An Experimental Visual Communication System

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Substantial technical and economic benefits are obtainable by fitting a visual communication system to a specific application. Some of the considerations involved in such adaptation are discussed in this paper.

An experimental system to demonstrate the specific adaptation to the problem of signature verification in a savings bank is described. It is shown that satisfactory images can be transmitted over a 5-kilocycle sound program circuit in 5 seconds. This result is obtained by reducing both the area scanned by the transmitter and the resolution of the reproduction to the minimum required for this application.

I. INTRODUCTION

Facilities for the transmission of visual material by facsimile have been offered to the public for over 30 years. Even so, facsimile has not become a very widely used service. In contrast, the post-war development of broadcast television has excited much interest in the use of television as a means for transmitting visual material. Industrial television equipment has been developed and sold for all sorts of applications. However, there is increasing awareness that television may not be the most suitable and least expensive way of filling some of the needs for visual communication for which its use has been suggested.

Television as a private visual communication means is attractive from many points of view. Much of the terminal equipment is similar or identical to that developed for broadcast purposes. Consequently, the costs of terminal equipment can be kept low through the benefits of mass production for broadcasting. In many installations the receiving terminal may be nothing more than a standard broadcast receiver. This has the added advantage that little training is required for operation of the receiver.

On the other hand, transmission of television signals produced under broadcasting standards requires a bandwidth of the order of four megacycles. Wherever distances greater than a few hundred feet are involved, suitable circuits of this bandwidth are expensive to provide.

These facts suggest the wisdom of examining the general problem of transmitting visual material. Such an examination should weigh the requirements of particular communication problems against the advantages offered by facsimile and by television.

In a broad way, one can distinguish facsimile and television by the character of the received image. This image is a permanent copy of the transmitted material in facsimile; it is transient when the transmission is by television. Since facsimile produces a permanent image, the material need be sent only once. In contrast, the transient character of the television images necessitates the transmission of the material often enough to avoid flicker and for as long a time as examination of the material is required.

These distinctions between facsimile and television suggest the application for which each system is most suited. Facsimile is the more appropriate medium if the material to be transmitted is itself in permanent form. Television is the more appropriate medium if the material to be transmitted is in transient form. That is, television should be used if motion is an important attribute of the original.

This seemingly clear-cut distinction between facsimile and television becomes blurred if one introduces the possibility that a permanent copy of a document may not be required and even may be undesirable. In such cases, the transient character of the television image is attractive.

A transient image, however, would be useful only if it were available for study for several minutes. This suggests the possibility that some system intermediate between facsimile and television might be useful. Since the person receiving the information could use no more than one document during the time required for his study of it, the system need have only the capacity to transmit a single document at a time. It would seem desirable that this system complete a transmission in a few seconds.

This speculative thinking only discloses that a hybrid visual communication system might have some advantages over either facsimile or television. But the difficulties of system design are not revealed. It was decided that a complete system should be built to gain some measure of the complexity of such hybrid systems. This experimental system was intended to demonstrate the feasibility of combining techniques from television and from facsimile to produce a visual communication system for a specific field of use. For this reason, the experimental equipment was built without regard for the usual engineering limitations of size or of cost. The sole aim was the investigation of the feasibility of tailoring a visual communication system to a single communication problem.

II. FEASIBILITY STUDY

Our preliminary thoughts and discussions about a new intermediate visual communication system revealed the fact that a study completely divorced from application would be of little value. Through the cooperation of Albert F. Kendall, Comptroller of the New York Savings Bank, it was decided that our feasibility study would be related to one of the more serious problems of larger savings banks.

With the growth both of individual savings banks and of branch banking it has become increasingly difficult to give each teller access to the complete file. Savings banks have been active in experimenting with the application of modern visual communication techniques to this problem. Facsimile, industrial television and slow-scan television all have been tried. None of these techniques has been found to be completely satisfactory. Therefore, our study was based on the problem of transmitting signature and account information from a central file to individual bank tellers at remote locations.

Fundamentally there are two requirements to be applied to a visual communication system for this service. The time required for transmission should be reasonably short and the rental fees for the communication circuits should be kept small. This latter requirement may be interpreted as meaning that the transmission bandwidth should be minimized and should be within the capabilities of a standard Bell System facility.

In order to keep the time of transmission short and the bandwidth small, the time-bandwidth product must also be minimized. This result is attained when no more than the necessary area of the copy is scanned and when the resolution of the received picture is no greater than is acceptable.

III. SYSTEM DESIGN

The information to be transmitted to the teller from the New York Savings Bank files is contained on a signature card and an account card, of which samples are shown in Fig. 1. The 3- x 5-in. signature card may be any one of several types. For individual accounts, the account number and the signature may appear at the top of the card or the signature may appear below a printed agreement. Another common variant provides for two signatures for a joint account, written below an extended form of printed agreement. In the case of every one of these cards, the signatures fall within an area 1 in. high. The account number, used for identifying the signature card, can be restamped to the left of the signature(s) in this 1-in. area. The significant information on the card may be contained therefore within a 1- x 5-in. rectangle.

The information of interest to a teller on the account card is contained

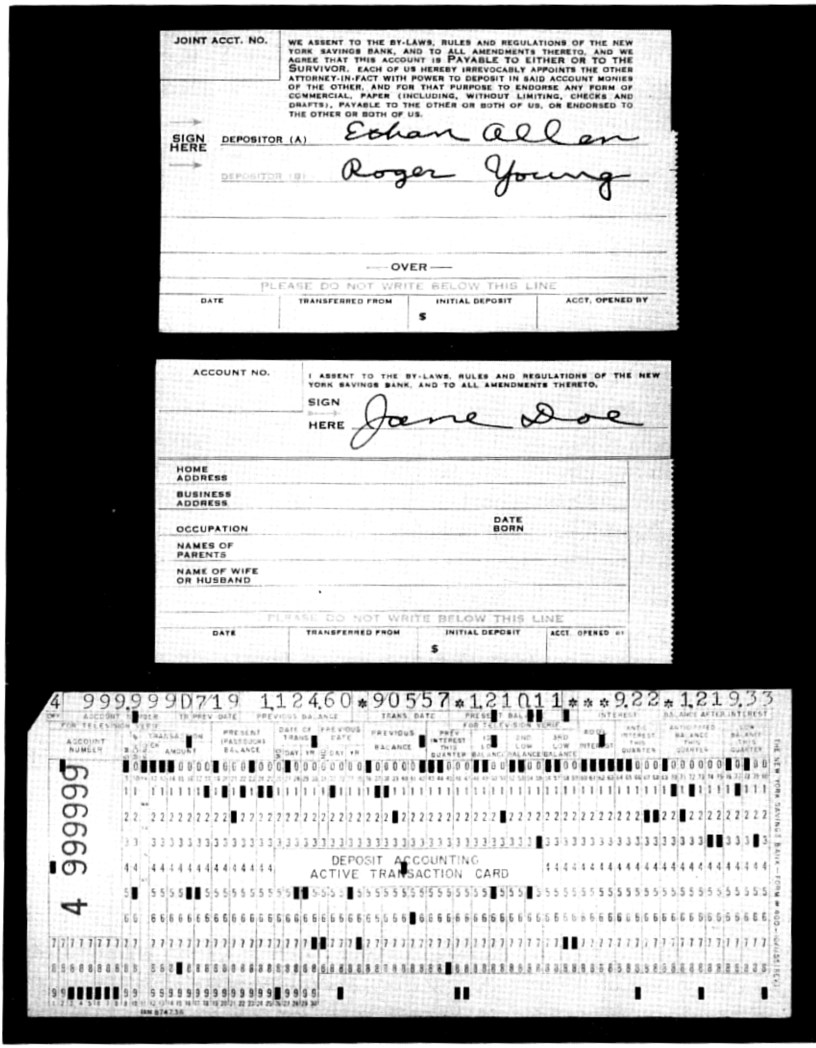


Fig. 1 — Signature cards and accounting machine card.

