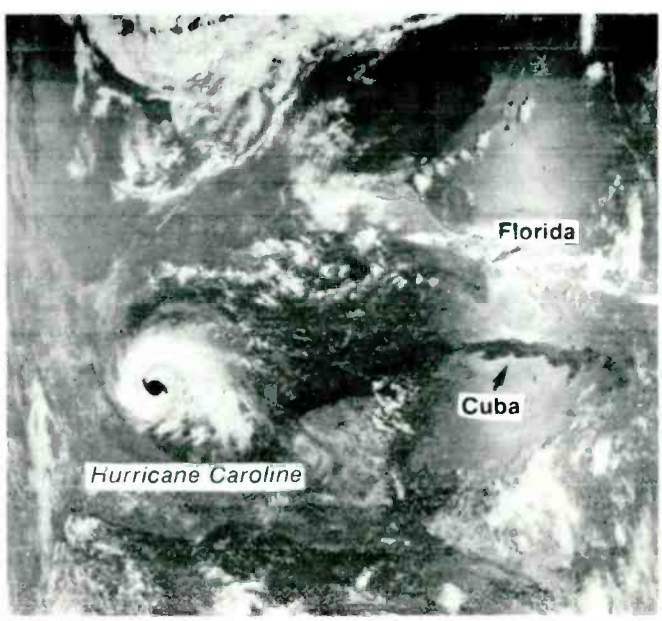
NOAA-4 Orbit No. 3530, August 23, 1975.



Southeastern United States showing Florida peninsula and Cuba. Shower activity can be seen in the Gulf of Mexico.

Daytime Visual

NOAA-4 Orbit No. 3605, August 30, 1975.



Hurricane "Caroline" poised in the Gulf of Mexico off the south Texas coast. "Sunglint" in the tropical Atlantic outlines the island of Cuba.

oscilloscope beam is intensity modulated by the detected APT signal applied to the Z-axis. Horizontal and vertical sweep voltages are applied directly to the X and Y axes of the scope to produce the raster. Photography is accomplished using a specially constructed oscilloscope camera which mounts directly over the face of the oscilloscope. A blue-actinic phosphor (P-11) flat-face kinescope provides the best results. Almost any good electrostatically focused oscilloscope may be used provided it has good dc dynamic stability. Spot size should be on the order of 0.03 cm or smaller. Approximately 20 minutes of useable time is available each pass for photography. During this interval, the SR produces 960 lines of data. If the vertical sweep voltage applied to the Y axis is set to produce a linear voltage ramp of approximately 4.0 volts in 6-2/3 minutes, a raster will be formed on the CRT consisting of 320 scan lines. Three such images can be photographed during each 20-minute orbit. A useable viewing area of about 9×9 cm is provided by a 5-inch round flat-faced CRT. Picture resolution is affected by the width of the scanning line (spot size) and hence care should be taken not to overscan or underscan. In general, no more than 10% aperture should be allowed between adjacent scanning lines.

This method of photo-oscilloscope reproduction has several advantages. First, excellent imagery with good picture resolution is obtainable; second, blanking and synchronizing are accomplished during each line, thereby eliminating the effects of Doppler; third, pictures are available immediately without darkroom processing. However, there are also some disadvantages. One is the relatively high cost of 4×5-in. Polaroid film, type 52 which is recommended; second, is the need to construct the full orbital image from a composite of three separate Polaroid exposures; third, and probably most important, is the susceptibility of oscilloscopes to 60-Hz ac hum.

Facsimile recording

The accompanying cloud-cover photographs were produced by a modified Times Model TXC-1E facsimile recorder. Exposures were made on Kodak Resin-Coated Type RC-FH enlarging paper. Kodak Type RC-NH Kodabrome enlarging paper is also acceptable and will produce a matte finish. Kodak type RC-FH paper produces a high-luster finish. The optical recorder system was modified slightly to increase the intensity of the modulated light source on the film and thus permit the use of an external lamp driver.

Table II — Nominal orbital parameters.

Altitude (above earth surface)	790 nmi (1464 km)
Apogee and perigee	790 nmi ± 25 nmi (± 46 km)
Inclination	101.7°
Nodal period (time of orbit)	115.14 min.
Precession of nodes	0.9857° per day

Drum phasing

The TXC-1E facsimile drum is phased to the satellite scanner by applying the negative-going sync pulse from the sync generator circuit directly between the cathode and grid of the pulse amplifier tube in the TXC-1E. The dc pulse developed across the plate load resistor is applied to the grid of a gas-filled thyratron which fires on each sync pulse, actuating a phasing relay. The phasing relay operates a stop arm and clutch mechanism on the motor drive causing the drum to rotate at a slower rate through a secondary clutch arrangement. Normal drum speed is resumed at a point where the angular position of the drum and the edge of the photographic paper coincides with the satellite scanner at earth edge. Once the drum has been positioned properly with respect to the scanning radiometer, the precision ac source applied through channel 2 of the ground station system will maintain accurate drum speed throughout the entire orbital pass.

Satellite orbital predictions and tracking.

ITOS Satellites are launched into a sun-synchronous 790-nm (1464-km) polar orbit. Nominal orbital parameters are given in Table II.

In such orbits, the satellite will cross the equator at approximately the same local (solar) time each day. The equator crossing longitude will be shifted westward on each successive orbit due to the rotation of the earth (1 degree per 4 minutes). NOAA-4, for example, has an apparent westward movement (nodal increment) of 28.75° and an orbital period of 115.0 minutes.

A computer is used for accurately forecasting equator crossing times. It takes into account both magnetic and gravitational influences exerted on the satellite orbit by the earth and other celestial bodies. APT predict messages are prepared and distributed daily at about 1903 Z from Washington, D.C., to major meteorological centers around the world via radio-teletype circuits and land lines. These messages are identified by the heading TBUS-1 and 2.[6] The data consists of orbital subpoints for each two-minute interval for a reference orbit three days in advance. Although the data is valuable, it is not essential. Reliable forecasts can be made 30 days or more in advance, by using any convenient reference orbit and calculating the predicted equator crossing time and longitude from the established satellite nodal period and increment. Since ITOS orbits are essentially circular, the argument of apogee and perigee need not be considered for practical APT use.

APT radioteletype predict messages (TBUS 1 and 2) are broadcast daily from station WBR-70, Miami, Fla., on 8.140 MHz and 13.624 MHz.

Monthly reference orbits for all ITOS satellites are printed and available upon request from the NOAA APT Coordinator, Washington, D.C. The data is sufficiently accurate to permit daily forecasts of equator crossings that deviate not more than 30 seconds from computer calculations.

Author's complete APT weather satellite ground station in Mt. Laurel, N.J.

Tracking procedures are considerably simplified through the use of a plotting board and a tracking diagram.[5] The plotting board is a polar projection of either the northern or southern hemisphere, and the tracking diagram is a plastic overlay designed for specific latitudes with isopleths of great circle arcs drawn at intervals of about 2 degrees (120 nautical miles).

Azimuth can be read directly from the plastic overlay and elevation angles can be extrapolated using charts available in the APT user's guide.[6] The orbit can be drawn on a transparent orbital overlay and will show the location of the satellite subpoint for any given time and corresponding azimuth, elevation data for positioning the antenna.

The ESSA Direct Transmission System Users Guide is a descriptive, highly informative document containing complete instructions for satellite tracking. This publication is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Acknowledgments

The author wishes to acknowledge the assistance of C.H. Vermillion, J.C. Kamowski, and Locke Stewart, Goddard Space Flight Center, Greenbelt, Md., for providing many helpful suggestions in the design of the system, and for their valuable critique of the author's photographs. Also, appreciation is expressed to E.J. Kille and C.B. Lee (W4NK) for their many ideas on modification and use of the TXC-1 facsimile unit and design of the lamp driver circuit.

Additional acknowledgment is made to R.W. Popham, APT Coordinator, NOAA/NESS, for providing valuable information of satellite orbital predictions and tracking procedures.

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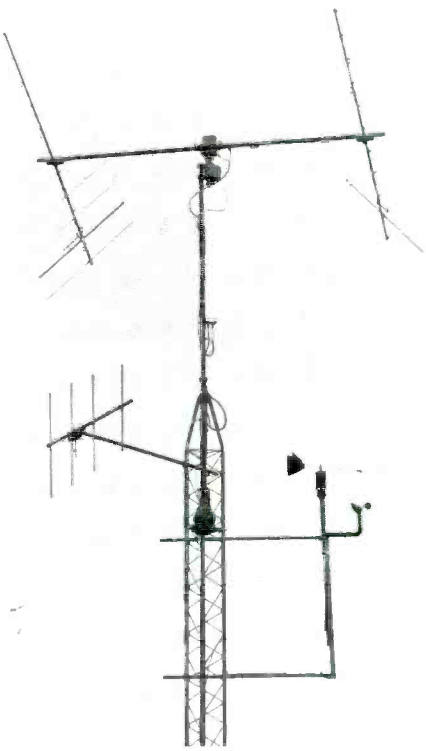
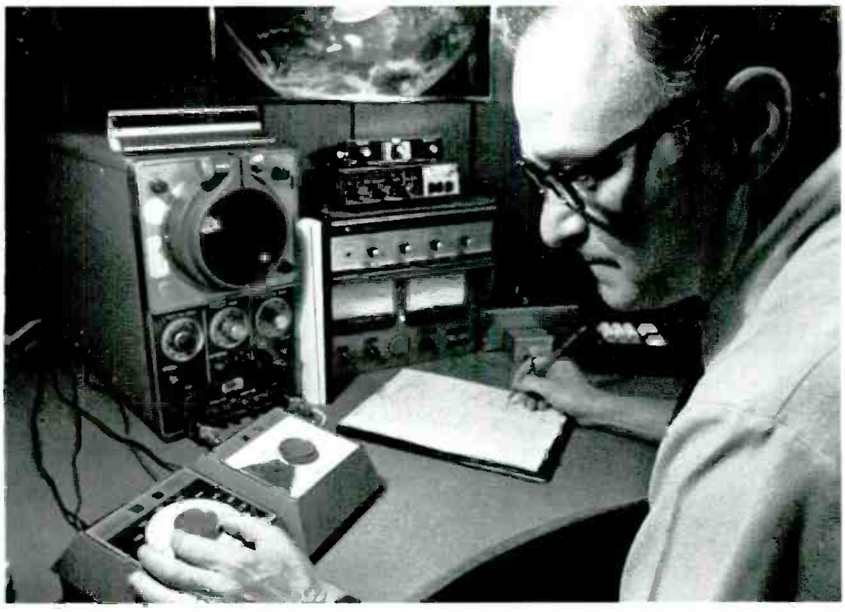
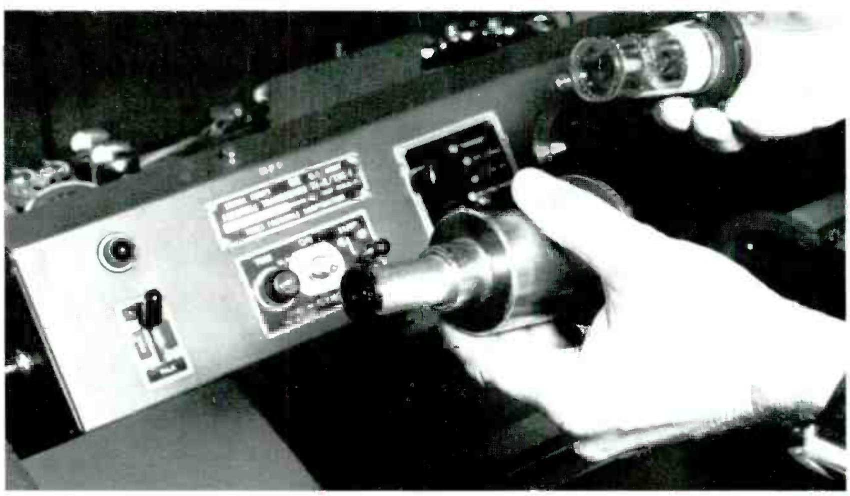
APT antenna—At the top is the cross-polarized tracking antenna and pedestal. Further down on the mast is the vertically polarized antenna used for reception of National Weather Service broadcasts from Atlantic City, N.J. Also shown is the wind direction indicator and anemometer.

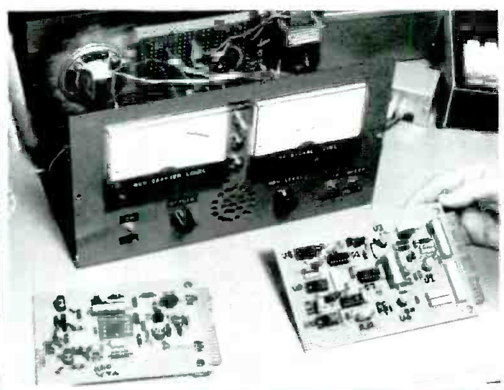




Author (above) makes tracking adjustments via two RCA tv rotator controls.

The four photos below, starting with the upper right-hand corner and moving clockwise, show:
1) construction details of the sync pulse generator and sweep generator IC logic boards contained in the control and monitoring console,
2) precision 1.440-kHz oscillator which incorporates a local crystal oscillator, series decade counter (÷1000), power supply, and wave-shaping network,
3) TKC-1 facsimile recorder, cassette recorder, and RCA digital clock-calculator (extreme left), and
4) the author holding the neon-glow modulator tube and lens system. Note that the light source is focused through a 10-power microscope eyepiece in the lens system.





Photos by John Semonish

Minorities in engineering

H.K. Jenny

Although minorities no longer encounter as many obstacles as in the past, only a small number have entered the engineering profession. Several programs are now underway to help increase their participation, including the RCA Minorities in Engineering Program (RCA-MEP) aimed at acquainting high school students with the engineering profession. Early reports indicate high student interest, providing a good prognosis of program continuation and increased enrollment requests. Completion of the pilot programs now underway at a dozen plant locations will provide inputs for further program improvements.

Up to about World War II, racial discrimination nearly closed many professions to minorities—among them engineering. Some of RCA's senior minority engineers pursued the long and difficult path of entering a profession foreign to the established way of life of their families, in that in the past, only such professions as law, medicine, teaching, and the clergy were available. They can look back now with much satisfaction on both their professional achievements and the avenues they paved for the following generations.

Today, engineering as a profession is more open; competence is what counts. This fact is demonstrated by the contributions made by minority engineers on RCA's engineering. team. Their inquisitive attitudes, thirst for knowledge, understanding of the laws of nature, and fascination with gadgetry (typical traits of the successful engineer) were highlighted in some recent interviews conducted in connection with RCA's Minorities in Engineering Program. Samples of these interviews are included (in the gray panels) in this article.

Despite the current opportunities, minority participation in the engineering profession is still very low as shown in Table I. Several reasons for this under representation include:

Table I — Participation of minorities in engineering as compared to percent of total population (1970 figures).

	% of U.S. Population	% of U.S. Engineers
Blacks	11.4	1.2
Spanish surnamed	4.4	1.6
American Indian	0.4	0.15
Oriental	1.1	2.9

- Lack of engineer role model—few minority youth have relatives or friends who are engineers and who could influence and guide them toward an engineering career.
- In many minority cultures, engineering is not considered as relevant or as "in" as medicine, law, teaching, and other more directly people-oriented professions.
- Lack of familiarity with and fear of tackling a profession that is visualized as requiring super brains.
- Perception by minorities as lacking the financial means to afford an engineering education.
- Negative attitudes created by 1) viewing engineering as a field with unstable employment, and 2) perceiving technology as being responsible for environmental and social ills.

Bill Curtis, Mgr., System Engrg., Automated Systems Division, Burlington, Mass., is one of the real pioneers in breaking down racial discrimination in engineering. He's done it by example as an internationally recognized authority on airborne radar systems. He's also done it in more basic, practical ways, by creating opportunities in engineering education for minority people. He graduated in 1934, from the University of Ilinois, received the MSEE the following year, and accepted a teaching position at Tuskegee Institute in Alabama. During World War II he helped develop and run a special program to train black pilots and mechanics for the Army Air Corps. Following the war he took advanced studies at Harvard University on a special fellowship. He earned another master's degree, and a PhD in engineering science and applied physics. After receiving his doctorate, he returned to Tuskegee Institute as Dean of Engineering.

Bill thinks engineering is one of the professions that is largely free of discrimination, and he sees management attitudes toward minority engineering improving steadily.

Why is engineering so important for minorities?

- Engineering is a profession that in itself provides the means for a good life as well as an opportunity to influence living conditions (for example, housing, environment, transportation, and entertainment).
- Engineering unemployment (4% at its worst) has always been substantially lower than many other professions and the national average.
- Estimates suggest that about 60% of industrial managers hold engineering degrees; thus, the profession provides a much needed route to adequate minority representation in the executive suites.
- An undergraduate engineering degree opens the door to other professions such as law, medicine, etc. Graduate business schools give preference to applicants with engineering degrees.

The national effort

A national effort to increase the participation of minorities in engineering is currently directed by The National Advisory Council for Minorities in Engineering (NACME). NACME is sponsored by the National Academy of Engineering, and its members include top executives from government, education, and industry. A.L. Conrad, RCA's chief executive, is a Council member. NACME has developed the extremely challenging objective of increasing the enrollment of minorities in engineering schools by a factor of 10 between 1972 and 1982. This accomplishment would bring minority representation to parity.

NACME is actively involved in many areas such as scholarships to students, grants to colleges, and special programs of orientation and motivation for students, parents, and teachers.

Several NACME programs are now under way, with two of particular interest because of RCA's participation:

MITE

MITE (Minorities Introduction to Engineering) is a national program administered by the Engineers Council for Professional Development. It is a summer program where selected high school students spend two weeks on the campus of an engineering school and become acquainted with both college life and the engineer profession. The students must have completed their junior year, are recommended by their schools, and attend at no cost. The program is funded largely by industry; the education aid committee of RCA, for example, pays for the MITE programs at Drexel, Lehigh, and New Mexico State

The MITE program is growing rapidly. During 1974, 10 colleges participated, involving 300 high school students. In 1975 this number increased to more than 1000 students at 24 colleges. Student reaction has been enthusiastic, even though the curriculum is quite advanced and demanding.

PRIME

PRIME (Philadelphia Regional Introduction for Minorities to Engineering) is a regional partnership of secondary schools, engineering colleges, industry and government employers of engineers, professional engineering societies, and community groups. It aims to provide engineering career information, identify potential engineering students, direct students towards assistance and scholarships, assist the educational community in developing curricula, encourage engineering colleges to challenge minorities to enroll, and show engineering as a desirable profession.

PRIME is in the formative stages and RCA along with other companies, is participating.

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Yau Kwan Pak, Global Communications, New York, had a good start on a career in physics until one of her college professors at the University of Hong Kong suggested that she had a special aptitude for engineering. Her first reaction was typical of the misconceptions of her time — women go into physics because it involves a lot less physical work then engineering.

Nonetheless, she took her professor's advice and graduated as the only woman among 40 receiving bachelor's degrees in electrical engineering in 1956. She's never looked back.

She came to the United States in 1958 and took a job in industry while attending night school at New York University. When she earned a master's degree in 1961 she joined RCA's Global Communications organization as an engineer working on communications network links.

Yuan may not be typical of all women who enter engineering, but she is well aware of some of the problems involved. She knows, for example, that some of her male co-workers remain a little dubious of her ability until she has proved it. This need to show proof before she's accepted is both frustrating to go through and satisfying to achieve. She believes the rewards are more than worth the effort, "today, the life of a minority female engineer is a lot easier than it was a few years ago."

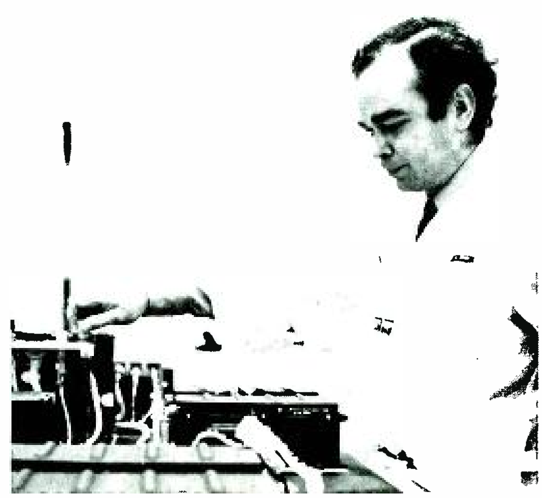
In July 1975, RCA's chief executive called upon the RCA engineering departments to develop programs aimed at supporting increased entry of minorities into engineering. Response has been outstanding, and at this writing 12 RCA locations are interacting with students.

The engineering departments have developed "grass roots" programs aimed at providing high school students with an understanding of the engineering profession. In addition, local Industrial Relations functions have developed working relationships with local high schools in gaining their cooperation and identifying applicable students. Requisities for participation are that students have the potential to enter engineering schools—potential manifested by the the taking of math and science courses, good scholastic standing, and an interest in learning about engineering.

RCA Minorities in Engineering Program (MEP)

Program concept

RCA-MEP seeks to identify minority high school students who have aptitude for engineering, thoroughly show them what engineering is about, and motivate those interested to enroll in engineering schools. An engineer, dedicated to his job and desirous of transferring some of this enthusiasm and interest to young people, is best able to convey a real feeling for the engineering profession.



Ed Elizondo, Astro-Electronics Division, Hightstown, N.J., first became interested in engineering while working with his father, a doctor in the field of radiology. He helped with the X-ray equipment, and became fascinated with crystal sets and tubes. He received the BSEE from Massachusetts Institute of Technology in 1955, an Electrical Engineering Diploma from the University of Havana in 1959, and an MS from the Polytechnic Institutue of New York in 1964.

Today he is responsible for the integration of all electrical equipment for the RCA Satcom satellite series that is now relaying telephone, television, and other communications signals throughout the United States.

Originally RCA-MEP was visualized as an after-school activity; however, enthusiastic reception of the program by the high schools has led to scheduling during school hours at most locations, with the students receiving credit for attendance. The number of students at each location varies from 6 to 26. Total enrollment covers about 195 students from 25 high schools, with both female and male representation.

Program content

Participation is the key to motivation. Program features include:

- Simulation games where groups of students experiment and compete.
- Guided design exercises, which lead the students through problem definition, analysis, and decision-making to the solution of problems of interest to them.
- Engineering work situation—a one-on-one work experience with an engineer.
- Kit fabrication—building a technical product (scientific calculator or multimeter), learning how it works and what it can do, and using it.