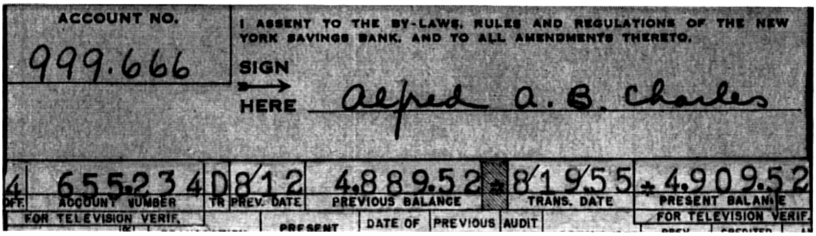


Fig. 2 — Bank signature and account card positioned so as to present only essential information.

in the left-hand 5 in. of a single line of type within the top $\frac{1}{4}$ in. of the card. As one step in optimizing the visual transmission of these data, the scanned area should be limited to the important 1- x 5-in. area of the signature card and the $\frac{1}{4}$ x 5-in. area of the account cards. A suitable arrangement of the two cards for such scanning is illustrated in Fig. 2, where the total scanned area of the two cards need be no greater than $1\frac{1}{4}$ x 5 in.

To maintain the two cards in this position, several types of card holders were considered from an operating and also a convenience point of view. Fig. 3 shows a laminated metal card holder in which the cards are placed into two depressions and held in place with a hinged cover (shown in right side of Fig. 4). Fig. 4 (left) shows a stiff plastic envelope which could be economically made and readily stacked. It is cut so that the positioning of the cards would be maintained when the holder was inserted in the transmitter. These two holder designs showed significant differences in loading and unloading times when used by a file clerk.

Fig. 5 shows the holder adopted for the experimental system, which can be loaded and unloaded more quickly than the previous designs. The thin holders are made from a laminate of thin fibre, each section cut with the appropriate mask to fit the particular card and assembled into a sandwich. Two types were made: one from brown fibre (top) to fit the single signature cards; the other from black fibre (bottom) to fit the single and double signature cards bearing the bank agreement. The cards are held flat with a spring clip on the right side which clamps both cards firmly in place.

The second factor to be minimized in reducing the time-bandwidth product is the resolution of the received picture. Experiments have been carried out at Bell Telephone Laboratories[1] with a television system to show how few scanning lines might be required to display signatures. Fig. 6, taken from that study, shows that two signatures can be recog-

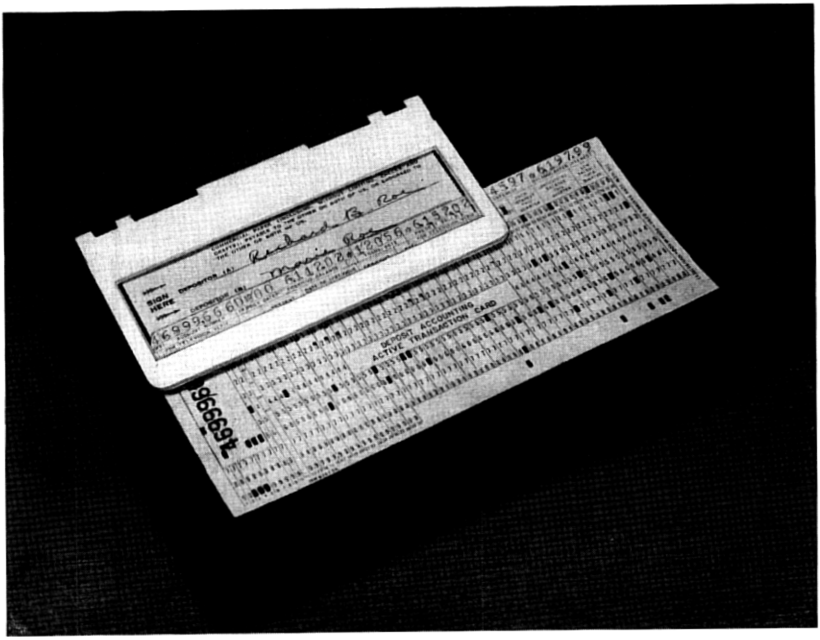


Fig. 3 — Metal card holder with hinged cover.

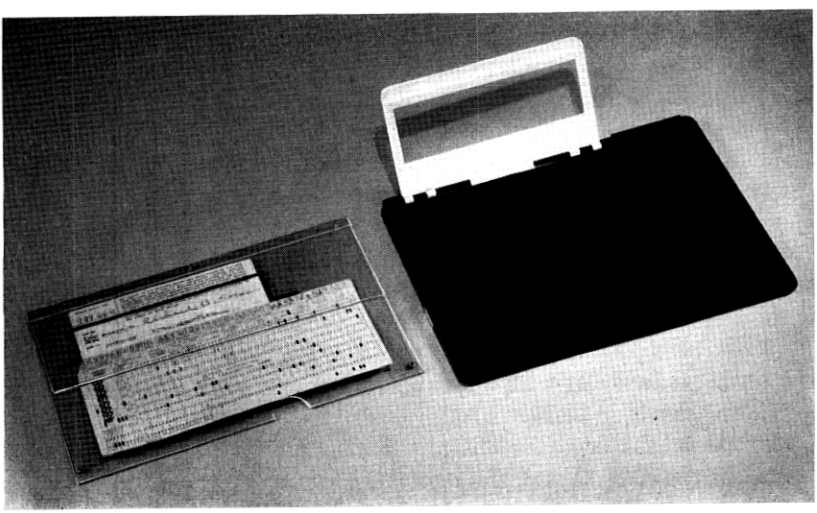


Fig. 4 — Experimental plastic and metal card holders.

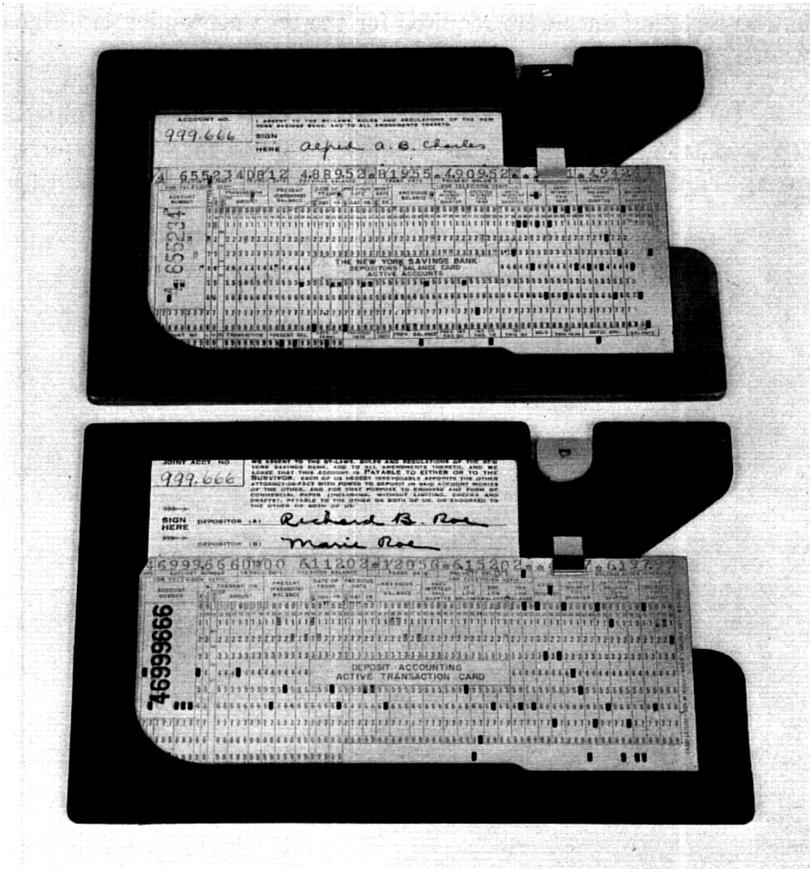


Fig. 5 — Card holder used in bank signature verification transmitter.

nized with little masking of their essential characteristics when 80 scanning lines are used. Fig. 7, taken from the same study, shows that a single signature and the numerals on an account card are quite readable when 120 scanning lines are used. In this illustration, there are 9 or 10 lines reproducing the line of numbers.

The printed digits on the account card are 0.150 in. high and 0.095 in. wide. Hence, the scanning line pitch is about 0.015 in. in the case where the digits are easily read. If the vertical dimension of the important area of the signature card — 1 in. — is scanned at this same pitch, it would be covered by only 67 scanning lines. However, it was concluded that 80 scanning lines were required for the area containing two signatures.

The more stringent of these two requirements, 80 scanning lines per inch, must be adopted for the whole area. With a scanning pitch of 0.0125 in., the signature area requires 80 lines, and the top $\frac{1}{4}$ in. of the account card requires 20 lines, or a total of 100 lines across the entire

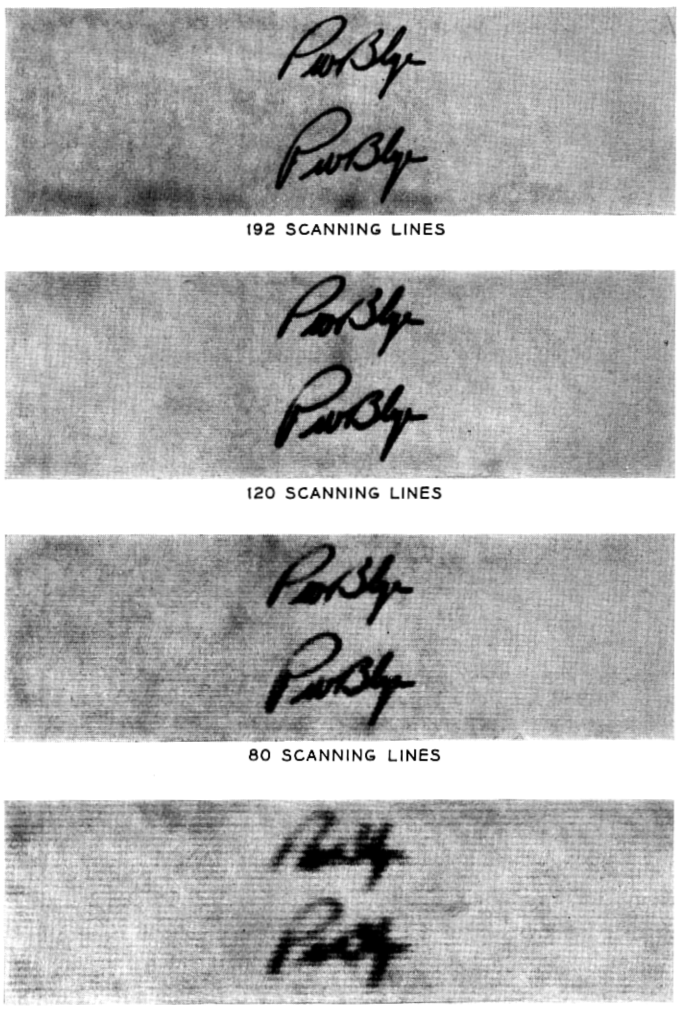


Fig. 6 — Two signatures transmitted over a TV system with scanning line structures as indicated.

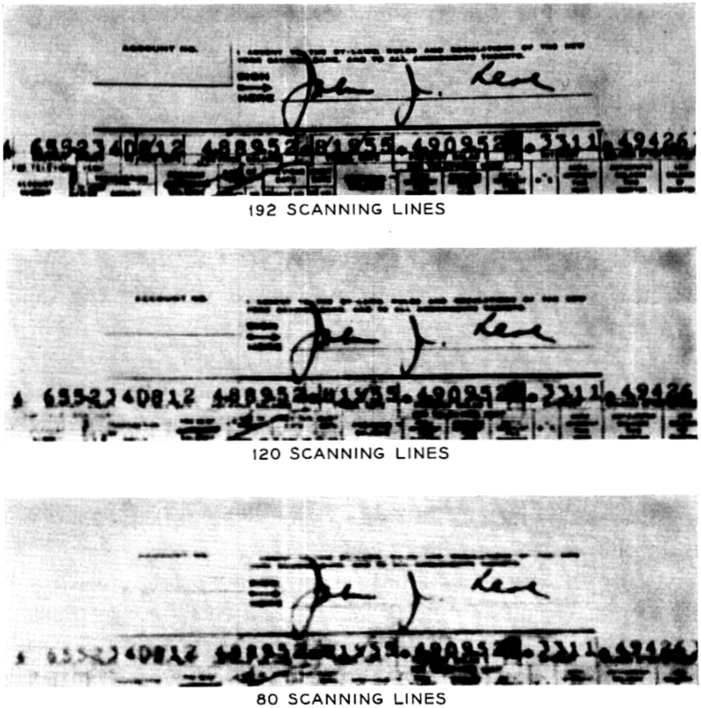


Fig. 7 — Bank signature and account card transmitted with scanning line structures as indicated.

$1\frac{1}{4}$-in. dimension of the two cards. It is of interest to compare this scanning line density with the 90 to 100 scanning lines per inch used in commercial facsimile systems.

It seems desirable to equalize the apparent horizontal and vertical resolutions in the reproduction. This condition is reached when the number of cycles of picture signal per scanning line is given by

$$f_l = l\,K\,N_v/2, \tag{1}$$

where

f_l = number of cycles per line,
l = length of line (inches),
N_v = number of scanning lines per inch,
K = vertical resolution factor.

The factor K takes into account the fact that the apparent vertical resolution is smaller than is given by the number of scanning lines. This decrease arises because scanning is a sampling process and the samples may or may not coincide with detail in the copy. M. W. Baldwin has suggested that the best value of K is 0.7.[2]

In the case of the signature and account cards, the lines are 5 in. long, and there are 80 scanning lines per inch. Substituting these values in (1), we have

$$f_l = 5 \times 0.7 \times 80/2 = 140 \text{ cycles/line.}$$

Since a total of 100 scanning lines is required to cover the significant areas of the signature and account cards, one transmission will consist of 14,000 cycles of picture signal.

This figure, 14,000 cycles, is a measure of the time-bandwidth product required for the transmission of the important information from the bank's file. We now have the problem of dividing this quantity into its two factors, time and bandwidth. The significant parameter at our disposal is the bandwidth of the type of Bell System facility which might be used for this service.

To give proper consideration to the various characteristics of the several types of circuits available in the Bell System, we must digress slightly to consider the waveform of signals which should be transmitted. It seems that the gradations of tone in signatures, arising from changes of pen pressure and writing speed, are not significant in the recognition of signatures. Consequently it is necessary to transmit only two values of picture signal, one corresponding to the background on which the signature is written and the second corresponding to the inked lines. It follows that we may make use of experimental results which bear on the transmission of telegraph-like signals.