Each location has developed a program with its own flavor. But common to all programs is the creative effort of the participating engineers in developing activities they feel will provide the student with an accurate image of engineering in a stimulating manner. Table II represents a typical outline of an active RCA-MEP.

Effort by location

Twelve geographical locations housing one or several RCA engineering departments are now actively engaged in RCA-MEP. Each location is responsible for the conduct of its program. A corporate steering committee is active and provides guidance and support; Corporate Engineering supplies the required brochures, educational material, games, and kits for the students.

All programs are closely coordinated to assure that experience gained and effective program contributions come quickly to the attention of the participating locations.

Table III summarizes MEP locations, key technical and industrial relations coordinators conducting the program, number of high schools participating, students involved, and program starting date.

Table II — Outline of an active Minorities in Engineering Program.

Session	Subject	Teaching aids	Student participation
1	Get acquainted MEP plan, goals, activities Introduction to RCA AED	Movie: "A Piece of the Action" Handout Tour of a satellite integration area	Introductory comments by students Group discussion of the movie See a satellite
2	What is engineering?— Types, jobs, accomplishments Guided design: home heating	Movie: "Nothing but common sense" Handout	Rap session—salaries jobs, hangups Group exercise
3	Satellites: types and missions Guided design	Tour of integration area RCA viewgraphs	See a satellite Observe engineers at work Group exercise
4	Satellite: structures mechanism, and thermal control Engineering achievements	RCA viewgraphs Movie: "Engineering Makes a World of Difference"	Group exercise
5	Satellite: electric power, guidance, and control Engineering work situation	Tour of fabrication area Movie: Challenge of the Future" Tour	Visit work area with one-to-one guide
6	Satellite: propulsion and command Calculator computations	Tour Sample problems Calculator kit instructions	Work problems with one-to-one guide
7	Electronic calculators Satellite: payload cameras, ranging, and telemetry	Calculator kits Movie: "Microelectronics"	Students build kit
8	Electronic calculators Numerical methods	Calculator kits	Students build kit
9	Electronic calculators Numerical methods	Calculator kits	Students bu.'d kit Calculation exercises
10	Electronic computers Computer applications	Guest Speaker	Terminal use
11	Wrapup: Program evaluation, career discussion	Certificate, movie Space program benefits	Students bring parents to evening session

The programs usually include 10 to 13 three-hour sessions conducted at RCA facilities on a biweekly schedule and mostly on school time. At several locations, school counselors also attend to obtain a better understanding of the engineering profession.

The following summarizes some of the major program features by location:

Burlington (Automated Systems Division)—Radar, a major thrust at this location, serves as the vehicle to explain engineering, covering both design and manufacturing aspects. An introduction to digital electronics includes some computer programming. Also included is a scientific calculator kit project.

Camden (Advanced Technology Laboratories, Broadcast Systems, Government Communications Systems Division)—The Camden program is directed at participation with PRIME. One of the first activities was to host 40 students, carefully selected by two high schools, who spent a day interviewing engineers and wrote reports on their findings about engineering for the other students.

Hightstown (Astro-Electronics Division)— The satellite theme is used to illustrate engineering demonstrating satellite types, structures, controls, propulsion, and payload examples. Included are calculator and computer programming and calculator kit fabrication. Guided design exercises include problem definition, analysis, and solution. There is a one-to-one review of engineering work situation (Table II).

Indianapolis (Consumer Electronics, RCA Records, SelectaVision VideoDisc Operations)—This program includes themes such as a career planning workshop with the assistance of college representatives and minority engineering school students; automobile engine assembly at a General Motors facility; in-

Table III — Summary of RCA-MEP's by location, including key personnel directing program.

Location	Tech. coord.	IR coord.	No. of high schools	No. of students	Studen level	Program start date
Burlington, Mass.	K. Palm	D. D'Agata	1	20	Jr./Sr.	Jan. 1976
Camden, N.J.	A. Merriam	W. Townsend	2	40	Fresh./Sr.	Mar. 1976
Hightstown, N.J.	W. Metzger	D. Broadhead	3	21	Jr./Sr.	Dec. 1975
Indianapolis, Ind.	T. Bridgewater	A. Beasely	1	20	Jr./Sr.	Dec. 1975
Lancaster, Pa.	R. Engstrom	T. Conway	1	8	Jr./Sr.	Nov. 1975
Meadow Lands, Pa.	K. Neumann	C. Reed	1	8	Jr./Sr.	Mar. 1976
Moorestown, N.J.	G. Field	R. Bell	4	19	Jr./Sr.	Nov. 1975
New York, N.Y.	S. Friedman	B. Fader	1	8	Sr.	Nov. 1975
Patrick AFB, Fla.	P. Barnette	W. Todd	4	11	Jr./Sr.	Mar. 1976
Princeton, N.J.	R. Rast	J. Bowker	5	26	Jr./Sr.	Nov 1975
Somerville, N.J.	R. Cohen	A. Bennett	1	6	Fresh.	Feb. 1976
Springfield, Va.	J. Leopold	J. Begley	1	8	Jr./Sr.	Jan. 1976

dustrial engineering; environmental engineering; space program fallouts; product design; management in action; and a calculator construction project.

Lancaster Picture Tube Division, Solid State Division) — Included in this program are discussions of various types of engineering as practiced at the Lancaster plant and demonstrated on a one instructor to four students basis with opportunity for student participation; electrical analog analysis of automobile suspension systems with parameter experimentation; and construction of a scientific calculator.

New York (Globcom, as the lead, with NBC/RCA Records cooperating)—There is substantial use of outside sources in this program such as the ERDA energy simulation game; the Kearny High School Space Administration project; the Princeton FRED (educational and entertainment microprocessor); NBC and Records visits; and a scientific calculator kit project. Wrap-up is with a presentation by the students.

Moorestown (Missile and Surface Radar Division)—This program is strongly tutorial oriented, introducing the students to digital electronics, computers, and computer programming. Students participate through problem solving, experimentation on trainers, building a scientific calculator kit, and Microtutor programming.

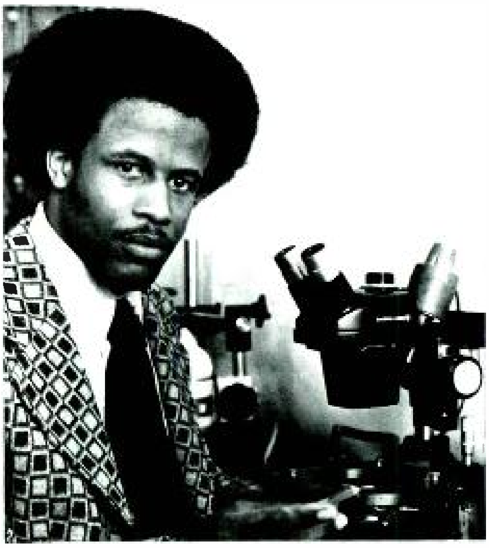
Meadow Lands (Mobile Communications Systems, Broadcast Systems)—An introduction to engineering careers is followed by sessions devoted to energy simulator, engineering employment, microprocessors (applications in education and entertainment), calculator construction project, calculator use, plant tour, and wrap-up with career workshop.

Patrick AFB (RCA Service Company)—An introduction to engineering precedes a tour of the JFK Space Center. Next, engineering math and calculator fundamentals, are discussed, followed by a scientific calculator construction project. A tour of the Service Company facilities emphasizing engineering aspects and a career workshop conclude the program.

Princeton (David Sarnoff Research Center)—One-third of the program covers general engineering topics and new developments at RCA Laboratories. Another third represents an

Leonard Rockett, RCA Laboratories, Princeton, N.J., studied pre-engineering at Southern Illinois University on a football scholarship and at Howard University, where he held what was virtually a full-time job in journalism to cover expenses. He received the BSEE in 1973 and joined the research training program at RCA. His work at the Labs includes applying the latest solid state devices to making tomorrow's television cameras extremely small and lightweight and simple and reliable enough for use in the home.

He immediately took advantage of RCA's graduate study program, with the result that he received the MSEE from Columbia University in 1975. He is currently on a full year leave of absence on an RCA doctoral study program at Columbia.



introduction to the world of microprocessors: their organization, programming, and use in FRED, the educational/entertainment application of microprocessors, and a field trip. The last third is a kit assembly project.

Somerville (Solid State Division)—This program differs from the others in that it mainly addresses high school freshmen. It contains two phases of 10 weekly sessions during the school year. The student-teacher relationship is mostly one-to-one and brings the student close to the engineer's activities. During the first phase the students are given a multimeter project—understanding its operation, building, and using it. A second phase covers a project to support an electronics laboratory to be established at the high school in which the students will then hopefully continue to work during their high school tenure.

Springfield (RCA Service Company)—Student participation is strongly emphasized here. Included are simulation games such as "Lost on the Moon" and "Planet Management Game;" building and operating logic gates, adders, clocks, counters; simple computer programming; game playing with FRED; and assembly of a scientific calculator. This is supplemented by an introduction to engineering careers workshop, introduction to logic, computers, and calculators, and a field trip to NASA's Goddard Space Flight Center.

Experience gained to date

RCA-MEP is intended as a long-range contribution to an ongoing national program. The program is still at too early a stage to judge its results accurately. However, much experience is being gained rapidly. As the first programs progress, we obtain continuing feedback useful for corrections aimed at improving program effectiveness.

A positive observation is the empathy with the problem shown by all levels of management, engineering, and industrial relations personnel involved in the program. Their desire to assist in the problem's solution is a key to program success.

Following is some of the feedback from the several dozen sessions held to date:

Students

Attendance:	Good
Attrition:	Low
Attitude:	Good to excellent. Minimal reluctance to participate and raise questions.
Reaction:	Program content appears effective and interesting to students.
Discipline:	No problems to date; far better than at school.
Background.	A few schools have not selected students as carefully as expected. Some seniors have inadequate math/science background for acceptance at engineering schools.
Counselling:	RCA-MEP staff, through personal counselling, is assisting students now making career choices and applying for college admission.
Future directions:	Preparation should start at earlier age; for instance, provide eight and ninth graders with a simplified, short introduction to engineering with prospect of RCA-MEP participation in later high school years. This may motivate them to enroll in math/science courses and study with greater interest.

High schools

— Enthusiastic and cooperative.
— Consider program content valuable for career development.
— Counselors are generally not well acquainted with the engineering profession. This program gives them closer acquaintance; many attend the session. Some requrested a special counselor-engineer workshop.
— Schools report increased interest in math and science courses among RCA-MEP participants.
— Students have reacted enthusiastically to the program upon returning to their schools.
— Several schools have requested engineering career presentations to their assemblies.

Tom Bridgewater, Sr. Engr., Television Receivers, Indianapolis, Ind., grew up in the West Indies where there was no electric utilities service. His introduction to electricity, at age 6, came through experiments his older brother ran with batteries and lamps. Tom was fascinated and began hoarding worn-out batteries, telephone parts, and finally an old radio chassis. A correspondence course and a lot of work soon made Tom the island's expert in radio repair.

He studied at the Norwood Technical College in England, where he received the equivalent of the BSEE in 1959. He joined RCA in 1968 and is now developing advanced electronics devices and remote tuning systems.

Tom stresses not just formal education but an even broader exposure to engineering. "Learn basics," he says, "and then really get acquainted with the technology by reading and by talking and working with the people involved."

Colleges

— RCA has obtained the cooperation of several colleges, which have sent people to explain admission requirements to the students and have brought along some minority engineering students, providing lively and helpful discussions.

ERDA (Energy Reserach and Development Agency)

— Since the energy field will require substantial engineering manpower in the next 20 years, we have brought the ERDA energy simulator presentation into the program at several locations to acquaint students with this employment potential.

Other industry and Agencies

— RCA-MEP includes sessions at other company (GM in Indianapolis) and government agency (NRL, Goddard Space Flight Center, etc.) locations.

Outlook

THe prognosis for RCA-MEP is excellent—auguring a continuing and noticeable contribution. This is indicated by the high degree of student interest and participation in the many sessions held to date.

The base of experience being rapidly accumulated is used for planning of the programs for the coming school year.

Diversity of programs by location has provided many high points enthusing both students and staff. There, of course, have also been some aspects that require remedy.

The lively interchange of experience now permits all locations to concentrate on the best features evolved so far. Matching student enthusiasm is the interested and cooperative attitude shown by the high-school personnel involved.

However, the main accolades must go those RCA people who have worked so hard in getting this program off the ground so rapidly—a task they have taken on in addition to their regular responsibilities—because they understood the problem and put their hearts, in addition to their minds, to its solution. It does not happen too often that the engineering population gets directly involved in a societal problem. In this case, they have responded magnificently.

RCA's top management, headed by A.L. Conrad with his important role of leadership in NACME, has shown a solid support of MEP despite the overall business recession, which has necessitated drastic measures of economy and retrenchment. Their desire to encourage increased minorities' entry into engineering not only assures program continuity but also a high degree of visibility of the virtuous efforts of those engaged in the program.

Progress towards the solution of a condition of human inequality represents a contribution to the history of mankind hardly surpassable by our everyday professional pursuits.

Hans Jenny, Mgr., Technical Information Programs, Corporate Engineering, Cherry Hill, N.J., is responsible for corporate wide planning and coordination of the RCA Minorities in Engineering Program. He is also responsible for RCA's technical communications, technical publications, and technical information systems programs. The overall objective of these programs is to enhance the process of technical information transfer and to support a stimulating working climate for engineers conducive to a high degree of technical excellence. This endeavor utilizes such vehicles as the *RCA Engineer, TREND, Technical Abstract Bulletins*, technical publications and presentations, as well as the all important informal information channels. Mr. Jenny also works closely with the related Engineering Education activity. If you are interested in communicating on these topics, please call Cherry Hill, PY 4251 or, from outside RCA, 609-779-4251.

Bernie Darrell, Missile and Surface Radar Division, Moorestown, N.J., is not only a respected authority in the radar signal processing world, but also has a demonstrated leadership capability that has put him in a position of special responsibility. Currently Bernie directs a team of more than 150 engineers, technicians, and support personnel charged with operating and maintaining two major radars on the South Pacific Atoll of Kwajalein in the Marshall Islands. He attended Brooklyn Technical High School in New York; and received the BSEE in 1951 from City College of New York. He then joined RCA.

His impression of the engineering profession is especially thought-provoking. "One of the first things I noticed, and it has persisted down through the years, is the camaraderie that exists within the scientific community. We work essentially as a team and as long as each team member pulls his weight he's accepted without qualification."

Transcalent solid-state power devices*

S.W. Kessler | R.E. Reed | H. Shoemaker | K. Strater

Transcalent devices, high-power solid-state power devices with heat pipes bonded to each side of the silicon wafer, have demonstrated their superiority over "hockey-puck" or "stud-mounted" devices. A Transcalent Rectifier and Thyristor have been developed, and a Transcalent Transistor is in the process of being developed.

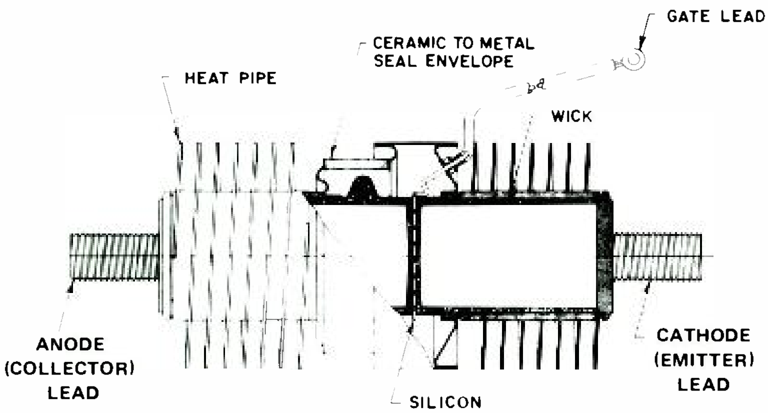
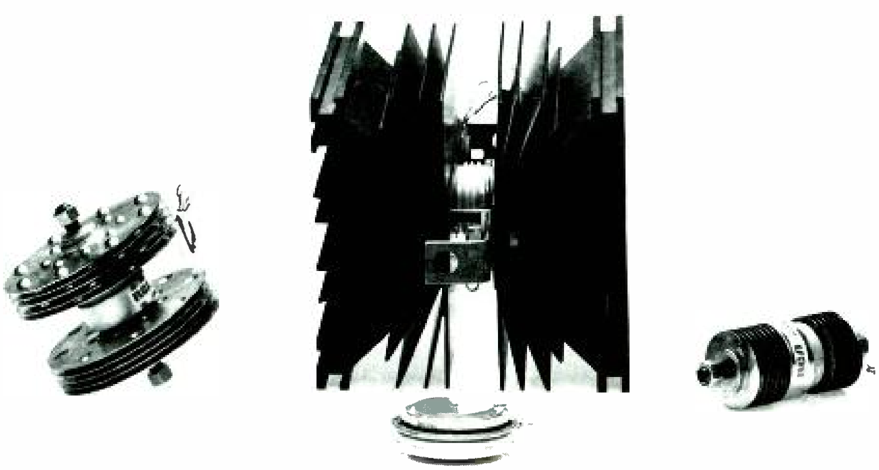


Fig. 1 — Cross section of Transcalent Thyristor. The gate lead may also be brought through the wall of the ceramic insulator between the emitter and collector of the device by brazing a feed-through to it.

TRANSCALENT, a term that means permeable to heat flow, best describes a new family of high-power solid-state power devices, known as Transcalent Transistors, Thyristors, and Rectifiers which have heat pipes bonded to each side of the silicon wafer, as shown in Fig. 1. The heat pipes attached to the silicon constitute a self-contained thermodynamic system that exhibits an effective thermal conductivity several orders of magnitude greater than copper.[1] This thermal conductance is achieved by the evaporation of a heat-transfer liquid from the capillary or wick structure in thermal contact with the silicon, the transport of the vapor to other parts of the heat pipe, condensation of the vapor along the walls of the pipe, and return of the condensate to the evaporator section through the capillary structure lining the inside wall of the heat pipe.

*The majority of the technical effort expended on the Transcalent device program was funded under Contract DAAK02-69-C-0609 and Contract DAAK02-72-C-0642, awarded to RCA in 1972 by the U.S. Army Mobility Equipment Research and Development Command (MERADCOM), Fort Belvoir, Va.

Right: 400-A (rms) Transcalent Thyristor type J15371. Left: 400-A (rms) Transcalent Thyristor with fins 4.25 in. diameter. Center: competitive method of cooling high-current solid-state devices in which a disc-shaped device (like the one in the foreground) is clamped between the large fins in the background. The device in the background has the same current capability as the RCA devices when the case temperature and the heat-pipe temperature of the respective devices are both 100° C.



The use of a wick structure distinguishes the heat pipe from other similar systems. When gravitational forces act against the condensate returning to the evaporator, the wick furnishes the "pumping force" required to complete the return. In addition, the capillary structure holds a thin film of heat-transfer fluid at the evaporator's surface. This thin film of liquid improves the heat transfer and permits the system to operate with a minimum of liquid. In Transcalent power devices, water is the preferred working fluid because of the temperature range in which silicon devices operate; water has the greatest latent heat of vaporization and the greatest surface tension of all liquids in this range. Since the heat pipes are vacuum devices, they operate nearly isothermally, with the vapor condensing at the coolest point. This feature provides freedom in the geometric design of the condenser and also assures that an equal amount of heat can be transferred to all of the fins of the Transcalent device regardless of how far they are from the silicon. Dimensions are limited only by the ability of the wick to "pump" the condensate back to the hot surface area where the liquid can be re-evaporated and the cycle repeated.

The initial Transcalent Rectifier, type J15401, was designed to conduct an average current of 250 A and to be cooled with 150 ft^3/min of air at an ambient temperature of 70°C.[2,3] The rectifier with its heat pipes and cooling fins was only 1 7/8 in. in diameter and 5 in. long, which included 1½ in. of stud length for fastening high-current leads to the device. The complete rectifier, with its integral heat-pipe heat sinks, weighed less than 10 oz. Competitive devices, often referred to as "hockey-pucks," are cooled by clamping them between large aluminum heat sinks.

Advantages of Transcalent devices

Applications experience with Transcalent devices has demonstrated their superiority over "hockey-puck" or "stud-mounted" devices, namely:

1) There are no mechanical clamps fastening the device to the heat sink. Industrial experience indicates that the clamping force relaxes through creep of copper and aluminum during the life of the "hockey-puck" thyristors. Inadequate cooling and lossy electrical contacts may result.

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2) Heat is extracted from both sides of the silicon with a minimum of material adjacent to the silicon. This arrangement produces a low-temperature gradient between the junction (which is limited in an SCR by silicon characteristics to a maximum temperature of 125°C) and the ultimate heat sink.

3) The thickness and the thermal properties of materials adjacent to the silicon are optimized to absorb the transient surges of power that must be dissipated from the silicon if blocking and control characteristics are to be maintained.

4) In operation the heat pipes are very tolerant to changes in power level because of their ability to respond quickly by evaporating an additional amount of working fluid. They exhibit a decreasing thermal resistance as the power level increases. This tolerance has been demonstrated by:

   a) The high surge-current rating for the Transcalent Thyristor.

   b) Operation of the device at 2000 Hz without derating its current for the additional dissipation accompanying the increased rate of recombination currents.

   c) Observing only a small increase in junction temperature when the device is operated under overload conditions.

5) The assembly has a high resistance to fatigue failure because the materials adjacent to the silicon and bonded to it either nearly match the thermal expansion of the silicon or are designed to yield elastically. By comparison, the rubbing surfaces of a clamped device are subject to fretting and scoring.[4,5] As fretting debris accumulates between the clamped surfaces, the contact resistance between adjacent materials increases and alters their electrical and thermal impedances.

6) Operation at higher ambient temperature is possible without current derating.

7) Transcalent devices are of smaller size and lighter weight because of the greatly reduced temperature gradient between the junction and the fins. Also, all of the fins are equally effective in dissipating heat because the heat pipe is isothermal along its entire length.

Transcalent Rectifier

The ratings of the J15401 Transcalent Rectifier are summarized in Table I. The low thermal impedance between the junction of the rectifier and the condenser of the heat pipe enables the device to be rated at full current up to a heat-pipe temperature of 125°C, the limit arbitarily set for the heat pipe.

Table I — Ratings for the Transcalent Rectifier, type J15401.

Characteristic	*Rating*
Peak forward or reverse blocking voltage	Up to 1200 V
Average forward current	250 A
Peak single-cycle surge-forward current (60 Hz)	8000 A max
Fusing I^2T (at 8.3 ms)	250,000 A^2 sec
Operable frequency limit (sine wave)	4000 Hz max
Heat-pipe temperature	125°C max
Thermal resistance:	
junction-to-case (dependent on power dissipated)	0.12°C/W
junction-to-air, with 150 ft^3/min air through fins (dependent on power dissipated)	0.25°C/W
Typical cooling air flow (25°C ambient at sea level)	150 ft^3/min at 0.4 in. H_20
Forward voltage drop (at 250 A average forward current)	1.3 V max
Operating attitude	Any
Maximum length	5.0 in.
Maximum diameter	1.94 in.
Weight (approximate)	10 oz
Storage and operating temperatures	Up to 125°C

The initial Transcalent Rectifiers were electrically tested while rectifying currents up to 550 A with a maximum dissipation of 500 W. The tests were conducted under the following operating conditions: 60-Hz current was rectified at an average current of 250 A with conduction angles of 180°, 120°, and 60°. Alternating current was also rectified at a conduction angle of 180° at frequencies varying from 200 to 4000 Hz. The thermal dissipation of these devices was also evaluated by varying the rectified current passing through them in the forward direction and by varying the air velocity cooling them. Fig. 2 summarizes the resulting data. The graph shows the dependency of the operating characteristics of the device on current, frequency, and air flow.

Table II summarizes typical test data at 60 Hz. For this test, the thermocouples were located between the fins on the device. Thermocouples 1 and 4 were located between the last two fins on each heat pipe or at the extreme ends of the pipes; thermocouples 2 and 3 were between the innermost two fins on each pipe. Although there is approximately 1 in. between the thermocouples along the length of the heat pipes, the temperature difference was never greater than 3°C along a given heat pipe and never greater

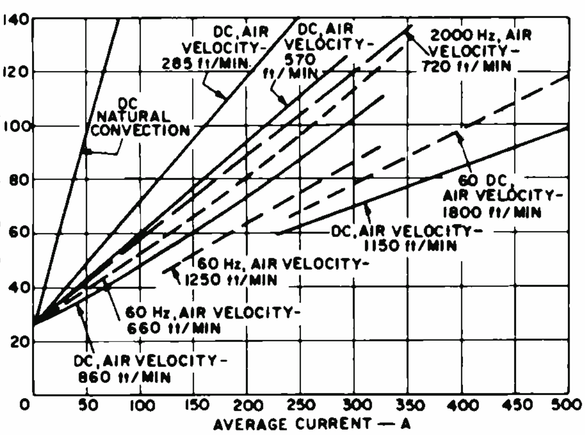


Fig. 2 — External surface temperature of the heat pipes of Transcalent Rectifier J15401 with fins approximately 2 in. in diameter as a function of current, frequency, and air flow.

Table II — Summary of test results for Transcalent Rectifier, type J15401.

Rectifier No.	*Average current (A)*	*Peak forward voltage (V)*	*Temperature (°C)* Thermocouple* 1	2	3	4	*Air Flow (ft^3/min)*
109	250	—	95	93	96	95	43
	300	—	101	101	106	105	
112	200	0.90	63	63	60	63	88
	250	0.98	71	72	75	75	
	300	1.00	83	84	86	85	

*Inlet air temperature was 27°C.

than 5°C between heat pipes on the same rectifier.

To prove the reliability of the Transcalent Rectifier, units were life tested at rated current for 4000 hr with reduced air flow, life tested at twice the rated current for 1700 hr, and cycle life tested at rated current for more than 10,000 cycles of 10 min on and 10 min off. Two units were also cycled on and off 50 times at rated current in an ambient of 25°C below zero to confirm the ability of the device to withstand frozen starts.

Purified water was used as the working fluid in the heat pipes of the devices tested because of its chemical compatibility with all of the materials of construction. Water also has high surface tension and a large latent heat of evaporation. Alternate working fluids with melting points less than 55°C below zero have been considered, but it is realized that there must be some sacrifice in thermal performance because these fluids have a lower latent heat of evaporation, a small specific heat, and less surface tension than water. The chemical compatibility of alternate fluids with other device materials must also be considered.

Transcalent Thyristor

After achieving the improved heat-dissipation capability of the Transcalent Rectifier, RCA developed a Transcalent Thyristor,[6,7] type J15371, cooled with the same heat-pipe design as that developed for the rectifier. The design objectives for the thyristor were a current rating of 400 A (rms with 180° conduction), a critical rate of rise of current rating (di/dt) of 800 A/μs, and a critical rate of rise of voltage rating (dv/dt) of 200 V/μs. The electrical characteristics of the Transcalent Thyristors, types J15371 and J15372, are summarized in Table III.

To take full advantage of the heat-pipe cooling of the silicon, the chip used in the Transcalent Thyristor was designed with an emitter diameter slightly smaller thar the diameter of the heat pipe; a cross section of the silicon chip is shown in Fig. 3. Note that the periphery of the emitter-to-gate junction is located within the bounds of the heat pipe and that the gate surrounds the emitter and is electrically insulated from the heat pipe by a thin layer of insulation. With this emitter geometry, all of the heat is generated within the bounds of the heat pipe when the thyristor is conducting current. The first advantage of this design is that the passivated edge of the high-voltage junctions operates at a cooler temperature than the emitter area of the silicon. Only a fraction of the small amount of heat generated in the silicon from reverse leakage current is generated at the outer edge of the silicon. With the edge of the silicon in the Transcalent Thyristor operating at a cooler temperature, the high-voltage junctions are less thermally strained than the junctions in a rectifier in which the area of conduction is not geometrically limited to the center of the silicon. Another advantage of this emitter design is a gate-to-emitter junction that can absorb the high transient dissipation (di/dt) generated in the silicon during switching without being damaged.

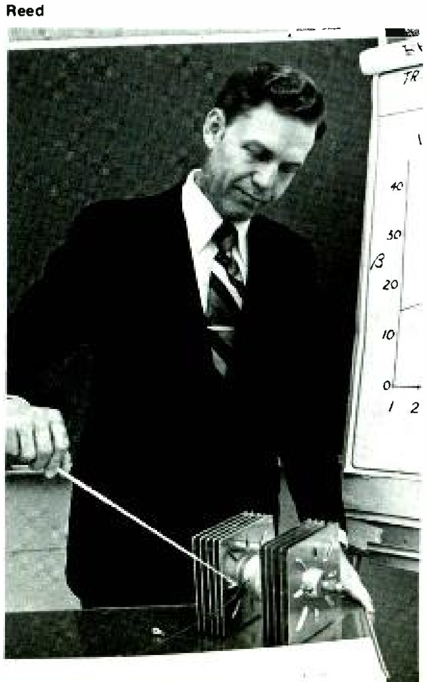
Robert E. Reed, Engineering Ldr., Power Products Materials and Processes Laboratory, Lancaster, Pa., received the BSEE with Distinction from the University of Oklahoma in 1952, the MS in physics from Franklin and Marshall College in 1971, and has continued his graduate studies with solid-state physics courses. He has been employed by RCA-Lancaster, since June 1952. His present assignment combines the supervision of the Materials and Processes Laboratory with the development of the transcalent devices described in this article. Mr. Reed is a member of Sigma Tau, Eta Kappa Nu, Sigma Pi Sigma, and the IEEE. He is the author of several papers and technical reports.

Howard Shoemaker, Diffusion and Dielectrics, Materials and Process Laboratory, Solid State Division, Somerville, received the BS in physics from Indiana University in 1964 and attended the graduate school of Physics at Princeton University from 1964 to 1966. Over the past four years his major responsibility was in the design, process development and fabrication of large-area Transcalent devices. He played the major role in the development of the sequence of diffusion, oxidation, and chemical vapor deposition processes used to fabricate these devices. Mr. Shoemaker has recently joined the staff of the Material Science Group of the Electrical Engineering Department at Pennsylvania State University.

Kurt Strater, Manager, Dielectric and Diffusion, Materials and Processes Laboratory, Solid State Division, Somerville, received the BA in Chemistry from New York University in 1953 and the MS from Newark College of Engineering in 1961 where he majored in Chemical Engineering. He joined RCA in 1958. In 1964 he was made Head of a Process Development Group for superconducting ribbon processing and was the recipient of an RCA Laboratories Achievement Award in 1965 for work on that process. In 1970 Mr. Strater was made Head of a Dielectric and Diffusion Group. He has published a number of papers in the various fields in which he has worked. He holds three patents.

S. W. Kessler, Jr., Sr. Engineer, Product Development, Lancaster, Pa., received the BS in industrial engineering from the University of Pittsburgh in 1949. He joined RCA-Lancaster in 1953 and worked at the Chemical and Physical Laboratory, the Semiconductor and Materials Division, the Special Power Device Engineering Group, and the Power Tube Department. Since joining that department, he has pioneered the development of Transcalent solid-state power devices. Mr. Kessler has authored and coauthored numerous papers on the subject of ceramic-to-metal seals, corrosion by alkali metals, heat pipes, and Transcalent solid-state power devices. He has been granted eight US patents. Mr. Kessler is a member of the American Society for Metals and the IEEE.

Reed



Strater

Kessler

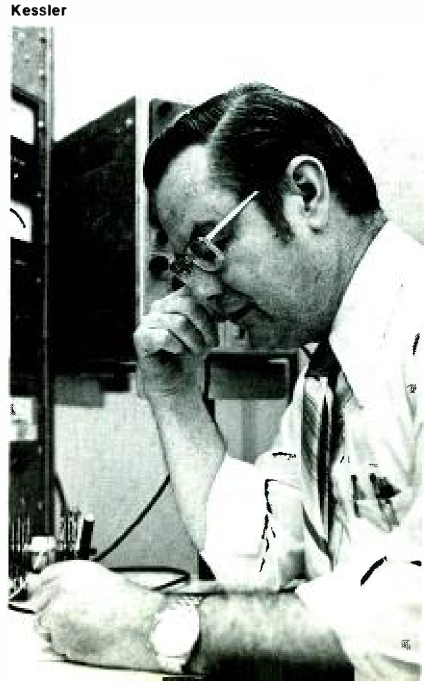


Table III — Summary of the electrical characteristics for the Transcalent Thyristor, types J15371 and J15372.*

Characteristic	*Rating*	*Characteristic*	*Rating*
Type J15371, nominal fin diameter, 2 in.		Cooling air-flow requirements	150 ft^3/min at 0.4 in. H_20
Peak forward or reverse blocking voltage	Up to 1200 V max	Typical forward voltage drop (at 250 A average forward current, 60 Hz)	1.5 V
Rms forward current (180° conduction angle)	400 A max	Operating attitude	Any
Average forward current (180° conduction angle)	250 A max	Weight (approximately)	10 oz
Peak single-cycle surge-forward current (60 Hz)	7000 A max	*Type J15372, nominal fin diameter, 4.25 in.*	
Peak 60-cycle surge-forward current (60 Hz)	2000 A max	Rms forward current (180° conduction angle):	
Maximum rate of rise of anode current during turn-on interval *di/dt*		with natural convection	80 A max
		with forced air cooling	400 A max
(switch from 800 V)	1000 A/μs max	Average forward current (180° conduction angle):	
Maximum rate of rise of forward		with natural convection	50 A max
blocking voltage *dv/dt*	200 V/μs max	with forced air cooling	250 A max
I^2T for fusing (at 8.3 ms)		Operating attitude:	
(max value at 25°C)	200,000 A^2 max	with natural convection	Axis horizontal
Gate current, dc		with forced air cooling	Any
(at 1.0 V dc typical)	500 mA max	Weight (approximate)	30 oz
Thermal resistance: junction-to-case (dependent on power dissipated)	0.12°C/W		
junction-to-air, with 150 ft^3/min air through fins (dependent on power dissipated)	0.25°C/W		

*Electrical characteristics of the J15371 and J15372 are identical except for the ratings defined in the second part of the table for natural convection cooling.

The second feature of the silicon chip designed for the Transcalent Thyristor is the trigger finger. The trigger finger is etched into the silicon at the periphery of the emitter-to-gate junction and forces the initally conducting region of the emitter to increase rapidly in size when the thyristor is switched. The gate, which surrounds the emitter, is metallized for high electrical spreading conductivity. These features also help to make a device capable of accepting a high *di/dt* or high pulse-repetition rate without damage to itself.

Emitter shorting contacts, or dots, are diffused at regular intervals in the emitter area to increase the *dv/dt* capability of the thyristor. These shorts provide an ohmic path through which displacement currents can flow around the emitter junction. In Fig. 3, the central shorting dot is shown. The actual shorted emitter structure is more complex; it consists of the central shorting dot surrounded by a large number of similar shorting dots, which lie on circles of increasing radii. The values of the radii are determined by the number of dots on each circle and the requirement that the linear distance between adjacent dots on any circle be a fixed constant. This design approach results in a nearly uniform distribution of shorting dots from the center to the edge of the emitter. By varying the fixed linear distance and the shorting dot diameter, the desired value of *dv/dt* can be achieved.

The silicon wafer for the thyristor is fabricated by an all-diffusion process. The resulting diffusion or doping profile through the silicon is shown in Fig. 4. The

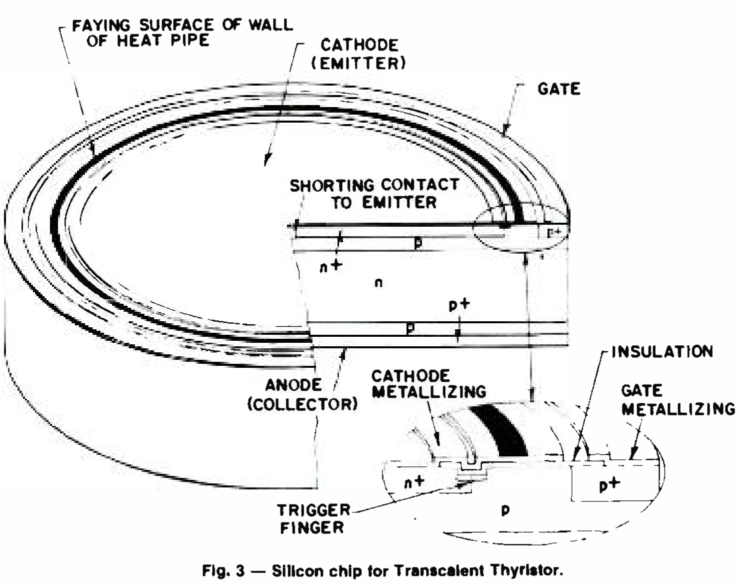


Fig. 3 — Silicon chip for Transcalent Thyristor.

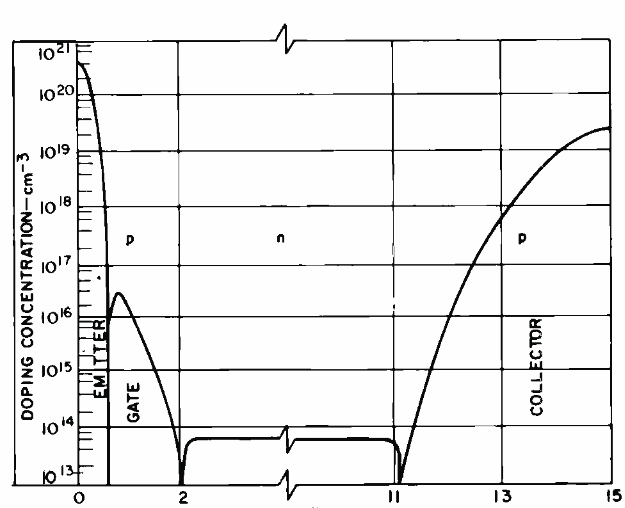


Fig. 4 — Thyristor doping profile.

Table IV — Operating characteristics for the Transcalent Thyristor, type J1537 (nominal fin diameter, 2 in.).

Thyristor No.	Ambient temp. (°C)	Exit air temp. (°C)	Average current (A)	Peak forward (V)	Temp. (°C) thermocouple 1	2	3	4	Air flow per thyristor (ft^3/min)
32	—	—	251	1.61	99	99	103	103	88
32	—	—	298	1.62	97	105	97	98	145
48	—	—	295	1.88	112	119	104	100	145
90	23.3	41.3	258	1.75	83	83	90	90	145
91	23.3	41.3	261	1.95	90	90	85	87	145
109	23.8	40.0	253	1.76	78	80	90	92	145

Table V — Transcalent Thyristor, type J15372, pulse-modulator switching tests—rectangular waveshapes.

Pulse duration (μs)	Repetition rate (pps)	Duty factor	I_{TM} peak current (A)	I_{GTM} peak gate current (A)	Voltage fall time (μs)
20	55	0.005	2,400	1.8	3
20	55	0.005	5,000	3.9	3
20	55	0.005	5,000	7.5	2.5
20	55	0.005	6,000	8.8	2.5

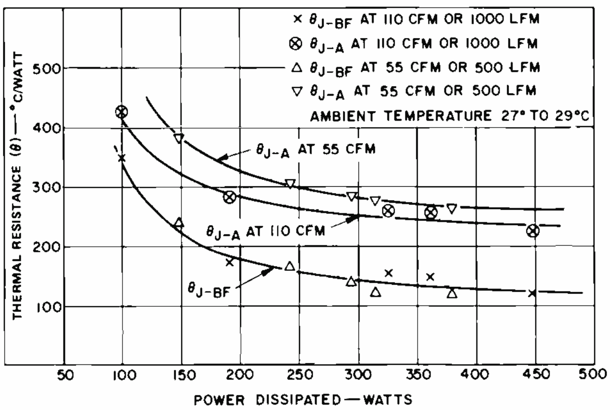


Fig. 5 — Thermal resistance between junction (J) and base of fins (BF) and between junction and ambient (A) as a function of power dissipated from device types J15372 or J15379.

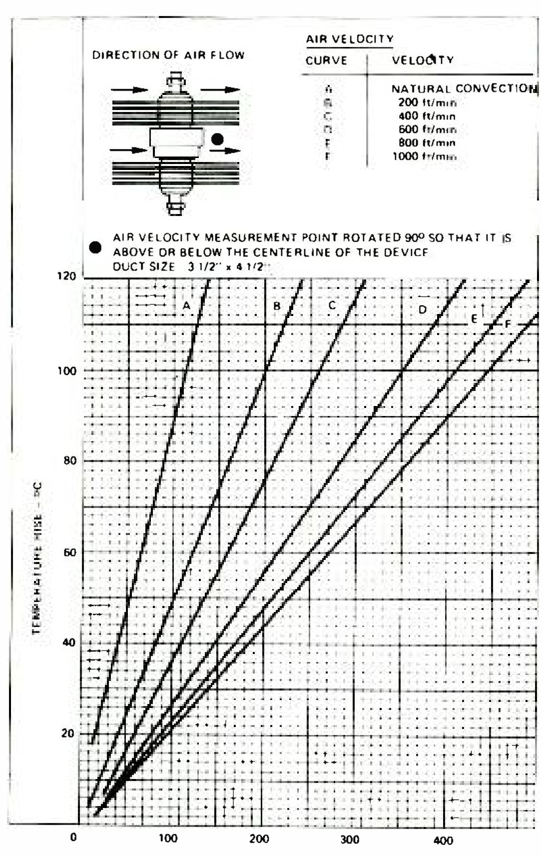


Fig. 6 — Temperature rise at the base of the fins versus power dissipated for the type-J15379 and J15372 devices at different air velocities.

doping profile shown is typical of a high-voltage Transcalent Thyristor. The blocking-voltage capability of the thyristor is determined by the wide, high-resistivity *n*-region.

Typical thermal operating characteristics are summarized in Table IV. The thyristor has a higher forward voltage drop than the rectifier, and therefore a greater amount of heat must be dissipated from the device while it is operating. This fact is reflected by the greater amount of air required to cool the thyristor, Table IV, than the rectifier, Table II.

Life tests similar to the Transcalent Rectifier tests described above were performed on the Transcalent Thyristors. The most notable difference in the results is that the cycle life test has passed 50,000 cycles at this time and is continuing. Two units were tested to destruction in the *di/dt* testing at 3800 A/μs. The peak one-half-cycle surge-current ratings at 60 Hz of the Transcalent Rectifiers and Thyristors are 8000 A and 7000 A, respectively.

Environmental testing of the Transcalent Thyristor has also been performed. The thyristor has been operated in an ambient of 25°C below zero for 4 hr and cycled on and off 25 times. Each time the thyristor was cycled on, the water in the heat pipes was frozen, but the power losses from conducting 400 A thawed the ice.

The Transcalent Thyristor type J15372 has also been subjected to shock and vibration tests. No damage resulted under the following conditions:

Shock 125 g, 4 ms, all three axes
Shock 500 g, 1 ms, all three axes
Vibration 5 g, 5 to 1000 Hz variable frequency.

The ability of the Transcalent Thyristor to withstand a large surge of current at a high *di/dt* was demonstrated by operating devices in a line-type modulator with the device switching stored energy into a resistive load. The shape of the pulse of current conducted by the thyristor was rectangular; Table V summarizes the test data. The voltage fall time has been found to be synonymous with the current rise time, *di/dt*.[8] Excessive circuit inductance prevented an accurate measure of the current rise time *per se*.

Means of cooling the Transcalent power devices other than the small, compact (2-in.-diameter) fin design requested by the military have been explored. The small fin diameter requires that the linear velocity of the cooling air be very high to pass a total volume of 150 ft^3/min. An increase in fin diameter to 4¼ in. resulted in a significant reduction in air velocity. With the 4 ¼-in.-diameter fin, 250 W can be dissipated from the heat pipes with a temperature rise of 60°C at the base of the fins at a linear air velocity of only 800 ft/min. At a temperature rise of 70°C, 80 W can be dissipated from the fins with natural convection cooling. The type J15379 rectifier and the type J15372 thyristor both have 4 ¼-in.-diameter fins.