Horton and Vaughan have reported that telephone message circuits can be used for the transmission of digital information satisfactorily in the band from 700 to 1700 cycles per second.[3] Carrier transmission is required to handle picture signals in this band, so that the baseband may be no wider than, say, 500 to 800 cycles per second. The more optimistic of the figures leads to the conclusion that nearly 20 seconds would be required to transmit our minimum picture signal over a message circuit.

Program circuits for sound broadcasting are available from the Bell System with bandwidths of 5 kc, 8 kc and 15 kc. By far the most widely available of these is the 5 kc circuit, the gain characteristics of which are substantially flat between 100 and 5000 cycles. The delay distortion of these circuits is at a minimum between about 1 kc and 4 to $4\frac{1}{2}$ kc.

This suggests that a baseband bandwidth of 3 kc might be used with vestigial sideband transmission about a carrier near 4 kc.

Under these conditions, it would require 4.7 seconds to transmit our minimum picture signal. This figure is sufficiently small in comparison with the total time required to order the information from the file clerk, locate the cards in the file and load the card holder that there seems to be little advantage in considering wider band circuits.

Actually, we have chosen a transmission time of 5 seconds instead of 4.7 seconds. This increase in time tends to compensate slightly for the imperfections of a practical terminal equipment.

IV. TRANSMITTER

In addition to the general characteristics of the system which have been discussed in the preceding paragraphs, certain peculiarities of the file cards place restrictions on the transmitter. The New York Savings Bank uses signature cards of several different colors for special purposes. In addition, some of these cards have been used for a good many years. Consequently, the background reflectance of the original copy varies significantly, and it was necessary to introduce an automatic gain control circuit in the scanner to compensate for the variation.

In addition to the color of the background, the bank's customers exercised their individualities and wrote their signatures with inks of almost every conceivable color. Fortunately it was found possible to provide sufficient gain in the scanner circuits to allow the signal corresponding to the ink to be sliced at a fixed amplitude.

The individuality of the bank's customers displayed itself in another way. It was found that the width of the lines in their signatures varied from 0.005 in. upwards.

The length of a reproduced picture element was fixed when the transmission bandwidth and the scanning standards were selected. No more than 6,000 picture elements per second can be transmitted in a 3,000 cps baseband. The scanning of a complete image with 100 lines in a time of 5 seconds means that each line is scanned in $\frac{1}{20}$ second. Hence, there can be no more than 300 picture elements per line. This means that each picture element in the reproduction can be no shorter than $\frac{1}{60}$ in. (or 0.017 in.), since each line is 5 in. long.

It is obvious that the signals corresponding to lines in the signatures as narrow as 0.005 in. would be reduced in amplitude after transmission through this system. It was learned, however, that there was no objection to artificially broadening these lines in the electrical equipment.

However, to resolve 5-mil lines on a 5-in. card demands good 1000-line resolution capability. Cathode ray tube scanners, as developed for entertainment television, fail to meet this requirement by nearly a factor of two.[4] Thus, because the required line scan rate is low, a mechanical scanner was suggested. Then, scanning spot size, and therefore resolution, would be only a question of precision machine work and len's capabilities. The problem of illuminating the subject material to obtain a useful electrical signal-to-noise ratio could then be divorced from any consideration of scanning spot size, as it cannot be in cathode ray tube or flying spot scanners.

4.1 *Scanner*

Fig. 8 is a photograph of the entire transmitter. The mechanical optical scanner or analyzer (which was constructed to Bell Laboratories specifications by Hogan Laboratories, Inc.) is located in the middle of the table top. The signal processing equipment for broadening the fine lines in copy, the frequency translation equipment and the power supplies are enclosed below the table top. A monitoring picture tube which reproduces the transmitted signal is mounted above the scanner.

A schematic of the optical path of the mechanical scanner is shown in Fig. 9. An optical system forms a reduced image of the illuminated card at the intersection of a spiral slit on a disc and a straight slit which is fixed parallel to the long side of the image. The intersection of the spiral and the straight slit forms a nearly rectangular aperture which sweeps across the image at a constant speed when the disc is rotated at a constant rate. The optical path is folded to save space, so that the objective lens actually views the cards through two front-surfaced mirrors.

A 60-cycle synchronous motor rotates the disc at 20 revolutions per second, causing the aperture to sweep across the slit and thereby scan a single horizontal line of the image for each revolution. The slit apertures are of such a size that the resolution in the horizontal direction is greater than 1000 lines.

A second motor, energized when the transparent lid is closed and an address button is pushed, moves the carriage forward. The carriage travel causes the image of the subject material to traverse across the fixed linear slit in 5 seconds, thus producing the vertical scan. At the finish of the scan, the carriage motor is automatically stopped, and the carriage releases and snaps forward into a position convenient for unloading and reloading the card holder. The light from each successive point of the image, as determined by the scanning aperture, is converted by a multiplier phototube to a proportional electrical signal.

Line-synchronizing pulses are derived directly from the rotating

Fig. 8 — Experimental transmitter unit of the bank signature verification system (door open).

scanning disc. Through a cleared circular slit on the opaque scanning disc, a small source of light is focussed onto a photo diode. An opaque section, properly positioned, interrupts this light, thus producing an electrical pulse once per revolution. This pulse, when processed and added to the outgoing signal, produces the line-scan sync signal for receiver synchronization.

A block diagram of the signature verification transmitter system is shown in Fig. 10. From the multiplier phototube and cathode follower in the mechanical scanner, the signal baseband frequencies are applied to a signal processing circuit, in which the analog signals, derived from scanning, are clipped either to black or to white signal level. The circuit likewise stretches the duration of fine line signals to a minimum value satisfactory for transmission. The rectangular output pulses pass through a low-pass filter and then modulate a carrier at 26.88 kc. A second stage of modulation and filtering produces a vestigial sideband signal for transmission having its carrier at 3.84 kc.

A portion of the output signal is demodulated at the transmitter to operate the picture display tube, which serves as a check on the outgoing signals.

4.2 *Signal-Processing Circuits*

A feature of the signal-processing circuit is its nonlinear pulse-stretching operation. Variable-duration pulses with a minimum duration of 160 microseconds can be transmitted through a band limited system of 3 kc and can be utilized satisfactorily with a proper receiver. The scanner, however, may generate signal pulses as short as 50 microseconds when it scans signatures or other material written with a very fine pen. The combination slicer and pulse-stretcher circuit operates on these pulses in the following manner. It recognizes first whether there is a signal pulse present or not, producing at its output a two-level signal free from the effect of background noise. Moreover, signal pulses arriving at the

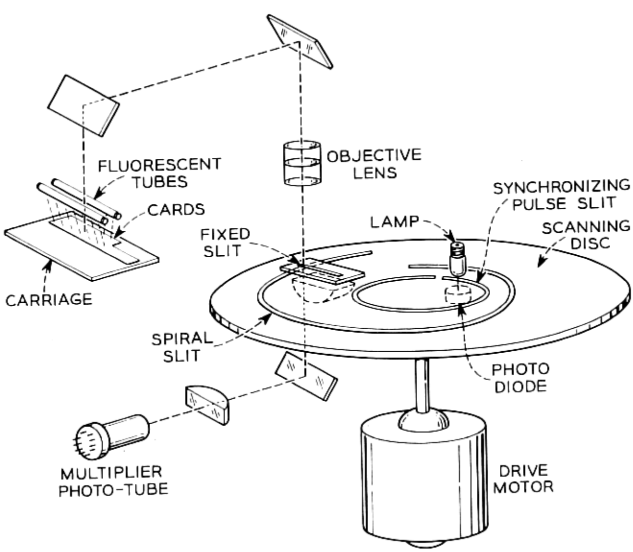


Fig. 9 — Optical path of the mechanical scanner.