Fig. 5 shows the thermal resistance between junction and base of fins and between junction and ambient as a function of power dissipated from device types J15372 and J15379. The air flow was measured up-stream from the device in a 4½ × 3½ in. rectangular air duct with the flow restricted from the space between the two sets of fins on the devices; each device was equipped with 10 copper fins of 4 ¼-in. diameter. Note that the thermal resistance decreases with increasing power. This decrease in thermal resistance is the result of an increase in the operating temperature and pressure of the heat pipes. The decreasing thermal resistance contributes an additional margin of safety to dissipating the power associated with an overload if the junction is operating at less than the limiting junction temperature at the time of the overload.

The temperature rise as a function of dissipated power for different air velocities for devices having 4¼-in.-diameter fins is shown in Fig. 6. As the air flow increases from natural convection to 1000 ft/min, greater amounts of power can be dissipated for a given rise in temperature.

Type-J15470 water-cooled Transcalent Thyristor.

Table VI — Test results of J15470 thyristor operated in a simulated welding circuit.

I_{TM} maximum total (peak) current (A)	No. of cycles at 60 Hz in a burst of current	Duty factor	V_{FM} peak on-state voltage
2355	12	0.20	1.8
4800	3	0.05	2.5
6000	1.7	0.03	3.2
5625	12	0.20	3.1

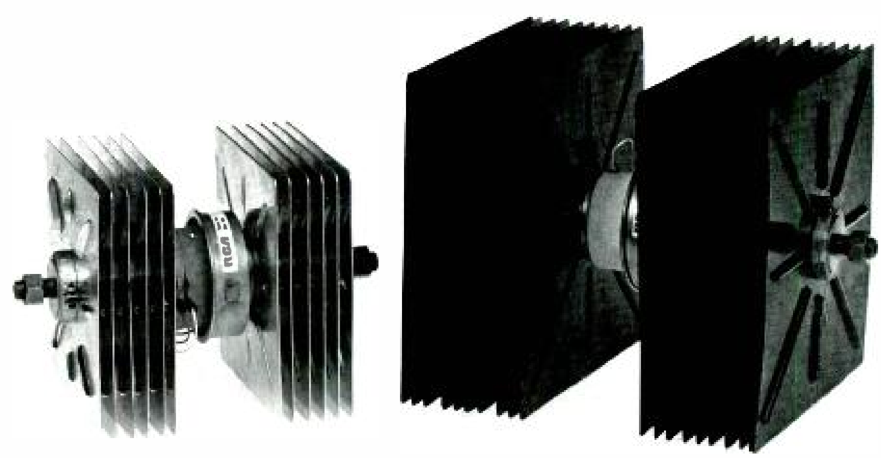
RCA has also designed a water-cooled Transcalent Thyristor, type J15470, using many of the features of the heat-pipe-cooled units. Hose connections are brazed into the walls of the cylinders, which are normally the walls of the heat pipes. The water is circulated by force against the thin metal support adjacent to the silicon chip. At a flow rate of 2 gal/min, one-half to each side of the silicon, the thyristor can be operated at an average current of 1000 A (an increase of 4:1 over the air-cooled units). Testing of the water-cooled thyristor is not complete, but the J15470 device will probably receive a conservative rating of between 1100 to 1200 A (rms). Life testing of the Transcalent water-cooled Thyristor must also be undertaken to confirm the proposed rating.

Water-cooled devices are very well suited to use where the device must conduct large surges of current at a relatively small duty factor. The J15470 was operated in a simulated welding circuit connected to the 60-Hz line. As Table VI shows, water-cooled Transcalent Thyristors are well suited for use in welding applications.

RCA is also currently developing a larger 1400-A (rms) air-cooled Transcalent Thyristor, type J15461, and a 900-A (average) Transcalent Rectifier. The largest (8-in.-square) fins are designed for natural convection cooling and can dissipate 700 W with 100°C rise in heat-pipe temperature. The power rating or current of the device may be altered by changing the length of the heat pipe, the size and material of the fin, and the cooling air flow.

Transcalent Transistor

RCA is presently developing a Transcalent Transistor.[9] The objective is a transistor having a collector current of 60 A and a sustaining voltage between collector and emitter greater than 400 V; other objectives and the results achieved



Right: 900-A (average current) Transcalent Rectifier, type J15463. Left: J15471 Transcalent Thyristor. The J15471 thyristor is capable of controlling 270 A (rms) with natural convection cooling and 540 A (rms) with forced air cooling at 500 LFM.

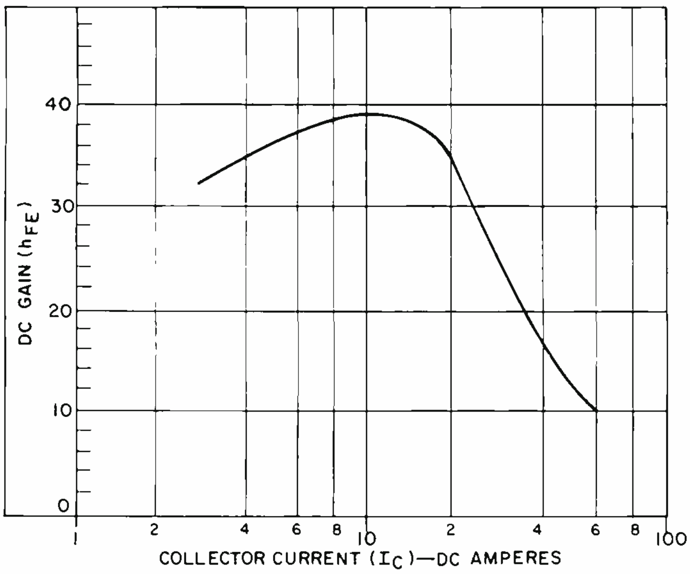


Fig. 7 — DC gain of transcalent transistor 37 at a collector-emitter voltage of 5 V.

Transcalent Transistor with aluminum pin fins.

Table VII — Transcalent Transistor characteristics.

Characteristics	*Objective*	*Results to date*
Cutoff frequency f_{hfe}	>4,000 Hz	>20,000 Hz
Operating frequency		20,000 Hz
Collector current I_c	60 A	72 A dc 85 A pulsed
Base current I_B	10 A	13 A
Max voltage capability		
V_{CBO}	750 V	990 V
V_{CE} (sus)*	400 V	510 V
V_{CE} (sat)*	1.25 V	0.6 V at 55 A
Pulsed current gain		
at I_c = 60 A	10 times	10 times
Turn-on time	5 μs	1.18 μs
Turn-off time	10 μs	1.97 μs
Power to be dissipated	500 W	524 W

*Pulsed: pulse duration ≤ 300 μs, duty cycle ≤ 2%.

to date are tabulated in Table VII. In Fig. 7 the dc gain versus collector current at a collector-to-emitter voltage of 5 V is recorded.

The construction of the Transcalent Transistor is more complex than that of the Thyristor. The emitter consists of 72 individual emitter fingers diffused into the base region of the transistor. The emitter fingers are of varying lengths and are arranged radially around the center of the silicon wafer. A print of one of the photomasks used in fabricating the wafer is shown in Fig. 8. The total emitter area is nearly 1 cm^2.

When the transistor is conducting current, each emitter finger behaves as an individual transistor; the effect is a parallel array of 72 transistors. If the

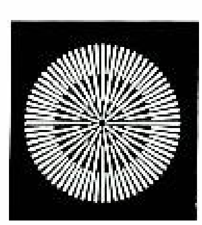


Fig. 8 — Print of a photomask used in fabricating a transistor wafer. Seventy-two emitter fingers (the white bars in the photograph) are arranged radially about the center of the pattern.

voltage drop between the base and emitter of one of the emitter fingers is less than its neighbors, that emitter monopolizes the current and enters a thermal runaway condition. To prevent this thermal instability, a ballast resistor with a positive coefficient of resistance with temperature is placed in series with each emitter finger.[10] The ballast resistor can locally increase the resistance to the flow of current to an emitter finger having a base-to-emitter voltage drop less than its neighboring emitters.

The ballast resistor is made from another silicon wafer of low resistivity by diffusing ohmic contacts into its surfaces. The ballast-resistor wafer is metallized, and mesa contacts are formed on one side of the wafer by etching away the silicon surrounding the mesa. The dimensions of the mesas are the same as the dimensions of the emitters on the transistor wafer.

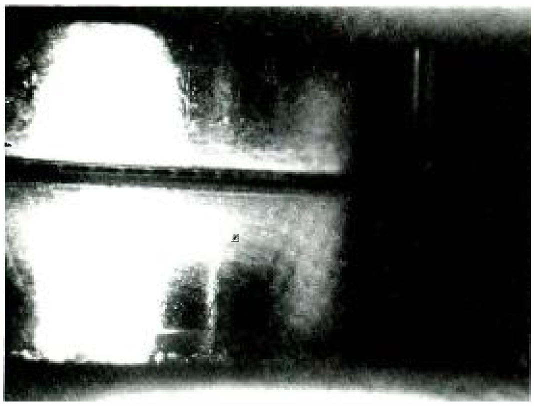
In assembling the Transcalent Transistor, the ballast resistor is placed on top of the transistor wafer so that a mesa contact area is aligned with each emitter. A schematic sketch of the wafer subassembly is shown in Fig. 9. The final assembly is made by welding the heat pipes together with the wafers clamped between them. The heat pipes are closed at the end bearing against the wafer assembly by means of a thin molybdenum disc. Silver foil is used between the molybdenum disc and the silicon wafer to obtain better thermal contact than would be obtained with two hard materials bearing against each other.

During operation of the transistor, resistive power losses in the ballast resistor are dissipated by the emitter heat pipe against which it is pressed.

The diffusion or doping profile of the transistor is shown in Fig. 10. The diffusion profile through the silicon determines the device characteristics. The high-resistivity collector region determines the voltage rating of the device. It is possible to obtain higher voltages by using a crystal of higher resistivity and by making the collector wider, but unless the emitter area is increased, a substantial penalty is paid in current-handling ability.

Summary

Transcalent solid-state power devices have been developed in recognition of the



Enlargement of the edge of a Transcalent-Transistor wafer compressed between the heat pipes. The toothlike projections between the heat pipes are the mesas etched in the ballast-resistor wafer.

need for improved component cooling. In the original development work,[2,7] RCA has successfully combined the superior heat-transfer capability of isothermal heat pipes with the desirable electrical functions of high-current silicon rectifiers, thyristors, and transistors.

A comparison of non-Transcalent solid-state power devices with Transcalent types[11] demonstrated that 10 oz of a Transcalent device perform the same electrical function as 10 to 15 lb of a heat-sinked "hockey-puck" or "stud-mounted" thyristor.

There is also an order of magnitude reduction in the space occupied by the Transcalent device. These advantages, along with a higher heat-sink operating temperature, without a corresponding increase in junction temperature, make Transcalent devices more suitable for use in many high-current applications. Some of the applications being explored are motor speed controls, welding controls, electrochemical refining, power conditioning (such as converters and inverters), pulse modulators, electrical vehicles, and induction heating as well as military and space applications where size, weight, and cooling are of prime importance. A new field of power-system load leveling is also evolving in which Transcalent devices will be used for the inversion of dc from super batteries, fuel cells, and photovoltaic cells to 60 Hz ac. Additional ratings, dimensions, and applications guidance are included in available technical data sheets.[12]

Acknowledgment

The success of the Transcalent device program is the result of the cooperation and expertise of two engineering groups: the Materials and Processes Laboratory at Somerville and the Materials and Processes Laboratory at Lancaster. The heat pipes and the surface geometry of the silicon wafers were designed at Lancaster as were the metallizing and bonding techniques required to incorporate the silicon wafer between the heat pipes. Somerville took the responsibility for development of the diffusion profiles that would assure that devices would exhibit the desired electrical characteristics.

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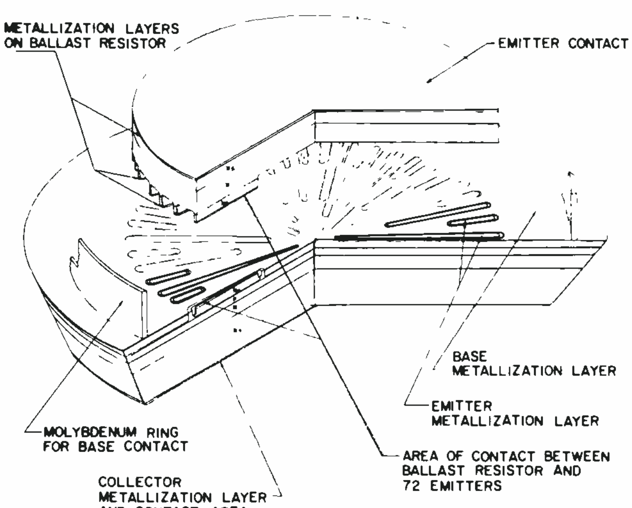

Fig. 9 — A ballast-resistor wafer is located on top of a Transcalent-Transistor wafer with the mesa contacts on the ballast resistor aligned with the 72 emitters. A molybdenum ring is soldered to the base periphery to distribute the base current evenly around the transistor wafer.

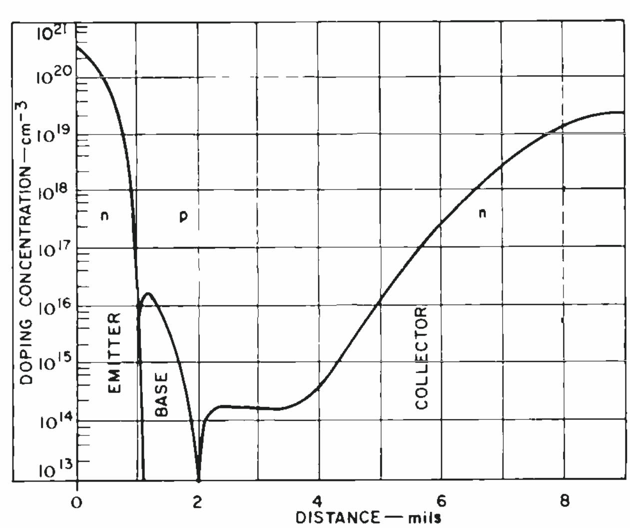

Fig. 10 — Doping profile in the transistor. The Transcalent Transistor is a triple-diffused *n-p-n* structure. The profile shown is typical of a 50-A 400-V transistor.

New techniques for automated engine diagnostics

R.E. Hanson | H.L. Fischer

Automated Systems Division has long been active in developing systems for simplified automatic diagnostic testing of internal combustion engines. However, simplicity of operation means sophisticated hardware and software based on ingenious testing techniques. This paper explains the concepts and rationale behind these principal techniques—idle performance testing, power testing, ignition system analysis, and starter current waveform analysis.

IN RECENT YEARS, industry has been seeking to develop the right combination of hardware and software to automate the comprehensive diagnostic analysis of the internal combustion engine.[1,2] Solutions to this problem lie in the dynamic control, analysis, and interpretation of basic engine parameters under various operating conditions during starting, idling, and full-power performance. ASD has made a number of technological breakthroughs in this area of diagnostic testing. This paper describes the principal ones related to spark ignition engines which include:

1) The use of deceleration dynamics, as measured via primary ignition signals, for identifying cylinder unbalance and misfire;
2) The use of the engine friction as a basis for simulating full power performance testing without using a dynamometer and without road testing;
3) The use of a computer for complete ignition analysis; and
4) The use of compression dynamics, as measured via starter current, as means for measuring ignition timing during cranking.

The above techniques have been implemented on two newly developed automatic diagnostic units. The Automatic Test Equipment for Internal Combustion Engine (ATE/ICE)[3] is a portable, completely automatic, stored-program diagnostic unit (see Fig. 1). This unit rapidly tests starting, idle misfire, simulated full-load power and battery charging voltage. These tests are made without the need for either a dynamometer or a road test. In addition, ATE/ICE provides instructions to the mechanic for visual inspections and program modules to aid in tune-up adjustments.

The Simplified Test Equipment for Internal Combusion Engines (STE/ICE)[4] is a hand-held, highly portable microprocessor-controlled test system (see Fig. 2). The system is currently programmed to test four different engine designs and relies on the training and proficiency of the operator to make the correct diagnostic decisions on the basis of fault indications and flip card references.

The following describes testing techniques developed by ASD which are currently being used in one or both of these systems.

Henry L. Fischer, Mgr., Product Design, Automated Systems Division, Burlington, Mass., received the BSEE from Tufts University in 1952. After initial employment with General Motors Corporation, he joined the staff of the Tufts University Electrical Engineering Department as a Research Engineer. Joining RCA in 1959, he was given responsibility for systems application and self-test programming of the Automatic Programmed Checkout Equipment for the ATLAS Missile. In later assignments, he was responsible for studies and design of a micro-modularized general-purpose aerospace computer. In 1963, Mr. Fischer assumed responsibility for directing all programming effort at RCA on Multi-System Test Equipment programs for the U.S. Army. He co-authored the *Program Design Handbook for Automatic Test Equipment*, 1968, and the *Avionic Design Guide for VAST Compatibility*, 1970. He has had management responsibility for numerous ATE operating systems for testing jet engine fuel controls and hydraulic accessories, an ATLAS Compiler and Run Time Operating System for the Army's EQUATE, and a performance-oriented diagnostic operating system for the Army's vehicular test programs, ATE/ICE. As a Product Design Manager, Mr. Fischer has been responsible for the organization and management of ATE/ICE programs at RCA since 1972. The performance of his people on these programs has twice been cited for technical excellence. Mr. Fischer was responsible for the development of vehicle diagnostics, operating system and diagnostic software, and new hardware on the current ATE/ICE system. He is a Registered Professional Engineer (MASS 12791) and a member of the IEEE and Sigma Xi.

Testing idle performance

One of the new test techniques developed by ASD for use with computerized vehicle test systems makes it possible to obtain more idle performance information, yet with less work by the mechanic. The only input required by a test system for a spark ignition engine is the points-opening signal. The technique uses the fact that the load of an engine and its accessories will cause measurable deceleration when subnormal power is developed in a given piston power stroke. By using the engine speed variations

Fig. 1 — Automatic Test Equipment for Internal Combustion Engines (ATE/ICE).

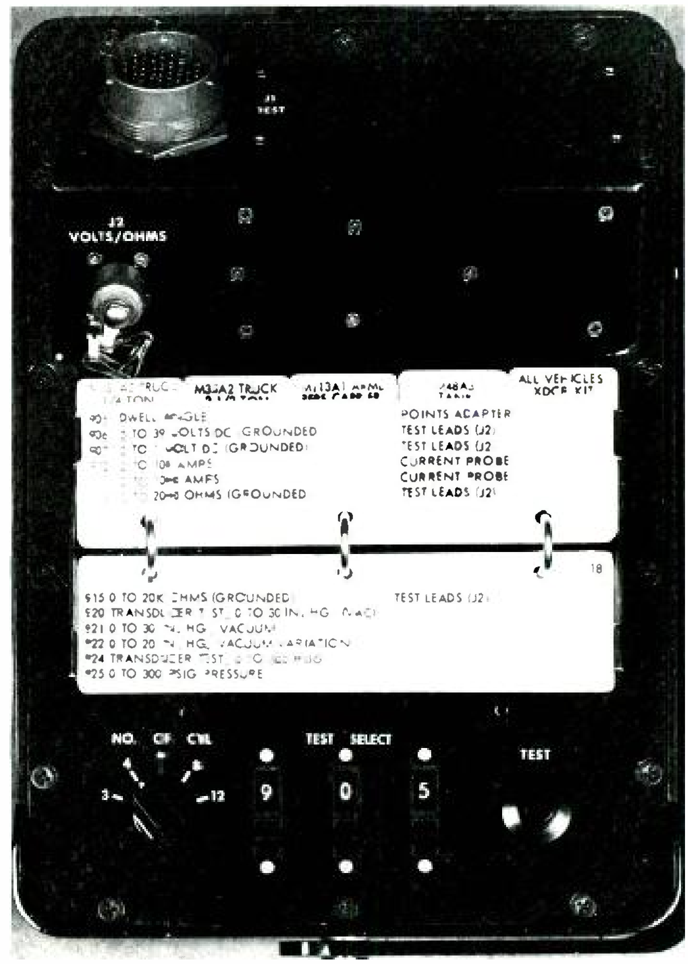

Fig. 2 — Simplified Test Equipment for Internal Combustion Engines (STE/ICE).

(derived from successive points-opening signals) for analysis of engine deceleration dynamics, a single misfire or a cylinder that does not produce power for other reasons such as low compression can readily be detected and isolated.

As implemented in the ATE/ICE system the idle performance test appears to be a single test simply requiring the user to keep the engine at near idle speed for about five seconds. Internally, however, the test is run in four parts: data sampling, gross misfire detection, random misfire detection, and periodic misfire detection. The first part inputs the time of points opening for 102 successive points openings and then uses this data to compute 101 successive speed values. The last three parts are the data processing portions of the test which make use of this data. In all three cases, the data is treated so that the average idle speed is not critical and the tests can be run anywhere between about 300 and 1000 r/min. This simplifies the mechanic's tasks since he is not required to preset the idle speed precisely.

Richard E. Hanson, Senior Member, Technical Staff, Automated Systems Division, Burlington, Mass., received the BS in Mechanical Engineering and Electrical Engineering from Rensselaer Polytechnic Institute in 1968 and 1970, respectively, and the MSEE from Northeastern University in 1974. In 1968, he joined Bendix Motor Components Division in Elmira, N.Y., Mr. Hanson joined Aerospace Systems Divison in 1970. He initially worked on failure mode analysis and development of related failure diagnostic routines in the RCA programs for automatic test of internal combustion engines for automobiles and trucks. In 1971 and 1972, on contracts for the U.S. Army Tank Automotive Command, he developed systems for testing a spark ignition engine's full throttle power capability using ignition interrupt techniques and also worked on diagnostics and associated hardware developments for BITE (Built In Test Equipment) systems on military vehicles. This included development of diagnostic test logic and integration of test programs and interface hardware which were used when the ATE/ICE PDU was interfaced with a BITE connector on a M151A2 vehicle More recently, Mr. Hanson was responsible for the diagnostic development and test program specifications for the ATE/ICE PDU to be used with the TK (Transducer Kit) for performance testing and fault diagnosis of M151A2 vehicles. Mr. Hanson holds three patents related to vehicle test equipment with nine other applications and disclosures in process. He is a member of the Instrumentation Society of America and Sigma Xi.

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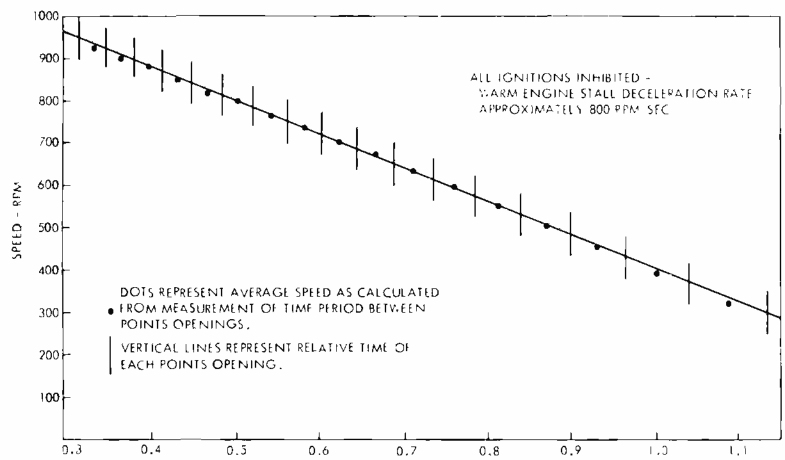

Fig. 3 — Typical deceleration run on military M151A2 vehicle.

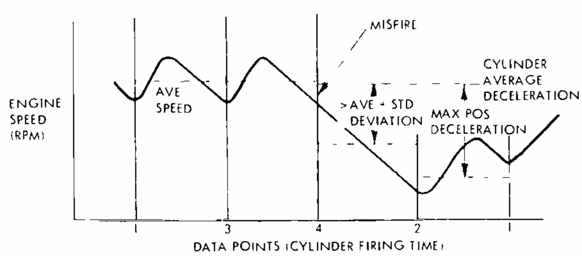

Fig. 4 — Misfire deceleration phenomenon.

Gross misfire detection

The first data processing portion of the test screens the data for *grossly misfiring* engines which result in large speed variations. This type of fault is typical of engines with excessively lean idle mixtures which result in speed variations of several hundred r/min. The processing included in this section finds the minimum and the maximum engine r/min recorded in the set of 101 speed values, calculates the mean and the difference, and then tests for excessive speed variation. The failure criterion used is:

$$(\Delta \text{ r/min})(\text{mean r/min}) > C$$

where Δ r/min is the maximum speed minus minimum speed, mean r/min is the (maximum speed plus minimum speed)/2, C is a constant.

The reason for multiplying (Δ r/min) and (mean r/min) can be seen by looking at Fig. 3 and remembering that it is desirable to keep the test independent of speed. At higher speeds the effect of a misfire is less than at lower speeds because the time from one points opening to the next is smaller and allows for less deceleration. Since the relationship between (Δ r/min) per misfire and speed is a linear one (as shown by the straight line in Fig. 3), the test product above is a valid misfire indicator which is independent of speed.

The test limit, C, used on M151 military vehicles by ATE/ICE corresponds to a speed variation equivalent to approximately nine successive misfires. For warmed-up vehicles of this type tested, with mechanically sound engines, the average deceleration rate was 765 r/min/s. At this deceleration rate, nine successive misfires correspond to a C of $2X10^5$. For this value of C, Table I gives examples of the maximum allowable speed variation at four different mean speeds.

For speed variations greater than those indicated, the test is aborted and a gross misfire fault is registered. For speed variations less than, or equal to, those given in Table I, the next data processing part of the test is run which checks for random misfires.

Random misfire detection

Random misfiring results in a calculated positive engine deceleration over two successive firing periods when a misfire has occurred (see Fig. 4). The misfire is detected by calculating the average deceleration rate between each of the 101 engine speed computations previously stored and testing the individual deceleration rates for a large deviation from the average for a given cylinder.

The system flags maximum positive deceleration, computes the average and standard deviation of deceleration rates for each cylinder, and compares maximum positive deceleration to the cylinder average. If the maximum positive deviation from the average for a cylinder corresponds to the deceleration characteristics of the engine, the system decides that a misfire occurred in either that cylinder or in the cylinder which should have fired immediately prior to it. To determine which of the two cylinders actually misfired (see Fig. 4), the deceleration rate for the preceding cylinder in the firing order is examined. If its deceleration rate is greater than the average plus the standard deviation for that cylinder and also approximates the deceleration characteristics of the engine, then it is indicated as the misfiring cylinder. To increase resolution, the process is repeated for two or more sets of 100 time periods. If, for example, the same cylinder is indicated as misfiring in two sets and the engine has four cylinders, then the engine misfire rate at idle equals or exceeds 4% on the indicated cylinder.

The results of the random misfiring portion of the test have more significance than simply pass or fail or an idle performance test. Failing this test on any cylinder indicates that some firings of that cylinder produce significantly less power than the average for the cylinder during the test. This is generally the result of either an air/fuel mixture problem or an ignition system problem creating marginal sparks. In the ATE/ICE system, failure of this portion of the test automatically results in branching to the ignition system test to start detailed fault isolation. Passing this portion of the test causes the third data processing portion of the idle misfire test to be run checking for periodic misfires (same cylinder misfiring repeatedly).

Periodic misfire detection

Periodic misfiring occurs when a spark plug is shorted or totally fouled, or the compression is unbalanced. Since the cylinder is consistently misfiring, it would not fail the random misfire test. When the engine is periodically misfiring, the average deceleration is higher than normal since no power or low power is consistently being produced by this cylinder. This fault is detected by checking the range of the average deceleration rates between cylinders (maximum average deceleration rate minus minimum average deceleration rate). A range greater than the predetermined test limit (600 r/min/s for M151 military vehicles tested by the ATE/ICE system) indicates either a compression unbalance problem or a periodic misfire and results in failure of the idle performance test. In the ATE/ICE system such a failure will also result in branching to fault isolation tests starting with the ignition system. Passing this portion of the idle performance test, and all others, indicates a smooth idling engine.

Testing full power performance without a dynamometer

Power testing without a dynamometer is accomplished electronically by using the inertial load and speed of an engine under controlled transient test conditions as a basis for calculating its brake, friction, and indicated horsepower versus speed characteristics. There is no calibrated external shaft load available when testing without a dynamometer, so to keep this independent variable in a constant known state for output evaluation, the external shaft load is kept at zero. The output torque then is also zero, and speed is the only indicator of engine performance (see Fig. 5). When three of the engine's four input variables are held constant (throttle position fixed at wide open throttle, external shaft load equal to zero, and firing ratio equal to a fixed ratio of 1 out of n, the engine's torque production (IHP) will equal its frictional load (FHP) at the point where steady-state speed is reached. Either a high frictional load or low torque producing capability results in a low steady-state interrupt speed. If the frictional load (including parasitic loads such as those of fans, generator, and other accessories) can be isolated then the frictional horsepower (FHP), brake horsepower (BHP), and indicated horsepower (IHP) of the engine can be computed.

Full power performance testing

Full power test conditions are simulated using the ASD ignition interrupt technique which, for a four-cylinder engine, interrupts four out of five potential firings. Figure 6 illustrates the steady-state operation of an engine under ignition interrupt load simulation. One fifth of the normal total power developed within the engine is balanced against the frictional power consumption of the engine. From the figure it can be seen that if the actual friction horsepower (or torque) were known at the balanced interrupt speed and the interrupt firing ratio was 1 out of 5, this friction horsepower value could be scaled by 5 (or the inverse of the interrupt ratio) to determine the actual indicated horsepower capability of the engine at that speed. Alternately it could be scaled by 4 to indicte brake horsepower capability at that speed since BHP=IHP −FHP=(5−1)(FHP).

Frictional load, including corrections for variations caused by changes in oil viscosity, temperature, and other frictional parameters, can be determined

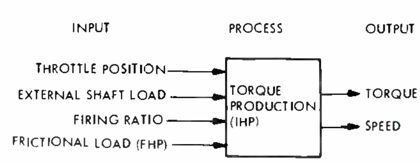

Fig. 5 — Engine power testing parameters.

by analysis of the deceleration dynamics of the unpowered engine at the steady-state interrupt speed. Speed changes in an engine result from unbalanced load conditions; such as acceleration when power developed exceeds power absorbed (by internal and external loads) or deceleration when power developed is less than power absorbed. This can be expressed by $T = I\alpha$ where T is the torque difference (between produced and absorbed,) I is the rotational moment of inertia for moving parts of engine, and α is the acceleration rate (deceleration rate if negative).

Thus, if the ignition is inhibited after an interrupt test no power will be produced and the engine will decelerate due to frictional torque characteristics of the engine. If the inertia (fixed engine characteristic) is known, then the frictional torque, T_F, can be obtained by simple scaling of the deceleration rate by the inertia factor. However, since the frictional torque is a function of speed (see Fig. 6), the friction torque must be obtained at the final interrupt speed if the condition is to hold where BHP = 4(FHP).

Fig. 7 illustrates a typical operating cycle for the full power performance test. The engine is run under simulated full load (full air and fuel flow) condition for approximately 40 seconds. This will generally be long enough to empty the carburetor bowl if a marginal or poor fuel supply exists (such as caused by a clogged filter or partially ruptured pump diaphragm). If the speed drops below a lower speed limit (2000 r/min), the power test is automatically terminated and "low power" is displayed. The ATE/ICE program then continues on to further fault isolation. At the end of the normal test duration (approximately 40 seconds), the test system stops inhibiting the ignition, allowing the engine to accelerate again. After the speed has increased by

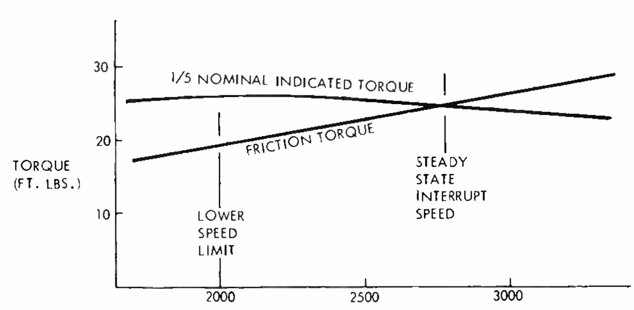

Fig. 6 — Ignition interrupted torque curves (M151A2 vehicle).

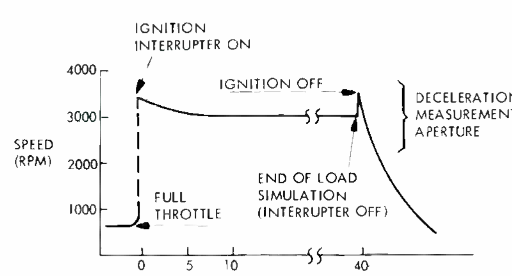

Fig. 7 — Full power performance test cycle.

500 r/min the ignition is completely inhibited while the deceleration rate, R_d, centered around the interrupt speed (r/min) is measured. The friction torque (T_F) is then calculated from:

$$T_F = IR_d$$

where I is the rotational moment of inertia for moving parts of engine. The indicated torque T_I, or total torque produced is given by:

$$T_I = 5T_F.$$

The brake torque, T_B, or output torque then is given by:

$$T_B = T_I - T_F = 5T_F - T_F = 4T_F.$$

Horsepower is computed by:

$$\text{HP} = \text{torque} \times \text{r/min}/5250$$

Testing ignition performance

Automated ignition system testing is conducted in the classical sense by performing a real-time waveform analysis of spark dynamics. Testing is performed during starting, idle, and full power operation. Evaluation is made in terms of how many "good" sparks are generated at the proper time in the engine cycle. Fig. 8 shows the characteristics of a typical spark. A good spark must meet several criteria, some absolute and some relative.

First, measured data for each spark are compared to absolute limits. The spark must be long enough to ignite the compressed fuel/air mixture. Thus, each spark duration is compared to an absolute lower limit of 1.0 ms. (Limits described here are from actual test design for an ignition system from a M151A2 military vehicle.) Similarly, unless there is a partial short in the secondary output system (such as a shorted cable or plug) the spark duration cannot exceed 3.5 ms. The spark zone voltage or firing line voltage measured 0.7 ms after initial points opening for each spark must also fall within a range of 500 to 1500 V.

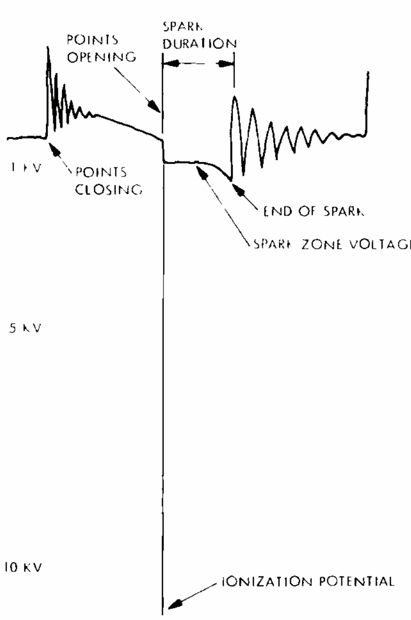

Fig. 8 — Typical ignition-system secondary voltage.

Second, the spark zone voltage and spark duration measured above must fall within limits relative to the average spark parameters. Thus, to compensate for the wide range of electrical performance between different vehicles and measurement uncertainties accumulated from the capacitive divider used in the secondary voltage pickup, the spark zone voltage is compared to limits of ±45% of the average value. Similarly, the spark duration is compared to limits of ±30% of the average value. A single limit of 0.2 ms is the allowed spark delay. That is, the time from initial points opening to when the spark voltage rises to about 3 kV cannot be greater than 0.2 ms for a good spark. A delay greater than this limit is usually from points arcing caused by bad points, condenser, or both. Thus, a good spark is a spark delayed less than 0.2 ms with spark zone voltage and spark duration within both absolute and relative limits.

Ignition limits vs engine operating regime

Some ignition system problems will prevent a vehicle from starting. Such "no start" vehicles with comparatively normal ignition systems (i.e., plugs not too bad, and coil normal) may experience erratic spark characteristics, especially at lower battery voltages and slower cranking speeds. Because of this "no start" ignition performance test criteria have intentionally wide tolerances. The test system takes ignition data until it finds three good sparks for each cylinder or until it has analyzed data on 14 sparks for each cylinder without having detected three good sparks. In the latter case the ignition system failed its performance criterion and fault isolation is conducted. Fault isolation constitutes automatic spark envelope analysis to isolate failed capacitors, coils, ballast resistors, points, plugs, cables, compression, or timing.

Spark duration limits for an "idling engine" are slightly tighter because of the more consistent operation of the engine at the higher idling speed and the higher energy input into the ignition system. The spark duration lower limit is 1.0 ms and the upper limit is 3.5 ms. Absolute limits on the spark zone voltage for each spark are the same at between 500 to 1500 V. The relative spark zone voltage limits are ±35% of the average value. The spark duration relative limits are ±20% of the average value, with a 0.2 ms allowable spark delay. Again, a "good" spark is a spark delayed by less than 0.2 ms with spark zone voltage and spark duration within both absolute and relative limits. The test system analyzes ignition data until it finds at least seven bad sparks for any cylinder or until it has analyzed 40 sparks per cylinder and not found seven bad ones. An exception to the above test procedure occurs when the ignition points are bad enough to give erratic operation such that the test system cannot reliably take a full set of spark data. If this occurs the test system will automatically attempt to get the full data set three times. A points fault is called out when the data set is not obtainable.

Occasionally a vehicle develops a marginal ignition system problem that will allow an engine to idle normally, but will prevent efficient operation of the engine under a loaded condition. Thus, an ignition test is also required with the engine in a simulated full power mode of operation. Because of the difference in combustion during "power tests", a more erratic spark zone voltage results. Thus, ignition limits used during this mode of operation are based on meeting absolute and relative limits for spark duration only. Since the energy required to fire a spark plug under full load operating conditions is higher than at idle, the average spark duration during the interrupt power test is shorter than similar data measured at idle. Thus, the absolute lower limit on spark duration for a good spark is set lower at 0.8 ms. The absolute and relative limits for good spark duration remain the same.

Testing ignition timing

An automated ignition timing test which does not require the mechanic to use a timing light or other additional transducers is an important factor in the development of effective automatic test equipment for the internal combustion engine. This technique takes advantage of the fact that in normal testing a clamp-on

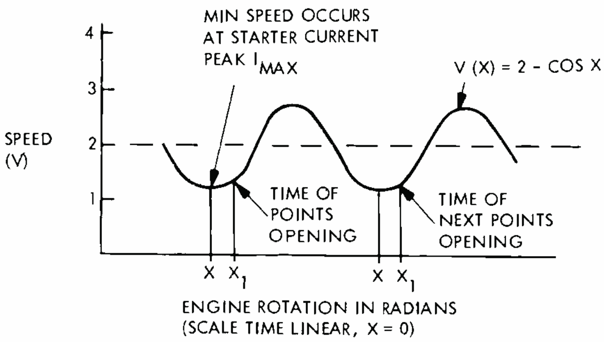

Fig. 9 — Timing from starter current waveform.

(or built-in) current probe is installed on the vehicle for compression unbalance testing from the starter current signal which can also be used simultaneously for an ignition timing test with no additional effort required of the mechanic.

Timing from starter current waveform is based on the dynamic relationship of the ignition primary waveform and the starter current waveform. To prevent the engine from firing and distorting the cranking current waveform, the ignition is inhibited during this test. Further current waveform integrity is assured by simultaneously testing it for an indication of compression unbalance.

The timing calculation is derived from the measurement of the time difference between the occurrence of two events—points opening and the corresponding starter current peak. Prior to calculating the time of a starter current peak, the digitized starter current data is processed by a recursive digital filtering algorithm to smooth out higher frequency variations caused by the rotating commutator bars of the starter. The timing angle calculation (in degrees) compensates for two major effects: speed variations and phase shift of current peaks with speed variations. During cranking, varying torque loads cause significant speed variations. Thus, conversion of the time difference measurement into degrees of engine rotation cannot be made by a simple scale factor. A sinusoidal speed versus time variation is assumed (see Fig. 9), and the instantaneous cranking speed is given as:

$$v(x) = 2 - \cos(x)$$

The average cranking speed between the current peak and points opening is then given by:

$$v_{ave} = 1/x_1 \int_0^{x_1} [(2-\cos(x)]\, dx$$

$$= 1/x_1\, [2x_1 - \sin(x_1)]$$

or

$$v_{ave} = [2 - \sin(x_1)]/x_1.$$

Knowing the average cranking speed over the interval of interest, other fixed scale factors, and units conversion factors, the average number of degrees between I_{max} and points opening can be approximated by the equation given below for the M151A2:

$$y = 100\, t_1/T\, [2 - \sin(x_1)/x_1]$$

where

y = average number of degrees I_{max} occurs before points opening

100 = conversion constant in degrees (derived from empirical data)

t_1 = sum of time in seconds I_{max} occurs before the associated point opening, for four consecutive cylinders

T = time in seconds for one full engine cycle (i.e., two crankshaft revolutions)

$x_1 = 2\pi\, |t_1|\, / T$ in radians

To compensate for the I_{max} phase shift with speed (from eddy current electromagnetic phenomenon), the following empirically derived equation is used:

$$z = 12.6 + 26.3(T - 0.90)$$

where z is the number of crankshaft degrees before top dead center (BTDC) that I_{max} occurs. The actual timing, T_A, in degrees BTDC is them simply

$$T_A = z - y.$$

Timing measurement accuracy within $\pm 2°$ is achieved with this technique.

Conclusion

The techniques described form a small but important part of the automatic test technology that ASD has applied to make possible the development of portable multi-function automatic test equipment. The result of five years of research and development sponsored by ASD and the U.S. Army Tank-Automotive Command, Warren, Michigan, this technology has already been applied to a number of Army vehicles including jeeps, trucks, troop carriers, and tanks. It is only a matter of time before it will catch on in the commercial world. Agriculture, mining, transportation and fishing industries have already expressed their need for effective off-road and "curb side testers.[5,6]

The internal combustion engine service industry as a whole is faced with increasing demands for error-free service procedures, improved operating economics and lowered emission levels.[7] The industry needs effective new test equipment that can be readily used in the shop, on the road and in remote field locations; equipment that identifies degenerating performance and failing parts;[8] equipment that is simple to use, automatic and foolproof; equipment that interprets the data it provides and gives answers and specific repair instructions; equiment that reduces repair time, is accurate, and cost effective.[9,10] The testers and test technology described in this paper are ready to meet the challenge. The systems knowledge needed to identify the application and to adapt the technology is the same as that used to develop these techniques and equipments and is also ready.

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Analog versus digital anti-jam video transmission

C.H. Haber| E.J. Nossen

This paper presents an evaluation of the relative performance provided by analog and digital video modulation approaches. Anti-jam (AJ) performance of these modulations is considered when used in concert with spread spectrum techniques such as frequency hopping and direct sequence pseudo-random modulation. These modulation approaches are compared on the basis of power efficiency, required channel bandwidth and degree of AJ protection for the same output video quality. The effect of video bandwidth compression and reduction techniques on the relative modulation performance is also presented. A description of an RCA developed wideband video AJ system, based on the results of this study, is also included.

For several years, there has been considerable discussion whether tactical video transmissions should be sent in analog or digital form. Analog transmission in the form of frequency modulation is obviously simpler to implement than digitized transmissions, which generally utilize some form of phase modulation. In some applications, digitized video has the advantage that it can be encrypted and is ideally suited to successive transmission and reconstruction over multihop links. Since the additional hardware complexity of digital video transmissions is well established, this paper will investigate the relative performance of analog versus digital transmission of video. Performance will be considered for a clear, non-jamming environment, and for a broadband noise jamming environment. In addition, the ability of bandwidth reduction and compression techniques to enhance the anti-jam performance of a video link is also investigated.

The objective of this paper is therefore to determine when analog transmissions provide optimum performance, and under what conditions the additional complexity of digital video transmissions is warranted by improved performance.