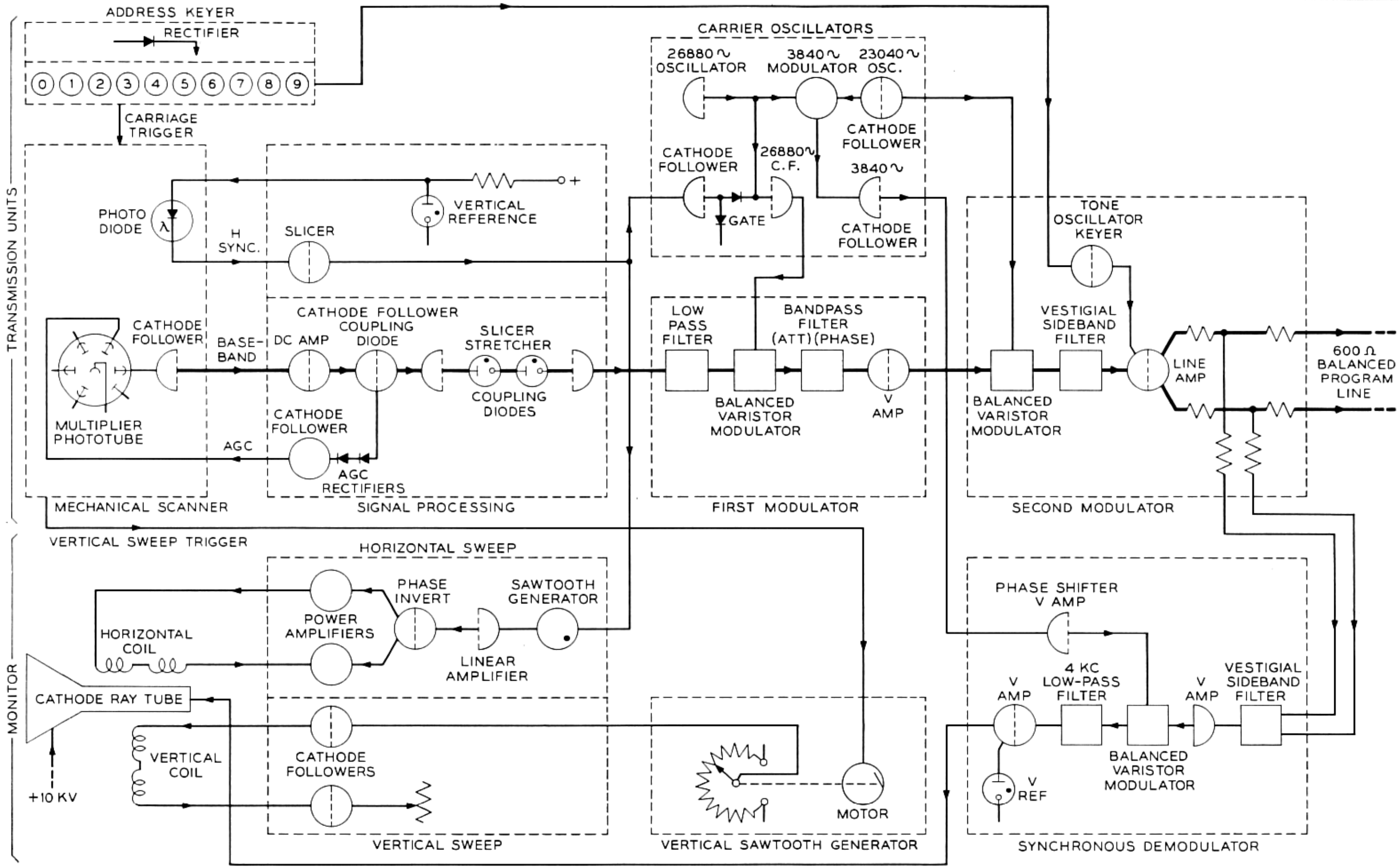


Fig. 10 — Block diagram of the transmitter terminal.

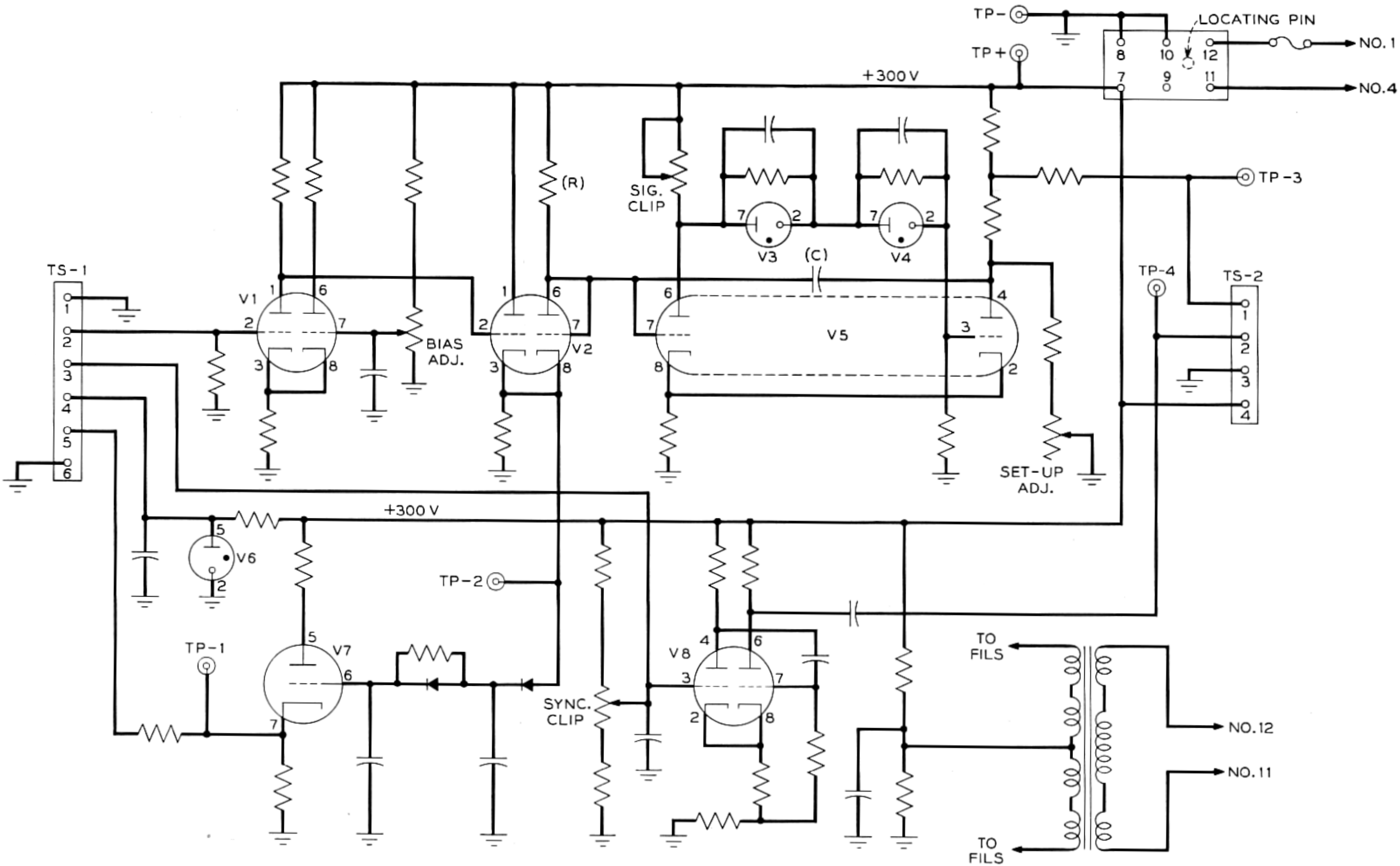


Fig. 11 — Schematic of the signal-processing circuit.

slicer input having duration less than 160 microseconds are lengthened and appear at the output as clipped rectangular pulses of 160-microsecond duration; the signal pulses of longer duration are merely regeneratively clipped into rectangular pulses with their longer durations undisturbed. The output signals of this unit are clean rectangular pulses corresponding to the inked lines or figures on the subject material to be transmitted.