Baseline system parameters

To arrive at meaningful results, a baseline system is assumed, and various performance characteristics specified. Fig. 1 is a baseline system, showing the various video processing options, from the camera through the link to the display. The camera provides the electrical output signal, which is compressed in bandwidth, if bandwidth reduction or compression equipment is included. The resulting output signal is then applied to a modulator and transmitter. The signal is radiated to the receiver, where it is demodulated and possibly expanded in bandwidth, to meet the requirements of the display. Parameters entering into the analysis are the required sensor field of view, resolution, scan rate, and desired picture quality at the display.

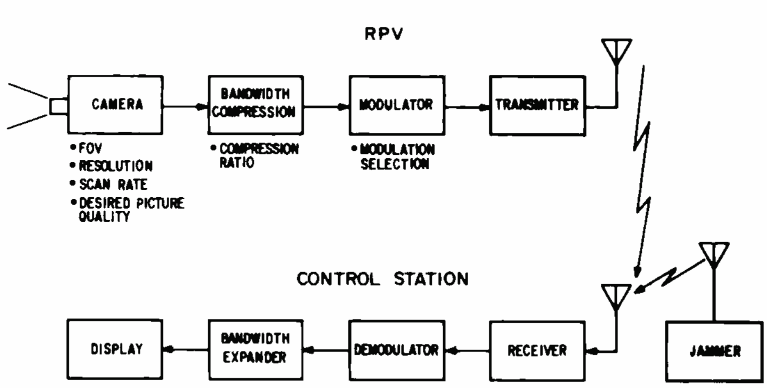

Fig. 1 — Link selection parameters.

When using bandwidth compression, the compression ratio provided by the technique used is also a key parameter. The outcome of the comparative analysis is to specify the signal modulation for optimum performance under clear and jamming conditions. Typical weapon video characteristics (similar to FCC standards) of interest in the operation of remotely piloted vehicles (RPV's) are listed below:

- 60 fields/s (2:1 interlace)
- 30 frames/s
- 1.33 aspect ratio
- 525 lines per frame
- 483-line vertical resolution
- 311-line horizontal resolution
- 200,445 picture elements per frame
- 4.2-MHz video bandwidth

The scan parameters of weapon sensors, such as the Maverick Missile seeker head camera, are very similar to FCC standards, with 30 frames/s, 525 lines per frame and slightly more than 4-MHz video bandwidth.

Required quality

An important parameter in the analysis is the ultimate signal-to-noise ratio, or picture quality at the display. Numerous studies have been undertaken and some are still in progress to determine what picture quality an operator requires to complete a mission. A well known study which has been performed with broadcast television is the Television Allocation Study Organization (TASO study).[1] Table I shows the results of that study in terms of picture quality, and the statistical viewer interpretation for various signal-to-noise ratios. The highest quality grade, called excellent, is representative of a broadcast studio monitor. About 25% of the viewers thought that a 38-dB signal-to-noise ratio provided such a picture quality. Note that the signal-to-noise ratio had to be raised to 50 dB before 75% of the viewers agreed that this was an excellent picture.

For tactical operations, a somewhat lower quality will probably be acceptable, such as the fine grade, which may require as much as a 38-dB TASO signal-to-noise ratio. The TASO signal-to-noise ratio is

Table I — TASO study results (television allocation study organization).

GRADE	DESCRIPTION	SIGNAL-TO-NOISE RATIO (DB) ADEQUATE FOR GIVEN PERCENTAGE OF VIEWERS		
		25%	50%	75%
EXCELLENT	EXTREMELY HIGH QUALITY	38	44	50
FINE	HIGH QUALITY, ENJOYABLE VIEWING, BUT PERCEPTIBLE INTERFERENCE	30	34	38
PASSABLE	ACCEPTABLE QUALITY, INTERFERENCE NOT OBJECTIONABLE	25	27	30
MARGINAL	POOR QUALITY, IMPROVEMENT DESIRABLE, INTERFERENCE SOMEWHAT OBJECTIONABLE	21	23	25
INFERIOR	VERY POOR QUALITY, COULD BE WATCHED, INTERFERENCE DEFINITELY OBJECTIONABLE	15	17	19
UNUSEABLE	PICTURE TOO BAD TO BE WATCHED	12	14	16

Table II — Video modulation alternatives.

MODULATION	ANALOG VS DIGITAL	HARD LIMITING REPEATER	CHANNEL BANDWIDTH (NULL TO NULL)	REQUIRED POWER DB
AM(VSB)	A	NO	5.3 MHz	+ 10
FM (β = 1.5)	A	YES	20 MHz	0
PSK: 2 ϕ	D	YES	120 MHz	+ 1
4 ϕ	D	YES	60 MHz	+ 1

β = MODULATION INDEX   * FOR TASO SNR = 38 DB

defined for VSB-am modulation, as the ratio of the rms value of the rf video waveform (zero to sync level) to rms value of the input noise measured in a 6-MHz bandwidth.

Many workers in the field have used other definitions of signal-to-noise ratio, involving different measures of video signal amplitude, as well as noise power. In this paper we will use the peak-to-peak signal (sync to white level) to rms noise ratio (unweighted). This ratio is usually considered to be 9 dB higher than the rms signal-to-rms noise ratio which is more common for other signal types.

The TASO signal-to-noise (SNR) depends upon the noise-spectral density, as well as its rms value, as illustrated in Fig. 2. For the same peak-to-peak signal-to-rms noise ratio, a higher TASO-SNR results for cases where less noise energy is concentrated at low frequencies, such as that for the parabolic noise density. Generally, low-frequency noise energy has a more objectional effect on picture quality. The parabolic noise spectrum is found at the output of an fm detector while the flat noise spectrum occurs at the output of a digital PCM decoder.

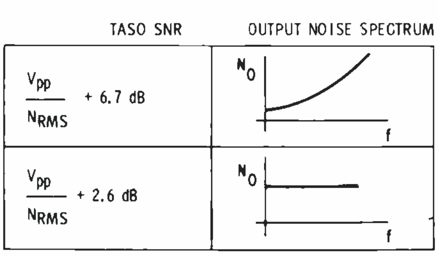

Fig. 2 — Scale factors applied to output noise spectrum to determine signal-to-noise.

The scale factors shown in Fig. 2 to convert a peak-to-peak signal-to-rms noise ratio to a standard TASO-SNR take into account the shape of the output noise spectrum, as well as the definition of peak-to-peak video signal amplitudes.[2] These relations will be used to compare the necessary PSK and fm transmitter power to achieve the same TASO-SNR. A TASO signal-to-noise ratio of 38 dB will be used as a reference value in many of the following analyses.

Video modulation alternatives

There are many video modulation alternatives (Table II). The techniques of amplitude modulation and vestigial sideband filtering do not lend themselves for use in relay operations where a hard limiting repeater is desirable to minimize the introduction of signal distortion. This vestigial sideband signal requires the least amount of rf spectrum and the largest transmitter power to achieve the desired

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Table III — Bandwidth requirements.

DIGITAL VIDEO BIT RATE $R_B = F_S \times K$

FOR $F_M = 4.2$ MHz

$F_S = 2.4 \times F_M$

$F_S = 10$ MEGA SAMPLES/SECOND

$K = 6$ BITS/SAMPLE

→ $R_B = 60$ MEGA BITS/SECOND

MODULATION		BANDWIDTH NULL TO NULL	GENERAL FORMULA
ANALOG FM		20 MHz ($\beta = 1.5$)	$BW = 2(\beta + 1) F_M$
DIGITAL PSK	2 Ø	120 MHz	$BW = 2 \times R_B$
	4 Ø	60 MHz	$BW = R_B$

video quality. The major candidates available for tactical video transmission are analog fm, and digital PSK, which may be either two phase or four phase. The channel bandwidth required for a typical analog fm transmission with modulation index of $\beta = 1.5$ is 20 MHz. The same amount of video information transmitted digitally would require a null-to-null bandwidth of 120 MHz for bi-phase modulation and 60 MHz for quadra-phase modulation.

PSK transmissions require about 1 dB more transmitter power at the referenced output signal-to-noise ratio due to the wider receiver bandwidth. The bandwidths required for the fm and PSK modulation are derived in Table III Considering a digital video sampling rate of 10 megasamples/s, and a gray scale capability of 6 bits per sample (64 gray levels), a digitized video bit rate (R_B) of 60 megabits/s results. Assuming four-phase PSK transmission, this rate requires a 60-MHz null-to-null bandwidth. Reduction of this bandwidth would result in serious distortion. The analog fm channel bandwidth is approximately five times the baseband signal bandwidth F_M when β equal 1.5. This results in a 20-MHz bandwidth requirement. Fig. 3 illustrates the relative carrier power requirements between digital PSK transmission and analog fm transmission, as a function of video quality. Note from the output signal-to-noise expression that the fm signal-to-noise ratio is directly proportional to the carrier power.

For digital transmissions, the output signal-to-noise ratio varies exponentially with carrier power in such a way that a small increase in carrier power can result in a drastic reduction of the bit error rate and therefore improved performance. The curve shows the crossover in power requirements at about 39-dB signal-to-noise ratio, according to the TASO definition. For desired video quality, below a TASO level of 39 dB, fm has an advantage of several dB. However, above 39 dB, less power is required by PSK. FM performance can be further improved by using pre- and de-emphasis filtering, which was not considered in this analysis.

Anti-jam requirements

When considering operation in a jamming environment, it is important to obtain maximum anti-jam (AJ) protection on the video link. Maximum protection requires the use of every available means for improving the link performance, such as the use of directive transmit and receive antennas to maximize gain, minimize beamwidth, and maximize the main beam-to-sidelobe ratio. The maximum available transmitter power consistent with size, weight, prime power and thermal constraints imposed by the RPV, must be used. A power efficient modulation approach is essential to gain those extra few dB's when power is limited. Furthermore, the minimum information bandwidth consistent with successful mission completion should be used. And finally, the transmitted signal should be spread over the widest possible frequency range, to force the jammer to dilute his jamming power.

MODULATION	OUTPUT SNR RELATIONS	REQUIRED OUTPUT SNR FOR TASO SNR = 38 dB
ANALOG FM	$\left(\frac{S}{N}\right)_0 = \frac{3\beta^2}{2}\left(\frac{C_{FM}}{N}\right)$ LINEAR WITH C_{FM}	$\left(\frac{S_{PP}}{N}\right)_0 = 31.3$ dB
DIGITAL PSK	$\left(\frac{S}{N}\right)_0 \sim \frac{1}{2(1 - ERF^*\sqrt{C_{PSK}/N})}$ EXPONENTIAL WITH C_{PSK}	$\left(\frac{S_{PP}}{N}\right)_0 = 35.4$ dB

$^*ERF(x) \frac{1}{\sqrt{2\pi}} \int_0^1 e^{-Y^2/2} dy$

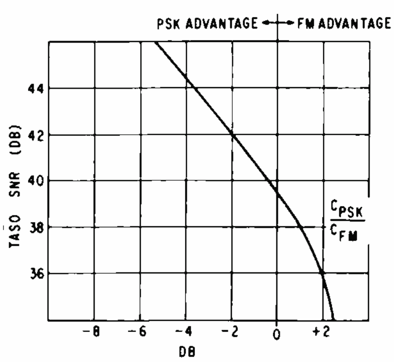


Fig. 3 — Carrier power ratio.

The relative AJ protection available from a digital PSK transmission, and an analog fm transmission are derived below.

CONDITIONS

- FIXED TRANSMITTER POWER (EXCEEDS NOISE REQUIREMENT)
- FIXED TRANSMISSION BANDWIDTH (EXCEEDS NON AJ REQUIREMENT)
- FREQUENCY HOPPING FILLS EXCESS BANDWIDTH
- BROADBAND NOISE JAMMER POWER DENSITY $J_0 \frac{\text{WATTS}}{\text{HZ}}$
- ATMOSPHERIC/FRONT END NOISE POWER DENSITY $N_0 \frac{\text{WATTS}}{\text{HZ}}$

$$\text{AJ ADVANTAGE (FM OVER PSK)} = \frac{\left[\frac{C_{PSK}}{(N_0 + J_0) B_{PSK}}\right]}{\left[\frac{C_{FM}}{(N_0 + J_0) B_{FM}}\right]} \times \frac{B_{PSK}}{B_{FM}} = \frac{C_{PSK}}{C_{FM}}$$

The conditions used for this comparison are clearly stated. The same transmitter power and transmission bandwidth are used, and both are in excess of that required for a non-AJ mode. The excess bandwidth is filled by frequency-hopping the signal. It is shown that the AJ advantage is again the ratio of the carrier power required for fm. In other words, at a high output signal-to-noise ratio, PSK has superior AJ performance, while at the lower signal-to-noise ratio, fm would show an advantage.

Bandwidth reduction/ compression

Generally, the amount of spectrum required for the video transmission does not leave much additional bandwidth for purposes of AJ protection. It is therefore important to apply video bandwidth reduction and compression techniques to reduce the information bandwidth. Bandwidth reduction can be defined as a technique to remove extraneous information before transmission, thereby providing the observor with less information. However, it is expected that all the information of interest will be transmitted. In bandwidth compression, the entire image is transmitted but redundancy is removed before transmission, thus minimizing the information loss, as the final picture is presented to the observor. Bandwidth reduction and compression techniques can be cascaded for increased AJ protection by minimizing the transmitted information bandwidth. The compression ratio provided by a compression technique can be defined as $CR = R_B / R_C$ where R_B is the input bit rate and R_C is the compressed output bit rate. A composite compression ratio covering both reduction and compression techniques can be defined in a similar manner.

Fig. 4 shows some examples of bandwidth reduction techniques. The two most promising techniques, frame rate reduction and underscan, are described. In frame rate reduction, initially a single snapshot of the target area may be transmitted at perhaps a one-frame/s rate. This would result in a 30:1 bandwidth reduction. As the mission progresses and the target is acquired, a real-time 4:1 reduction appears realistic. This would still provide seven and a half frames/s. A full frame of video is still presented to the operator, but it will occur at a lower frame rate. Storage devices are required at both the transmitter and the receiver, so that the frame rate can be slowed down and then refreshed again, to provide a flicker free display to the operator. Frame storage can be implemented with a silicon storage tube, charge coupled devices or a digital memory. The second promising technique, which can provide from 10:1 to 100:1 bandwidth reduction, is underscan or electronic zoom, where only the target area is scanned. As Fig. 4 shows, if the area can be reduced both in X and Y dimensions, a considerable bandwidth reduction can be obtained.

Bandwidth compression techniques fall into two basic categories. The first processes time-domain video samples directly to achieve compression, and is generally limited to compression ratios on the order of 2:1. Well known techniques of this type include differential PCM, delta modulation and the use of predictive techniques. The more powerful bandwidth compression techniques use two-dimensional transformation of the image, transform domain sampling and truncation of the resulting coefficients. Typical compression ratios run as high as 10:1 without serious image degradation. Examples of transform algorithms are the Haar, Hadamard, Fourier and Slant transforms.

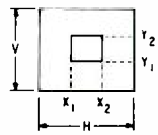
TECHNIQUE	DESCRIPTION	IMPLEMENTATION	TYPICAL BW REDUCTION RATIO
FRAME RATE REDUCTION	• REDUCE NUMBER OF FULL VIDEO FRAMES/SECOND • REDUCED SCANNING RATE/FRAME • FULL 525 LINES/FRAME RETAINED	• SILICON STORAGE TUBE • CCD'S • DIGITAL • DISC	REAL TIME 4:1 (7.5 FRAMES/SEC) SNAPSHOT 30:1 (1 FRAME/SEC)
UNDERSCAN	• SCAN TARGET AREA ONLY • REDUCED SCANNING RATE • FULL RESOLUTION IN SCANNED AREA  BANDWIDTH REDUCTION $= \frac{V}{Y_2 - Y_1} \times \frac{H}{X_2 - X_1}$	• SILICON STORAGE TUBE • CCD'S • DIGITAL • DISC	FROM 10:1 TO 100:1 DEPENDING ON MISSION, FOV, ETC.

Fig. 4 — Examples of reduction techniques.

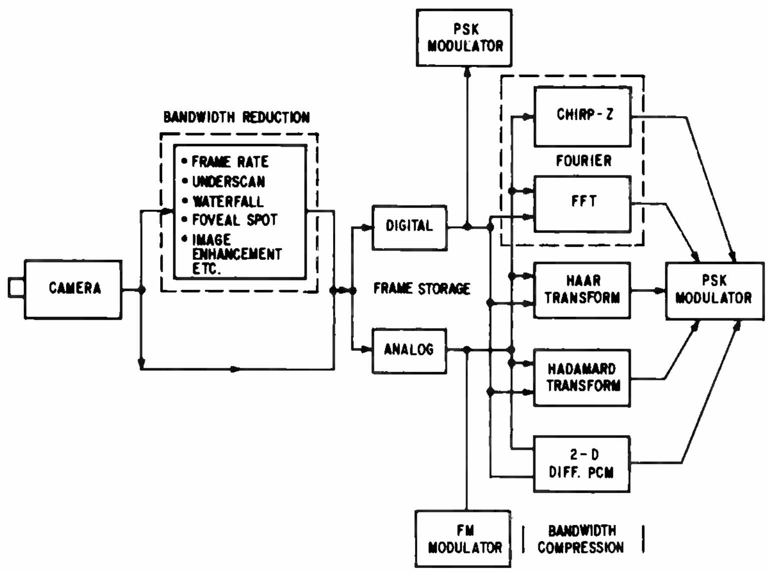


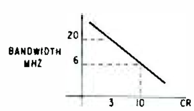
Fig. 5 — Video transmission options at the RPV.

Video processing/ transmission options

The many video transmissions options available at the RPV are summarized in Fig. 5. The camera output can first be subjected to some form of bandwidth reduction, since these techniques can reduce the information bandwidth rapidly with minimum hardware. A partial or full frame will then be stored in analog or digital form. At this point, it can be transmitted by means of the respective modulation shown, or it can be further subjected to bandwidth compression.

After bandwidth compression, the selected modulation is generally digital PSK. All of the compression transforms can be implemented in digital form, while the Fourier transform also has an analog implementation using the chirp Z algorithm.[3,4] The latter shows promise for a low-cost bandwidth compression implementation through the use of charge coupled devices. Once the information bandwidth has been reduced, there are two spread spectrum options. These include frequency hopping and direct sequence pseudo-noise modulation. Analog fm transmissions lend themselves only to frequency hopping, while digital PSK transmissions can be frequency hopped as well as spread, by means of a pseudo-random sequence.

Fig. 6 illustrates the composite compression ratio required (reduction + compression) for various amounts of AJ gain, when a pseudo-noise PSK modulation is used. The four-phase PSK information bandwidth is 60-MHz divided by the composite compression ratio. For a channel bandwidth of 20 MHz and a desired AJ improvement of 10-dB, a 30:1 composite compression ratio is required. A 20-dB capability requires a 300:1 composite compression ratio. Obviously, as the channel bandwidth is allowed to grow to 100 MHz, the compression requirements can be relaxed. Fig. 7 shows the effect on relative AJ protection of using bandwidth compression with the PSK transmission. These results are independent of any bandwidth reduction provided, since this would not improve the relative AJ performance, but would improve the absolute AJ protection for both modulations. The compression ratio reduces the digitized video data rate R_B, resulting in reduced information bandwidth and a corresponding reduction in carrier power. This all results in improved AJ protection with PSK modulation. The curves show the amount of improvement as a function of desired TASO signal-to-noise ratio with compression ratio as a parameter. As the compression ratio increases, a very substantial amount of AJ performance improvement is realized with PSK.



CHANNEL BANDWIDTH	REQUIRED CR	CR FOR 10 DB AJ	CR FOR 20 DB AJ
20 MHZ	3 1	30 1	300 1
100 MHZ	1 1	6 1	60 1

4 Ø PSK BANDWIDTH = $\frac{60\ MHZ}{CR}$

Fig. 6 — Composite compression ratio required for PN-PSK.

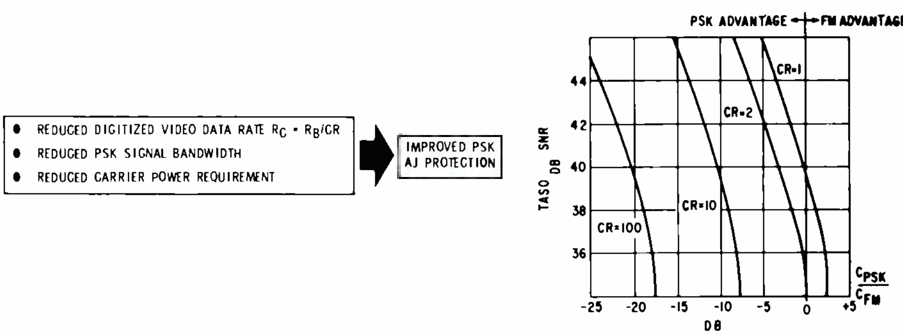


Fig. 7 — AJ protection resulting from bandwidth compression.

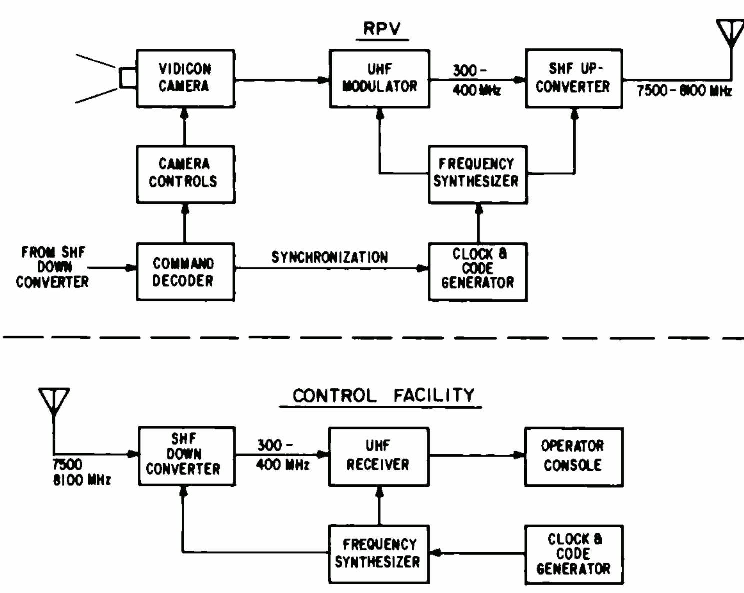


Fig. 8 — Block diagram of RCA demonstrator (video portion).