The processing circuit is illustrated in detail in Fig. 11. This circuit, consisting of seven tubes, performs baseband signal amplification, automatic level control of the output signal, regenerative clipping and pulse stretching. The eighth tube on this chassis is used as a conventional slicer for the line sync signal.

The picture signal, as derived from a cathode follower in the scanner, has a maximum peak-to-peak value of 0.5 volt and a bandwidth of 10 kc. It is first amplified to a value of 40 volts by a dc amplifier and cathode follower. Tube V1-2 is a bias control to adjust the no-signal or black-signal level at the output to 60 volts. The white level signal, corresponding to the card background, is peak detected at this point, and through a fast-operate and slow-decay RC time constant, adjusts the voltage applied to the multiplier phototube through the cathode follower V7. The automatic level control action sets the background signal level at this point at a value of 100 volts, regardless of the color or the luminance of the card, within reasonable limits.

The signal is then sliced and shaped by the tubes V2-2 and V5-1. The slicer is direct-coupled, and the level of signal slicing is adjusted by changing the grid voltage on V5-2 through the signal-clipping control and the reference voltage tubes V3 and V4. The operation of this slicer has been modified by the positive feedback capacitor C.

When a negative signal pulse, due to the scanning spot crossing a black line on the card, arrives at the output of the cathode follower, it is transmitted through the diode V2-2 to the grid of V5-1, which tube has been conducting current. Since the cathodes of V5-1 and V5-2 are common, plate current in V5-2, previously zero, is quickly turned on by the simultaneous action of cathode and grid signals. The negative voltage pulse, developed across its plate resistor, is fed back through capacitor C to the grid of V5-1. The grid potential of V5-1, reduced below cutoff by the signal applied through the diode, is reduced still further by this positive feedback, since the pulse disconnects the grid from the low-impedance signal driver by inactivating the diode V2-2. Capacitor C now charges through resistor R to the potential of the cathode follower, at which point the diode V2-2 becomes conducting, returning the control of the slicer condition to the signal cathode follower.

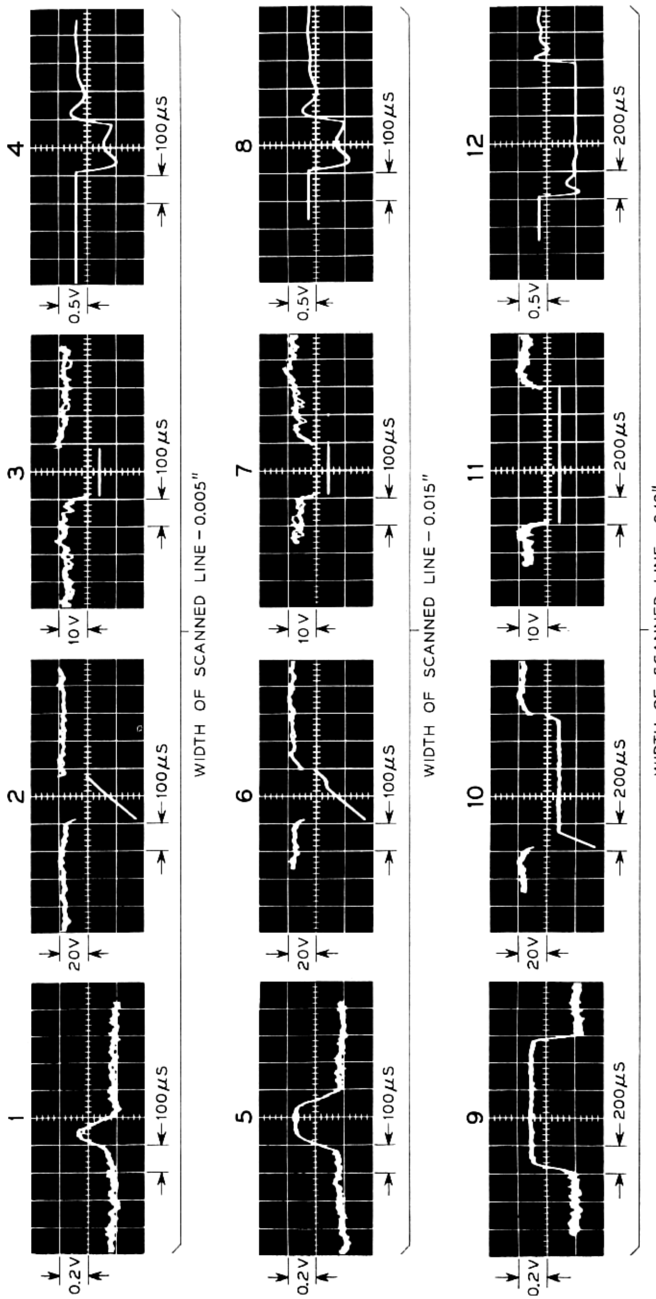


Fig. 12 — Waveforms of signals in the processing circuit.

If the signal pulse duration is longer than the time constant of the circuit composed of R and C, the charge cycle of the capacitor is terminated at the potential of the cathode follower, which remains at the triggering potential. The slicer circuit is therefore held in the triggered condition for the full duration of the pulse, since the voltage on the cathode follower is now controlling.

If the signal pulse duration is shorter than the time constant of the RC circuit — the cathode follower potential having become more positive due to the termination of the signal — the charge cycle of the capacitor terminates the triggered cycle, just as in a monostable multivibrator. The output pulse length is therefore determined by the RC circuit for signal pulses shorter in duration than the time constant of the clipper; it is determined by the length of the pulses themselves, if their time duration is greater than the time constant of the clipper.

By connecting the charging resistor R to the positive supply potential, a more linear portion of the timing exponential curve is used, and there is little lengthening of signal pulses of the same or longer durations than that of the RC circuit.

By setting the time constant of the slicer circuit to 160 microseconds, signal pulses arriving at the slicer input having duration less than 160 microseconds are lengthened and appear at the output as clipped rectangular pulses of 160-microsecond duration; the signal pulses of greater duration are regeneratively clipped into rectangular pulses with their durations undisturbed. The ouput signals of this unit are clear rectangular pulses corresponding to the inked lines or figures on the subject material to be transmitted.

The action of this combined slicer and pulse-lengthener circuit is illustrated in Fig. 12 by the waveform photos taken during its operation.

Photos 1, 5 and 9 show signal pulses of 50, 150 and 1000 microseconds respectively derived from scanning lines of the widths indicated.

Photos 3, 7 and 11 indicate the voltage across the common cathodes of the circuit and shows that the sliced pulses are of 160, 160 and 1000 microseconds duration respectively.

The output pulses, applied to the low-pass filter circuit are shown in photos 4, 8 and 12. The effect of the impedance characteristic of this filter on the extremely sharp transitions of the output waves is noticeable.

Photos 2, 6 and 10 show the wave shape at the input grid of the slicer. Photo 2 indicates that, after the slicing operation has been begun by the front edge of the short duration input pulse, the duration of its operation is controlled by the decay of the RC circuit.

Photo 10 shows that the slicer operation is controlled by the length of the signal pulse when it is longer than the time constant of the *RC* circuit.