Trade-off conclusions

In general, below a 39-dB TASO signal-to-noise ratio, fm requires less power. And without bandwidth reduction or compression, PSK requires about three times the bandwidth of an fm transmission. Digital video therefore requires more power and bandwidth than analog video transmission. A bandwidth compression ratio for digital video of at least 2:1, is required to break even with fm. Bandwidth reduction can be applied to analog video fm transmissions while remaining in the analog domain and also to digital PSK transmissions. In fact, RCA has implemented an fm frequency-hopping AJ system, which accommodates video bandwidth reduction down to 25 kHz.

RCA video anti-jam link

The RPV/AJ communication system uses direct sequence pseudo-noise and frequency hopping for protection of the command data, and frequency hopping to protect the sensor video information. A block diagram of the video portion of the AJ Communication System is shown in Fig. 8. At the top, the RPV equipment is shown, while the bottom illustrates the control facility equipment. The video signal in the RPV simulator is obtained by aiming a vidicon camera on a target scene. The RPV/AJ communication system is shown in Fig.9.

The camera can be controlled in pan, tilt and zoom by means of the camera controls. Messages to implement the various camera actions, are obtained from the AJ command link and the command decoder. The command decoder also provides for synchronization of the clock and code generators on the RPV. The baseband video signal from the camera is applied to a UHF modulator. This is driven by a frequency-hopping UHF synthesizer, which can select any output frequency in the 300- to 400-MHz band, in 25-kHz increments.

The 100-MHz wide UHF band is then up-converted to SHF, in the 7500 to 8100 MHz range, where it is radiated by a horn antenna. The frequency synthesizer also selects the appropriate 100-MHz band within the SHF frequency range. It is thus possible to frequency hop over a 600-MHz band with frequency increment of 25-kHz. A uniform spectrum could thus be preserved, even if the video baseband spectrum were reduced down to nearly 25-kHz. The actual video modulation index of 1.5, so that the instantaneous RF spectrum is approximately 5 times the baseband spectrum.

At the control facility, the antenna receives the signal within the 7500- to 8100-MHz range, and down-converts this to the 300- to 400-MHz UHF band. Obviously, the frequency synthesizer must select the appropriate 100 MHz interval at SHF for the down conversion process. In the UHF receiver, the 300- to 400-MHz band is de-hopped by means of the frequency synthesizer injection. A 70-MHz IF, within the UHF receiver, contains a limiter/discriminator for the final video demodulation. The baseband video is then applied to the operator's console for display. The frequency synthesizer is driven by a clock and code generator, in synchronism with the equivalent units in the RPV. Since the control facility is the master, synchronization tracking is performed in the RPV.

Fig. 10 shows the control console that is used in the demonstration system, and it illustrates the video display as it looks in the frequency-hopping mode. Fig. 11 shows a mockup of an RPV/AJ command receiver and video transmitter for use in future RPV's.

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Fig. 9 — RPV/AJ communication system.

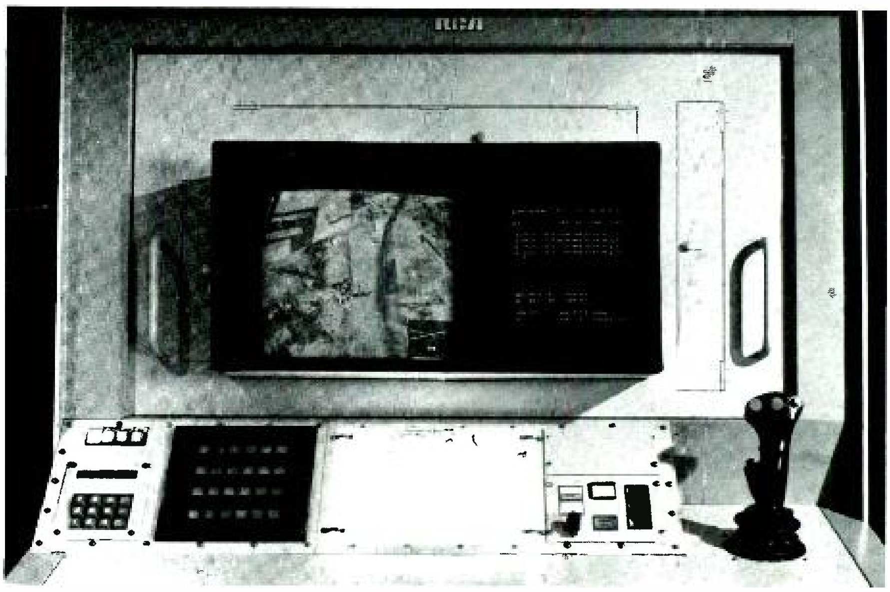

Fig. 10 — RPV control console.

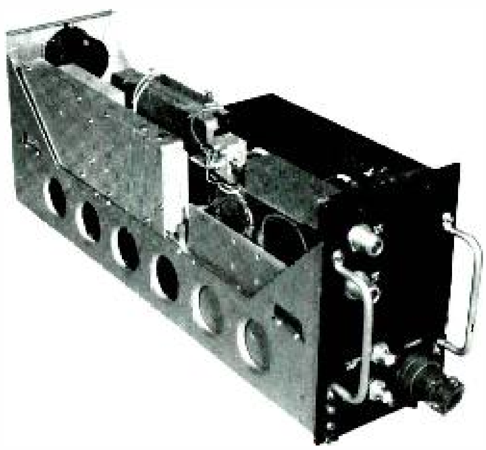

Fig. 11 — This mockup shows actual MIL qualified components from RCA's latest state-of-the-art SHF wideband link which is now in a service test phase.

A simple, coherent optical processor for computers

Dr. R. Shahbender

A novel magneto-optic processor is described. Garnet films that support magnetic bubble domains are used to obtain an all-electronic equivalent of optical transparencies. The garnet films may be used instead of transparencies for the input or for the spatial filter plane. The processor can realize a high time-bandwidth product, and the capability of electronic switching of the spatial filter.

FAST PROCESSING of large time-bandwidth product signals taxes the capabilities of most computers. An alternative approach is the use of optical processing techniques. The availability of relatively inexpensive lasers has enhanced the attractiveness of these techniques. However, the lack of simple methods for converting time-varying signals to optical signals has mitigated against widespread use of optical processors.

Magneto-optic effects

Magneto-optic effects are potentially useful for converting time-varying signals to optical signals. The useful optical signal, expressed as a fraction of incident illumination, obtained from magneto-optic devices is generally low. This has limited the utility of such devices and has required the use of high-intensity illumination for device operation. The enhanced magneto-optic properties of recently developed orthoferrites and garnets[1-4] can lead to optical efficiencies that are high. These materials may be used for the realization of systems that combine magneto-optic interactions and bubble domains for signal processing. Alternatively, these materials may also be used to good advantage in configurations where the magnetic domains are not bubbles, e.g., in modulators or laser deflectors.[5,6]

In the simplest case, polarized light with an intensity I_o incident on a crystal of thickness t, specific Faraday rotation θ, and absorption coefficient α, will have its plane of polarization rotated by an amount $\pm\theta t$ corresponding to propagation through domains magnetized parallel and anti-parallel to the direction of propagation. The intensity after an analyzer, set at an angle ϕ with respect to the input polarization is:

$$I_\pm = C I_o e^{-\alpha t} \cos^2(\phi \pm \theta t) \quad (1)$$

The analyzer may be adjusted to maximize the optical contrast ratio (I_+/I_-) between oppositely magnetized domains. Alternatively, it may be set to maximize the difference $\Delta I = (I_+ - I_-)$ in the intensity of light emerging from oppositely magnetized domains. For either case the optical efficiency of the sysem may be defined as:

$$\eta = \Delta I / I_o \quad (2)$$

For maximum contrast, and assuming $\theta t < \pi/4$

$$\phi = (\pi/2 + \theta t) \quad (3)$$

and

$$\eta_c = C e^{-\alpha t} \sin^2 2\theta t \quad (4)$$

For maximum signal ΔI,

$$\phi = \pi/4 \quad (5)$$

and

$$\eta_D = C e^{-\alpha t} \sin 2\theta t \quad (6)$$

The above expressions describe adequately the behavior of garnets. For rare-earth orthoferrites, propagation along the direction of magnetization is characterized by both a Faraday rotation and a large non-magnetic birefringence.[7,8] The birefringence drastically limits the maximum efficiency that may be obtained with these materials in a simple optical arrangement. Depending on the total Faraday angle θt, a limited amount of birefringence may be tolerated before the intensity I_+ is reduced significantly.[1] The expressions given above may thus be used for estimating the performance of low birefringent orthoferrites.

System description

Consider the optical system shown in Fig. 1. Lens L_c collimates a point source of monochromatic light which illuminates the input plane P_1. If the input plane P_1 is an optical transparency with an amplitude transmittance given by $f(x,y)$,

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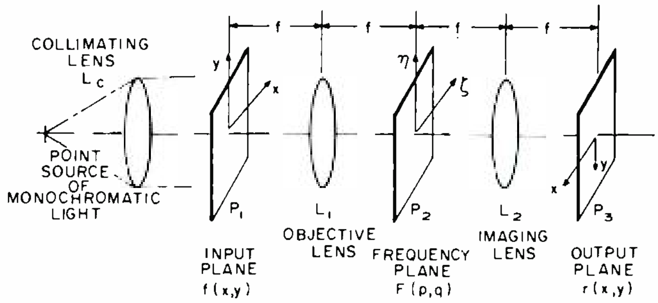

Fig. 1 — Two dimensional frequency plane processor.

then the complex-valued light distribution in plane P_2 is:[9]

$$F(p,q) = \iint_{-\infty}^{+\infty} f(x,y)e^{-i(px+qy)}\,dxdy \qquad (7)$$

where p and q represent spatial frequency variables having the dimensions of radians/unit distance. The distance variables ξ, η in plane P_2 are related to p and q by:

$$\xi = \lambda pf/2\pi \text{ and } \eta = \lambda qf/2\pi \qquad (8)$$

where ξ is in the direction parallel to x, η is in the direction parallel to y, λ is the wavelength of the illumination and f is the focal length of the lens.

The function $F(p,q)$ is the Fourier transform of the function $f(x,y)$. This transformation represents a fundamental property of spherical lenses. By using a second lens the inverse transform of the function $F(p,q)$ may be obtained. For signal processing, it is generally desirable to modify the signal represented by the input transparency $f(x,y)$. This is accomplished by inserting a second transparency with transmittance given by $H(p,q)$ at plane P_2. The light distribution at plane P_2 is given by:

$$R(p,q) = F(p,q)H(p,q) \qquad (9)$$

Lens L_2 displays the Fourier transform of $R(p,q)$ in plane P_3 as:

$$r(x,y) = (1/4\pi^2)\iint_{-\infty}^{+\infty} F(p,q)H(p,q)e^{-i(px+qy)}\,dpdq \qquad (10)$$

Monitoring of the light distribution at plane P_3 gives a signal proportional to the input signal modified by the filter function.

Conventionally the input time-varying signal is recorded in a raster scan on photographic film. The optical transparency is illuminated by a laser, and the Fourier transform is formed at the back focal plane of the transforming lens. A second transparency with a recording of the desired filter function is placed at the transform plane to modify the signal transform. For some applications it is desirable to monitor the filtered spectrum. This may be accomplished by using a Vidicon to convert the filtered spectrum to an electrical signal which is then displayed on an x-y scope as shown schematically in Fig. 2. Alternatively another lens may be used to form the inverse transform of the filtered spectrum and the filtered time-varying signal may be obtained from the Vidicon.

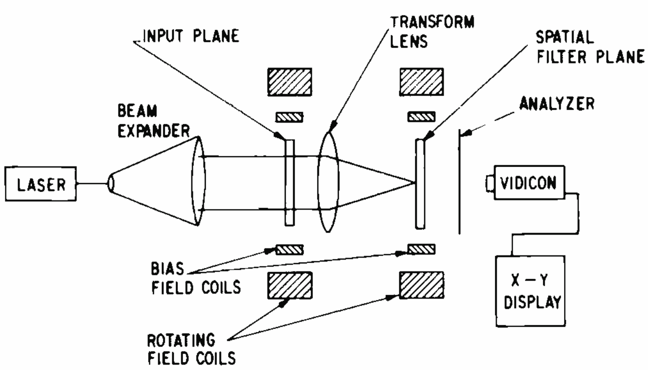

Fig. 2 — Magneto-optic coherent optical processor.

To realize an all-electronic processor, the input and filter transparencies are replaced by magneto-optic garnet films.[4] The input data and the filter functions are in the form of strings of bubble domains propagated along channels formed by ion implantation.[10]

Fig. 2 shows how a beam expander is utilized to uniformly illuminate a garnet chip with polarized monochromatic light from a laser source. The chip contains an array of bubble domains corresponding to the input data. If an analyzer is positioned after the input plane, the light after the analyzer will have an amplitude distribution $f(x,y)$. The Fourier transform of this distribution is $F(p,q)$ and is formed at the back focal plane of the transform lens. A second garnet chip containing an array of bubbles corresponding to the filter function $H(p,q)$, and a second analyzer will give a distribution $R(p,q)$. This distribution may be monitored by the Vidicon to give the filtered spectrum of the input data, or it may be transformed with a second lens to give an amplitude distribution $r(x,y)$. The Vidicon may now be used to obtain the filtered time-varying output signal. It is not necessary to place an analyzer after the input plane.

Garnet films suitable for magneto-optic applications have been successfully grown by liquid-phase epitaxy from a lead flux onto $Gd_3Ga_5O_{12}$ substrates.[4] The nominal compositional system for these films is $(BiTm)_3(FeGa)_5O_{12}$. Fig. 3 shows the Faraday rotation and absorption as a function of wavelength for a sample film.[4] At $\lambda = 6328$Å, and for a film thickness of 10μm, the efficiency η_D = 11%. According to recent data, the observed absorption is partially a result of Pb incorporated into the films. It may be possible to obtain still higher efficiencies by using Pb-free films at a different wavelength.

The magnetic properties of the BiTm-garnet films (σ and $4\pi Ms$) are compatible with a bubble diameter of 5 μm. The value of l measured for a number of films of differing compositions ranged between 0.3 and 1.7 μm. The high field mobility is approximately 450 cm/s/Oe. The films are suitable for supporting high-density bubble arrays, and for allowing high-speed propagation of bubble streams using field-accessing techniques.

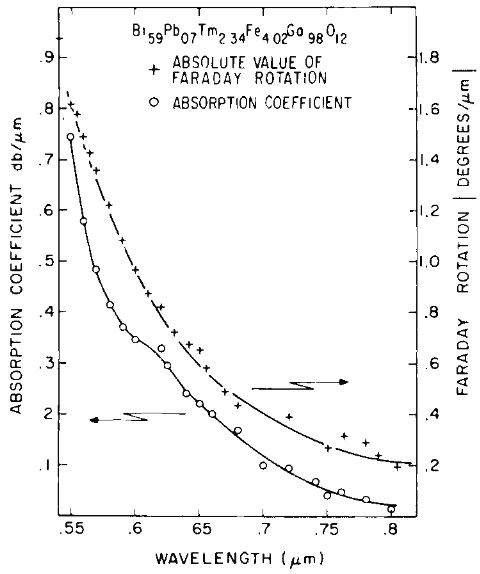

Fig. 3 — Absorption and Faraday rotation spectrum of sample garnet films.

Ion implantation[10] may be used to define the propagation paths in the garnet chips. This allows unobstructed viewing of the bubbles. Other chip functions, e.g., bubble generation annihilation, may be realized by use of conventional permalloy-conductor designs.

The ion-implanted layer is estimated to be about 2000Å thick.[10] The effects of this layer on the optical properties of the garnet film are expected to be negligible.[12]

Experimentally, a herringbone pattern of domains[13] was created in a BiTm sample film. An expanded polarized beam from a 1-mW HeNe laser was used to illuminate an area of approximately 1/4-inch diameter in the film. A zero-order spot and four first-order diffraction spots were easily seen on a screen placed after the garnet film.[6]

Figs. 4 and 5 show possible systems organizations for the chip. In Fig. 4, the chip is organized as a single recirculating shift register.

The data rate and chip capacity are limited by the same factors as in bubble memories. Realizable values are on the order of 10^5 bps and 10^5 bits per chip for a chip of 0.3×0.3-in.

In Fig. 5, the chip is organized into a large number of serial shift registers. The incoming serial bit stream is accepted by a semiconductor shift register and converted to a parallel output. This is used to energize the write generators on this chip. For a chip with dimensions of 0.3×0.3-in., it is possible to have 300 shift registers, each containing 300 bits (a total chip capacity of 9×10^4 bits). At a frequency of 100-kHz, the effective serial data rate is 30-Mbps.

Acknowledgment

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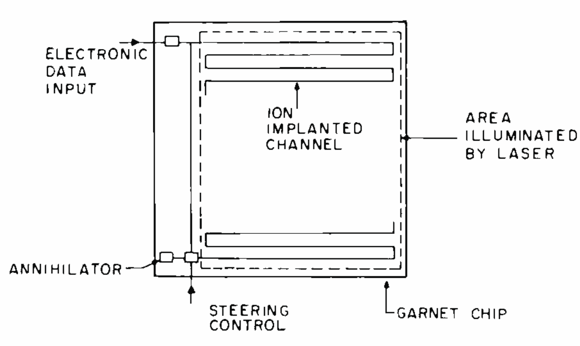


Fig. 4 — Chip organization—single shift register.

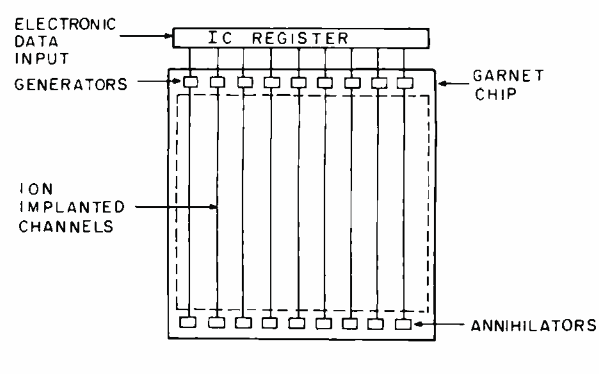
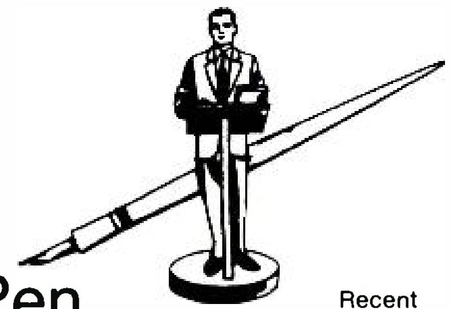


Fig. 5 — Chip organization—multi-shift register.



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preparation and properties of conductors, semi-conductors, dielectrics, magnetic, electro-optical, recording, and electro-magnetic materials.

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210 Circuit Devices and Microcircuits

electron tubes and solid-state devices (active and passive); integrated, array and hybrid microcircuits, field-effect devices, resistors and capacitors, modular and printed circuits, circuit interconnection, waveguides and transmission lines.

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215 Circuit and Network Designs

analog and digital functions in electronic equipment; amplifiers, filters, modulators, microwave circuits, A-D converters, encoders, oscillators, switches, masers, logic networks, timing and control functions, fluidic circuits.

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220 Energy and Power Sources

batteries, solar cells, generators, reactors, power supplies.

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240 Lasers, Electro-Optical and Optical Devices

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245 Displays

equipment for the display of graphic, alphanumeric, and other data in communications, computer, military, and other systems, CRT devices, solid state displays, holographic displays, etc.

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SERIES 300 SYSTEMS, EQUIPMENT, & APPLICATIONS

310 Spacecraft and Ground Support

spacecraft and satellite design, launch vehicles, payloads, space missions, space navigation.

SPACECRAFT with controlled flexible appendages, Multi-loop analysis of a precision pointing — J. Pistiner, G.T. Tseng, L. Muhlfelder (AED, Pr.) *AIAA Journal of Spacecraft and Rockets* (10/75).

312 Land and Water Transportation

navigation systems, automotive electronics, etc.

COLLISION AVOIDANCE, A new kind of radar for — J. Shefer, R.J. Klensch, H.C. Johnson, G.S. Kaplan (Labs., Pr.) *1974 SAE Transactions* Sec. 1 Vol. 83.

325 Checkout, Maintenance, and User Support

automatic test equipment, (ATE), maintenance and epair methods.

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340 Communications

industrial, military, commercial systems, telephony, telegraphy and telemetry, (excludes: television, and broadcast radio).

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370 Computer Programs (Scientific)

specific programs and techniques for scientific use, computation, simulation, computer aided design.

SOFTWARE ENGINEERING APPLIED: a real-time simulator case history — S.R. McCammon (MSRD, Mrstn.) *IEEE Trans. on Software Engineering*, Vol. SEI, No. 4 (12/75) p. 377

380 Graphic Arts and Documentation

printing, photography, and typesetting; writing, editing, and publishing; information storage, retrieval, and library science.

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Author Index

Subject listed opposite each author's name indicates where complete citation to his paper may be found in the subject index. An author may have more than one paper for each subject category.

Commercial Communications Systems Division

Advanced Technology Laboratories

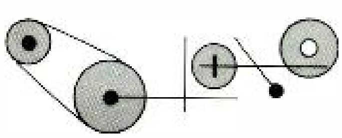
Missile and Surface Radar Division

Automated Systems Division

Astro-Electronics Division

Patents Granted

to RCA Engineers



Solid State Division

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Protection circuit — M. Glogolja (SSD, Som.) U.S. Pat. 3931547, Jan. 6, 1976.

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Method of vapor deposition — M.A. Polinsky (SSD, Som.) U.S. Pat. 3934059, Jan. 20, 1976.

Start-up circuit for a deflection system — W.F. Dietz (SSD, Som.) U.S. Pat. 3936115, Feb. 3, 1976.

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Fabricaiton of liquid crystal devices — A. Sussman (SSD, Som.) U.S. Pat. 3938242, Feb. 17, 1976.

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Commercial Communications System Division

Speaker muting system — R.G. Ferrie (CCSD, Mdwlds.) U.S. Pat. 3927376, Dec. 15, 1975.

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Short end-fire circularly polarized antenna — O. Ben-Dov (CCSD, Gibbsboro) U.S. Pat. 3932876, Jan. 13, 1976.

Television studio control apparatus — L.J. Thorpe (CCSD, Camden) U.S. Pat. 3936868, Feb. 3, 1976.

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Consumer Electronics

Method of making a multiplicity of multiple-device semiconductor chips and article so produced — L.H. Trevail, B.A. Hegarty (CE, Indpls.) U.S. Pat. 3924323, Dec. 9, 1975.

Black level clamping circuit for a television signal processor — B.J. Yorkanis (CE, Som.) U.S. Pat. 3927255, Dec. 16, 1975.

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Lid latch mechanism for a disc record player — L.D. Huff (CE, Indpls.) U.S. Pat. 3930653, Jan. 6, 1976.

Variable amplitude timed alarm system — C.F. Rose (CE, Indpls.) U.S. Pat. 3931621, Jan. 6, 1976.

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Class D amplifier — J.C. Peer (CE, Indpls.) U.S. Pat. 3939380, Feb. 17, 1976.

Lid interlock apparatus for disc record player — L.A. Torrington, R.R. Oberle (CE, Indpls.) U.S. Pat. 3940148, Feb. 24, 1976.

Timing error detecting and speed control system — C.D. Boltz (CE, Indpls.) U.S. Pat. 3940556, Feb. 24, 1976.

Deflection system with overscan protection — J.C. Peer (CE, Indpls.) U.S. Pat. 3940661, Feb. 24, 1976.

Deflection system — D.W. Luz (CE, Indpls.) U.S. Pat. 3938004, Feb. 10 1976.

Comb filter for video processing — J.G. Amery (CE, Indpls.) U.S. Pat. 3938179, Feb. 10, 1976.

Low output impedance voltage divider network — A.L. Limberg (CE, Som) U.S. Pat. 3942046, Mar. 2, 1976.

Government Communications Systems Division

Optical isolator — D. J. Parker, (GCSD, Camden) E. Kornstein (GCSD, Burl.) U.S. Pat. 3559101, Jan. 27, 1971; assigned to the U.S. Government.

RCA Records

Center hole formation in an information storing disc — M. Pravervand (Records, Indpls.) U.S. Pat. 3938810, Feb. 17, 1976.

Engineering News and Highlights

Hillier appointed Senior Scientist; Hittinger to head Research and Engineering

Hillier

Hittinger

Anthony L. Conrad, RCA President and Chief Executive Officer, announced the appointments of **Dr. James Hillier** as Executive Vice President and Senior Scientist, a new position, and **William C. Hittinger** as Executive Vice President, Research and Engineering.

In his new post, Mr. Hittinger succeeds Dr. Hillier, who has been responsible for RCA's research and engineering activities for more than seven years. Both Mr. Hittinger and Dr. Hillier will report directly to Mr. Conrad.

Commenting on the appointments, Mr. Conrad said: "With technology developing at an unprecedented pace, we believe the new structure will permit us to keep in closer touch with new developments and to speed our evaluation of them."

As Senior Scientist, Dr. Hillier will act as principal advisor to Mr. Conrad and will conduct specific analyses and studies of engineering and scientific programs of interest to the Company. He also will serve as RCA's principal contact with leading scientific organizations and associations both here and abroad.

Mr. Hittinger will have direct responsibility for the research and engineering activities in RCA, including the RCA Laboratories in Princeton, N.J., one of the nation's leading electronic research centers.

Mr. Hittinger, an RCA Executive Vice President since 1972, formerly was responsible for the RCA Consumer Electronics, Solid State Electronics, Picture Tubes and Distributor and Special Products activities. He also is a member of the RCA Board of Directors.

A veteran of more than 25 years in electronics, Mr. Hittinger joined RCA in 1970 after serving as President of General Instrument Corporation, a post he had held since March 1968. Prior to that he had held a number of top executive positions with companies affiliated with the Bell Telephone System.

Dr. Hillier, who first joined RCA in 1940 as a research physicist, is a scientist of worldwide renown. He first came into prominence for his contributions to the development of the electron microscope and for his subsequent role in encouraging the growth of electron microscopy as a research technique of wide importance in biology, medicine, chemistry and other sciences.

Dr. Hillier, who has written more than 100 technical papers and has been issued 40 U.S. patents, has been an RCA Executive Vice President since 1969.

Promotions

RCA Alaska Communications, Inc.

J.C. Elliott from Sr. Engr. to Principal Engr. (J.E. Wakefield, Radio & Satellite Engrg., Anchorage)

W. Evitt from Sr. Engrg. Assoc. to Sr. Engr. (L. Herlocker, Multiplex Engrg., Anchorage)

J. Gove from Sr. Engr. to Supervisor, Circuit Provision (B.M. Snodgrass, Plant Services, Anchorage)

D.B. Mosier from Tech. Writer to Logistics Support Specialist (J.E. Martin, Pipeline Admin. & Logistics, Anchorage)

C.T. Riddle from Sr. Engrg. Assoc. to Sr. Engr. (L. Herlocker, Multiplex Engrg., Anchorage)

Consumer Electronics

P.C. Olsen from Sr. Mbr., Engrg. Staff to Mgr., Vendor Contacts & Measurements (J.M. Wright, Product Design Engrg., Indpls.)

Distributor and Special Products Division

W. Stobbe from Sr. Mbr., Product Engrg. Staff to Principal Mbr., Product Engrg. Staff (J.D. Callaghan, Product Develop. & Engrg., Deptford)

W. Bachman from Mbr., Product Staff to Sr. Mbr., Engrg. Staff (J.D. Callaghan, Product Develop. & Engrg., Deptford)

F.R. DiMeo from Product Develop. Specialist to Mgr., Design & Drafting (J.D. Callaghan, Product Develop. & Engrg., Deptford)

Brook named Chief Engineer

Philip Schneider has announced the appointment of **A. William Brook** as Chief Engineer of RCA Americom.

Mr. Brook was graduated with honors from Manchester University, England, in 1955 with the degree of BSc (Tech). He has worked with G.E.C., England, Bell Telephone of Canada, General Electric, IT&T, and Adler Electronics. Since joining RCA Global Communications, Inc., in 1970, Mr. Brook has worked on the design and implementation of satellite communications systems for use in Alaska and the contiguous states. In his present position of Director, Systems Engineering and Facilities Planning, he directs the Plant Extension, Transmission, Traffic, and Switching Engineering Sections of the RCA SATCOM Project. He is the author of several publications and is a member of the Institution of Electrical Engineers (London). He is a Professional Engineer of the Province of Ontario.

Missile and Surface Radar Division

J. Campbell from Sr. Mbr., Engrg. Staff to Principal Mbr., Engrg. Staff (D. Bowman, Advanced Microwave Technol., Mrstn.)

C. Campopiano from Principal Mbr., Engrg. Staff to Ldr., Engrg. Sys. Proj. (R.A. Baugh, Sys. Design in AEGIS Dept., Mrstn.)

A. Massey from Principal Mbr., Engrg. Staff to Ldr. Engrg. Sys. Proj. (E. Behrens, Programming Requirements & Analysis, Mrstn.)

Solid State Division

G.W. Barclay from Ldr. to Mgr., Wafer Fabrication Bipolar IC (J. Schramm, Findlay)

S.Cohen from Sr. Mbr., Tech. Staff to Ldr., Tech. Staff (H. Borkan, Monolithic Arrays, SSTC, Som.)

J. Fabula from Mbr., Tech. Staff to Ldr., Tech. Staff (H. Borkan, Monolithic Arrays, SSTC, Som.)

H. Pujol from Admin., Market Planning to Ldr., Tech. Staff (G.K. Beckmann, MOS Applications Engrg., Som.)

RCA Service Company

J.J. Kirk from Engr. to Ldr., Engrs. (J.E. Connaway, Systems Engrg., Va.)

W.E. Pettee from Engr. to Ldr., Engrs. (J.E. Connaway, Sys. Engrg., Va.)

A.W. Simonaitis from Engr. to Mgr., Goddard Optical Res. Facil. (W.K. Powell, MADOS, Lanham, MD)

Picture Tube Division

J.W. Axmacher from Engr., Equipment Design & Develop. to Engr. Ldr., Equipment Design & Develop. (C.E. Shedd, Equipment Design & Develop., Lanc.)

R.J. D'Amato from Sr. Engr., Product Develop. to Engr. Ldr., Product Develop. (A.M. Morrell, Tube Develop., Advanced Design, Lanc.)

Awards

Automated Systems Division

The Minuteman Memory Device Team of **Roger V. Avan, Joseph P. Connors, Jr., Roy E. Dehm, Harry B. Pettit, Robert E. Rooney,** and **Wing Wong** has been selected for a Technical Excellence Award.

The Minuteman Memory System consists of a 10-million-bit magnetic drum, controls, and associated data processing circuitry. ASD started this program in February 1975. The contract called for delivery of 11 systems, with the first due at the end of June. These systems had to meet the ultrahigh reliability and environmental requirements of Minuteman III specifications. Not only did the team deliver drums which met these requirements, but also delivered units ahead of schedule and within budget.

This performance was the key factor in the recent award of a $3 million contract for 22 additional systems and a request from the customer for quotes on 23 more.

Government Communications Systems Division

The Technical Excellence award has been made to **Mike Kleidermacher** of Digital Communications Equipment Engineering for his outstanding contributions to the TENLEY program. Mike's involvement with the KG-82 Loop Key Generator included all phases of design including LSI chip design, logic design reviews, intensive printed-wiring-board layout check, and design of the basic flow chart for the PROM subsystem controller.

Mike has been very effective as a consultant on other units of the TENLEY system, and has provided impressive design and programming competence to the ST-33 checkout unit.

RCA Laboratories

Dr. William M. Webster, Vice President, RCA Laboratories, announced that 28 scientists have been given RCA Laboratories Outstanding Achievement Awards for contributions to electronics research and engineering during 1975.

Recipients of the awards are:

Dr. Robert A. Bartolini, for initiative in the analysis and evaluation of optical recording materials.
Dr. Alan E Bell, for the analysis of thermal diffusion problems in several critical research projects.
Dr. Donald J. Channin, for the application of liquid crystals to LSI reliability and design problems.
Dr. Andrew G.F. Dingwall, for innovative contributions to the technology and application of semiconductor devices
Dr. Richard J. Himics, for sophisticated use of organic materials in a variety of relevant practical applications.
Dr. Robert S. Hopkins, Jr., for leadership and technical contributions in the development of digital tv frame synchronizer.
Stanley P. Knight, for the development of improved tv tuner designs.
Dr. Michael J. Lurie, for contributions to

Automated Systems Division's Technical Excellence Award winners are pictured with Duane Belden, Plant Manager (far left) and Eugene Stockton (far right) Chief Engineer, both of ASD Burlington, and Harry Woll, Division Vice President and General Manager (next to Stockton). Minuteman Memory Device Team members are (left to right) Harry Pettit, Joseph Connors, Wing Wong, Robert Rooney and Roy Dehm. Roger Avan, ASD Van Nuys, was unavailable for the photograph.

(Left to right) Charley Schmidt, TENLEY Program Manager; Don Parker, Manager, Digital Communication Systems; Mike Kleidermacher, GCSD Technical Award Winner; and Neil Van Delft, Leader, look at a printed-wiring-board for the TENLEY program.

Awards (cont'd)

the development of optical systems for high-density recording.

David G. Ressler, for contributions to graphical data-capturing systems and related computer-aided-design programs.

Dr. Charles H. Anderson, Dr. John G. Endriz, Dr. Jules D. Levine, for a team effort in the conception and technical evaluation of potential new consumer displays.

Jeremiah Y. Avins, Dr. Arthur H. Firester, Dr. W. Ronald Roach, Joseph P.L. Walentine, for a team research effort resulting in the development of a VideoDisc defect detector.

Dr. Michael Ettenberg, Frank Z. Hawrylo, Dr. Harry F. Lockwood, for a team effort leading to key innovations in the technology of optoelectronic semiconductor devices using liquid-phase epitaxy.

Dr. Dennis G. Fisher, Glenn O. Fowler, for a team effort in applying Auger electron spectroscopy to the solution of many vital problems in thin-film technolgoy.

Michael T. Gale, Dr. Karl Knop, for a team effort in the conception and development of embossed diffraction color microfiche capable of zero-order readout with conventional projectors.

Dr. Lawrence A. Goodman, Dr. Aaron W. Levine, Dr. Dietrich Meyerhofer, Edward F. Pasierb, Jr., Dr. Eldon B. Priestley, for a team effort in developing a highly reliable, commercially acceptable, liquid-crystal field-effect display of excellent quality.

Technical Excellence

MSRD 1975 Technical Excellence Award Winners are pictured at their Dinner on February 24. First row: (left to right) R.M. Cooper III, A.J. Savard, M.Lehrer, Division Vice President and General Manager, A.G. Chressanthis, J.C. Volpe, Chief Engineer, M.R. Paglee. Second row. R. Lieber, J.E. Gentry, D.C. Drumheller, W.A. Harmening, W.I. Smith, G.M. Sparks, J.A. Lunsford, L.W. Martinson. Third row: T.E. Anderson, G.J. Ross, J. Liston, E.W. Veitch, C.W. Yeisley, R.A. Craft, G.S. Oakes, Jr., H.A. Ulrich, F.E. Ogle, P.L. Magness . B.A. Francis, C.J. Hughes, G. Jacobson, E.G. May, R.D. Rippey, and F.T. Schwartz were unavailable.

Missile and Surface Radar Division

At the Annual Technical Excellence Awards Dinner, held in Moorestown on February 24, **Andrew G. Chressanthis** received the 1975 Technical Excellence Award. He was cited for his consistently high level of technical performance on the AEGIS EDM-3C MTI experiments. In his remarks, **Joe C. Volpe**, Chief Engineer, said "Andy Chressanthis is everybody's candidate for top technical honors almost every year. For a lot of years he's been the guy you go to when you're in trouble over some aspects of radar signal processing." Mr. Volpe also commented that this was the first time that a woman, **Nan Savard**, would receive an award.

Quarterly Award recipients were:

First Quarter

R.M. Cooper, III
R.A. Craft
G. Jacobson
P.L. Magness
M.R. Paglee
R.D. Rippey
G.J. Ross
A.J. Savard
F.T. Schwartz
H.A. Ulrich

Second Quarter

B.A. Francis
J.E. Gentry
E.G. May
C.W. Yeisley

Third Quarter

R. Lieber
J. Liston
J.A. Lunsford
L.W. Martinson
F.E. Ogle
G.M. Sparks
E.W. Veitch

Fourth Quarter

T.E. Anderson
A.G. Chressanthis
D.C. Drumheller
W.A. Harmening
C.J. Hughes
G.S. Oakes, Jr.
W.I. Smith

Letters

To The Editor
RCA Engineer
Building 204-2
Cherry Hill, N.J. 08101

March 31, 1976

As one directly involved in the corporate financing of the Circleville glass plant, I read with great interest the story in this issue of the RCA Engineer. It seemed to me, however, to contain one important omission. It is the role played by Harry Seelen in this venture.

Harry is presently retired from a position he held with great distinction for a number of years before his retirement as General Manager of the RCA Picture Tube Division. In that role, he played a major part in the development and implementation of RCA's major role in the picture tube industry. Indeed, he can rightfully be called one of the key RCA pioneers who made color television a reality.

It was Harry who first conceived the idea of our making our own glass. He personally led the fight for a number of years to gain approval for this project over the objections of those in the corporation who felt we could never master the specialized techniques sufficiently to make the project a success. Were it not for his strong belief in the viability of this venture and his willingness to pursue it after some initial rebuffs, there would not be a Circleville plant today!

I hope that you will see fit to publish this letter in a future issue and to send a copy to Harry.

Julius Koppleman
President
RCA Service Company
Cherry Hill, N.J.

Webster, Hittinger named to National Academy of Engineering

Dr. William M. Webster, Vice President, RCA Laboratories, and **William C. Hittinger,** Executive Vice President, Research and Engineering, have been elected to the National Academy of Engineering. The Academy cited Dr. Webster for "contributions to the development of gas discharge and solid-state devices" and Mr. Hittinger for "contributions to high-frequency transistors and management in industries involving advanced technology."

Flory and Simon named Fellows by RCA Laboratories

Dr. William M. Webster, Vice President, RCA Laboratories, has named **Robert E. Flory** and **Allen H. Simon** Fellows of the Technical Staff of RCA Laboratories. The Fellow designation is given by RCA in recognition of a record of sustained technical contributions in the past and in anticipation of continuing technical contributions in the future. Both men have a history of distinguished research. Mr. Flory has done noteworthy work in the field of video recording while Mr. Simon has made a number of significant contributions in data-processing system design.

Professional Activities

RCA Laboratories

Dr. Fred Sterzer has been named FY 1977 National Lecturer for the IEEE Microwave Theory and Techniques Society.

M. Caulton, B. Perlman, and **F. Sterzer** are committee members of the IEEE Microwave Theory and Techniques Society. F. Sterzer and M. Caulton are also Technical Program Chairmen for the MTT/S International Symposium.

Philip M. Heyman, was a member of the Program Committee for the 1976 Society for Information Display International Symposium.

Obituary

John F. Eagan

John F. Eagan, Jr., Manager, RCA Frequency Bureau, Cherry Hill, died at his home in Haddonfield on April 10. Mr. Eagan studied Electrical Engineering at Lehigh University and RCA Institutes. He served in the U.S. Army Signal Corps during World War II. Mr. Eagan had just completed thirty-five years with the RCA Frequency Bureau and had been Manager of the Frequency Bureau in Cherry Hill since 1953. He represented RCA on several committees, including the International Electrochemical Commission and the Radio Technical Commission for Aeronautics. He was a Member of the IEEE and the National Association of Broadcasters.

International language of technology

Find a dictionary that translates conversational English to any other language. Then look up the meaning of "pot," "bridge," "dissipation," and "cap." The probability is very small that their technical meanings of variable resistor, Wheatstone-Type circuit, dissipation factor and capacitor will be included.

The translation of technical terms, especially in the form of jargon, is a well known problem, and one which I thought I had a good understanding of. Through numerous meetings with engineers from many European countries and from Japan, I had acquired what I thought was a respectable proficiency in talking to people through a language barrier. But during a recent trip to the People's Republic of China, the lesson came home with no uncertainly — the language barrier is a real one and difficult to overcome.

The subject of the discussions was electronic components, and the talks were held with two groups. Our first contact was with several non-technical management people, who had to be made to understand the technical data in order to convince them that we should be given the opportunity to talk to the appropriate engineers.

The process turned out to be painfully slow and often frustrating. One member of their group was quite proficient at English, but had to resort often to a little English-to-Chinese dictionary. It helped on some occasions, but not often. Part of the problem lies in the English language. Many words, unfortunately, have multiple meanings, which leads to multiple entries on the Chinese side. But how can you point out the correct one when the written language is undecipherable? When dealing with Europeans, there is often some common root, from Latin, old German, or whatever, to help give some clue. But here the dictionary, as often as not, was more confusing than clarifying.

The result was generally poor. Such phrases as dissipation factor, self-resonant frequency, surface impedance and bridge circuit were totally untranslatable. We got across merely the fact that there was a technical topic that had some relevance to our meetings. Surprising to me was the difficulty with the phrase "silk screening". To the best of my knowledge, the process was invented as an art form in China. The words finally got translated, but the result was a set of very puzzled looks which seemed to say "What in the world does that have to do with electronic components?" There was obviously some problem in the translation.

While much of the conversation turned out to be barren, the objective was achieved, in that their component people (engineers) were finally brought into the discussion. Names were exchanged (they never told us what their specific jobs were) and we discovered that none of them spoke English. Despite that, however, communication turned out to be remarkably easy, swift and accurate.

The magic ingredient was the international — truly international — language of mathematics and schematic diagrams. A bridge circuit, quickly sketched, brought smiles and nods of understanding before it was half-completed. An inductor with a dotted-line capacitor made a non-problem out of translating "self-resonant frequency". A tiresome chore had become a pleasant and productive game.

The lessons, to me, were two-fold. First, the symbols we have come to accept without a moment's thought as lowly tools of the trade, are really elements of a globally understood shorthand. They make possible the transmission, from one mind to another, of complex concepts far beyond the capability of general vocabulary.

But the other lesson is that the universal language is severely limited in its scope. It is useful only in the specialties for which it was created. It is useful only when both communicating parties have been adequately educated in the same field. By no means is it the magic key to universal understanding among all mankind.

When you think about it, that last point applies even when the language being used is the same. The specialist here at home is taken to task, often with good reason, for failing to communicate because of his insistence on using technical terms and jargon.

In sum, I suppose, the language of the specialist is both a channel and a barrier. To another specialist it communicates across any cultural or lingual fences. To the non-specialist it remains a mystery even when those fences don't exist.

And I still wonder what "silk screening" meant to them.

Harry Kleinberg
Manager, Corporate Standards Engineering
Cherry Hill, N.J.

Praba is Gibbsboro Ed Rep

R. L. Rocamora, Manager, Antenna Engineerng Center, Broadcast Systems, Gibbsboro, N.J., has appointed **Dr. Krishna Praba** as Editorial Representative for the Antenna Engineering Center. In this capacity, Dr. Praba is responsible for planning and processing articles for the *RCA Engineer.*

Dr. Praba received the BSc in Physics from Madras University (India) in 1951, the MSEE from Princeton University in 1962, and the PhD from the University of Pennsylvania in 1964. Prior to joining RCA, he was associated with Fischer & Porter Co., Warminster, Pa. where he developed flow instruments and process control systems, and with Drexel Institute of Technology as an Assistant Professor of Electrical Engineering. Since joining RCA in 1967, he has mainly been responsible for analytical work on antenna arrays. He has developed several computer programs for antenna design and has worked on the various multiple antenna installations that have been developed, or are under development, by the Antenna Engineering Center. He has published several papers on the above subjects and holds five U.S. Patents. Dr. Praba is a member of IEEE, a member of Sigma Xi, and a fellow of the British Computer Society.

Licensed engineers

When you receive a professional license, send your name, PE number (and state in which registered), RCA division, location, and telephone number to: *RCA Engineer,* Bldg. 204-2, RCA, Cherry Hill, N.J. New listings (and corrections or changes to previous listings) will be published in each issue.

RCA Records

Benjamin Chang, Indianapolis, Ind., P.E. 16479 Ind.

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