Photo 6 indicates the slicer operation when the signal pulse is approximately of the same duration as the *RC* time constant. (The loading of the oscilloscope at this point of the circuit shortens somewhat the decay time of the *RC* circuit.)

A second conventional slicer circuit, V8 and associated components, operates on the pulse from the photo diode in the scanner. It produces an output rectangular pulse synchronized in time with the black-signal pulse produced at the termination of each scanning line by the scanning spiral. The negative pulse is passed to the carrier-oscillator unit where it operates a gate circuit consisting of one-half of a 12AU7 and associated diodes. The 26.880-kc carrier is interrupted during the time the gate is open. This carrier zero is used for blanking the reproducer beam and, after separation, for horizontal synchronization of receiver scanning circuits.

4.3 *Carrier Modulation*

Modulation of the carrier at 3.84 kc with the picture signals is done in two balanced modulator stages (see Fig. 10). The picture signals, having been limited to a nominal bandwidth of 3 kc by a low-pass phase-equalized filter, modulate a 26.88-kc carrier in a lattice copper-oxide varistor. The output balance has been adjusted so that signals corresponding to inked lines on the original cards produce maximum modulation. Signals corresponding to background information produce half-maximum modulation and synchronizing signals gate out or produce zero carrier.

The double sideband frequencies around the 26.88-kc carrier are then filtered with a band-pass filter having flat loss and linear phase characteristics through the wanted-frequency band from 23.88 to approximately 28 kc. Tolerances are unspecified over other frequencies in the two sidebands, since they are eliminated in the vestigial filter which follows the second stage of modulation.

The resulting band of frequencies then modulates a 23.04-kc carrier, resulting in a 3.84-kc carrier with double sidebands. The result is shaped by a linear-phase low-pass filter which partially reduces the upper sideband and produces half of the vestigial shaping requirement of the system.

An identical filter located in the terminal receiving equipment completes the vestigial sideband shaping. Since it is located in the receiver,

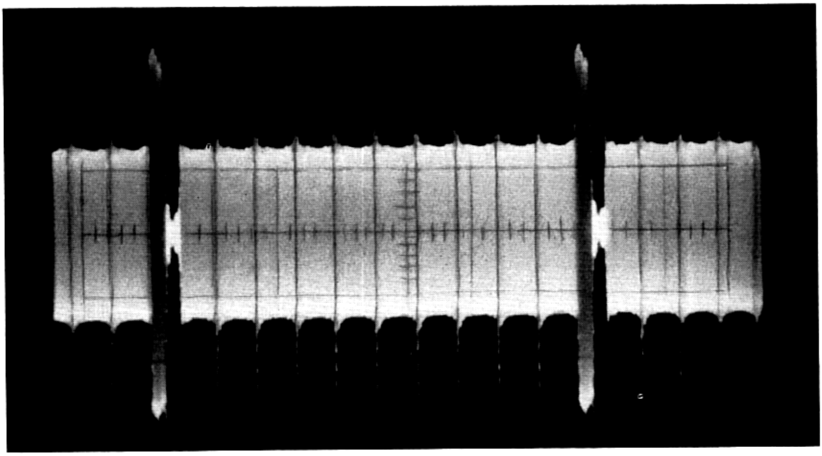


Fig. 13 — Oscillogram of transmitted signal.

this arrangement assists in reducing noise produced by the transmission lines.

The outgoing signal occupies the band from 840 to nearly 5,000 cycles and is transmitted to the balanced program circuit through an output line amplifier.

The waveform of the transmitted signal, corresponding to slightly more than one line, is shown in Fig. 13. The carrier amplitudes corresponding to the horizontal sync signals, to background and to inked lines are easily recognized.

4.4 *Addressing*

Since it requires 5 seconds to transmit a single message to one teller, means must be included to direct each message to a particular teller, so that the transmitter and the wire circuit can be released for the use of other tellers. This switching is accomplished by sending a short pulse of tone of a different frequency for each receiver at the start of each transmission. The frequency of the tone, which serves as the address selector, is chosen by the transmitter operator by means of a key switch mounted on the operating console. This address tone, a single frequency between 400 and 775 cycles per second, likewise serves as the vertical-start signal and activates the vertical scan for the chosen receiver. A momentary-contact relay, activated when the carriage on the scanner begins to move, gates a 40-millisecond burst of the address and vertical-start frequency, which is mixed with the picture signals.

The scanner carriage motor is started by two switches in cascade, one on the carriage cover and the other on the address key. Both must be closed to send the picture information, but the sequence is unimportant.

The processing and modulating circuits are located below the top of the operating console. The monitor unit, with its cover removed, is visible in Fig. 14.

4.5 *Operation*

The bank signature card and the corresponding account card are positioned in a card holder.

The card holder is pushed into position on the top of the scanner carriage with the transparent lid lifted.

Closing the lid and pushing the address button, in any order, initiates the transmission to a particular receiver.

A reproduction of the subject material is displayed for a short time on the picture monitor.

After the 5 seconds required for transmission, the carriage auto-

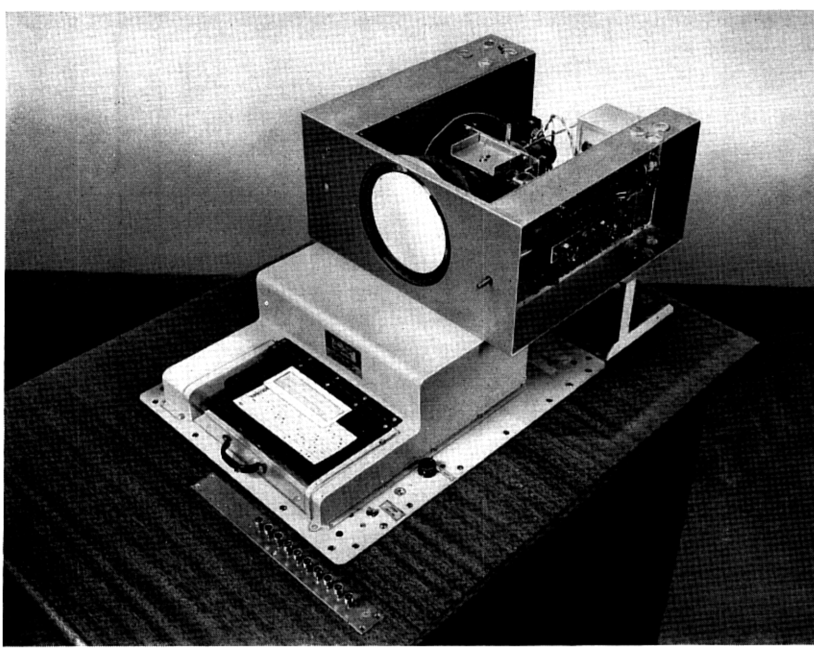


Fig. 14 — Transmitter unit, showing monitoring tube assembly.

matically returns to its "unloading" position, where the card holder can be easily removed.

A second loaded card holder can be inserted immediately for transmission of another message to another teller.

V. RECEIVER

It has been pointed out that the receiver for this experimental system should have several unusual characteristics. The selection of only one of a group of receivers, through the use of a burst of tone of a particular frequency at the onset of a transmission, does not present any very difficult problems. However, our desire to present the received picture in nonpermanent form is a different matter. Here the problem is that of displaying a picture for possibly as long as a few minutes from a single transmission lasting only 5 seconds. Obviously, storage of some form is required.

5.1 *Storage Devices*

A study of several storage devices was made to determine their relative ability to convert the electrically stored signal into a visual form. Magnetic storage drums were discarded because of circuit complexity required to avoid display flicker. The transmitted signal could be recorded on a magnetic drum turning one revolution in 5 seconds and reproduced at the same speed repetitively for display on a long-persistence-phosphor kinescope. However, it was found that the intense writing beam of such a kinescope is distracting to the viewer. Familiarity with this type of presentation does enable some persons to disregard the beam's presence, but others always find it annoying. The signal might be recorded on a drum rotating at $\frac{1}{5}$ rps and reproduced at 60 rps for flickerless display, but the accelerating time of the drum would have to be added to the file-search and transmission time. Existing sampling techniques could enable the magnetic drum to run continuously at the high speed but at the expense of added circuit complexity.

Electric-to-electric or signal-converter storage tubes, and electric-to-visual or direct-view storage tubes were investigated. The electric-to-electric variety of tube has little to recommend it over the electric-to-visual model as to relative performance in this application, and the direct-view type requires much simpler circuitry.

Tallying the advantages and disadvantages of these forms of storage, it appeared that, if large enough direct-view storage tubes could be made to accommodate a full-size presentation of the $1\frac{1}{4}$- by 5-in. scanning field, such tubes would permit the simplest form of receiver. The bright-trace form of direct-view storage tubes available at the outset were 5 in. in size. These tubes have a working diameter of 3.5 in., and, for full-scale reproduction of the scanned area, we required 5.2 in. Both the Radio Corporation of America and the Farnsworth Electronics Company agreed to supply experimental quantities of 7 in. tubes with a working diameter of 5.5 in. The literature should be consulted for descriptions of the functioning of this tube.[5, 6]

A second form of electric-to-visual storage tube, best known as a dark-trace cathode ray tube, has been produced in 7-in. diameter models by the Skiatron Corporation and its licensees.[7]

All these storage tubes have their relative merits and faults, but very little comparative data are available. In order to ascertain the operational characteristics of the tubes that were — or could become — available, it was determined to construct three separate display units.

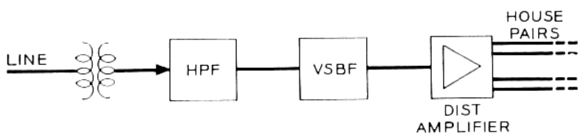


Fig. 15 — Common equipment block diagram.

5.2 *Receiving Equipment*

Since there may be several teller's display units at a single terminal location, it was logical to split the receiving equipment into two units. One unit consists of the equipment common to all of the receiving installation, in which the incoming signal is partially processed and then distributed to the several display units. This common-equipment unit is shown in Fig. 15. An isolating transformer feeds filters which complete the vestigial-sideband spectrum shaping and eliminate power frequency harmonics. The signal is then amplified for distribution. The individual display units comprise the remaining portion of the equipment.

A block diagram of the control units for each display tube is shown in Fig. 16. The received signal is processed in three branches to achieve the required functions. The first branch includes a narrow band-pass amplifier for display unit selection. The tone burst at the beginning of a message intended for this station is passed through this amplifier to initiate the vertical deflection and simultaneously open a gate in the picture signal branch. The tone burst for other display units will be rejected by the selectivity of the narrow band-pass amplifier. Consequently, the only display unit responding to a transmission is the one to which it is addressed.

The second branch processes the received signal to provide a highly stable, continuous, horizontal sweep. The signal is envelope-detected to regain baseband, and the horizontal sync pulse is separated and stabilized by standard television methods. The stabilized sync pulse drives the horizontal sweep for the display tube.

The third branch processes the picture signal. The received signal is translated to a higher-frequency region, for more accurate envelope detection. This is accomplished by a single modulation and band-pass filtering. After suitable amplification, the high-frequency signal is limited to three levels. This limiting effectively removes the central signal portion corresponding to the bank card background, and peak-limits the signal levels denoting the pen strokes of the signature or the typed account information. The signal at the ouput of the slicer is a high-frequency carrier modulated with the picture signal. Therefore, it may be coupled easily to the writing grid of the direct-view storage tube, which is at high dc potential. The curvature of the grid characteristic of the storage tube is sufficient for demodulation of the signal. An identical slicer is used in the circuits for the dark-trace cathode ray tube. However, an additional rectifier is provided at the grid of the tube in order to gain the greater writing beam currents required by this tube for acceptable contrast of the display.

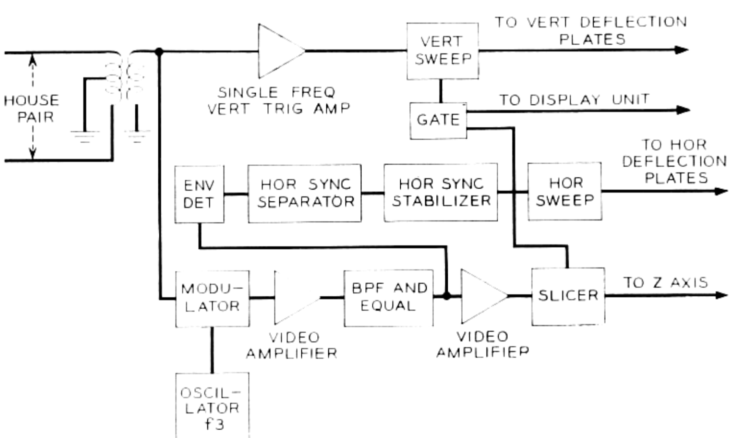


Fig. 16 — Teller's control and display unit block diagram.

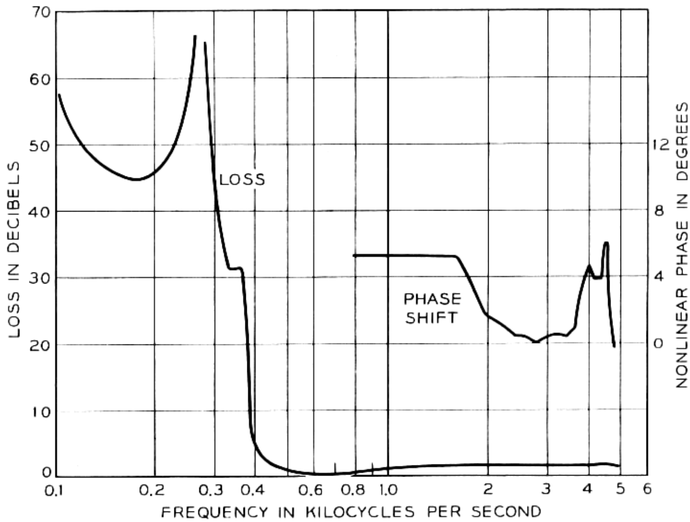


Fig. 17 — Amplitude and phase characteristics of high-pass filter of common equipment unit.

Circuits are provided to protect the storage tubes against loss of deflection voltages.

5.3 *Common Receiving Equipment*

The incoming program line is terminated in the common receiving equipment unit. This unit is intended to be installed in a location convenient to a building's telephone-distribution terminal. The received composite signals are filtered by a 400-cps high-pass filter to remove the induced 60-cps power frequency and its first six harmonics. The amplitude and phase characteristics of this filter are shown in Fig. 17. A vestigial sideband "half-filter" completes the vestigial sideband shaping and also acts to reduce noise outside the useful frequency band. The over-all characteristics of the two parts of the vestigial sideband filter (one part is included in the transmitting equipment) are shown in Fig. 18.

The filtered signal is amplified. Provision is made at the ouput of the distribution amplifier to feed as many as four balanced 600-ohm lines to as many teller's display units.

The tones for selection of a teller's display unit can be located every 75 cps from 400 to 775 cps. The principal picture sideband is 0.84 to 3.84 kc and the vestigial sideband extends to nearly 5 kc.

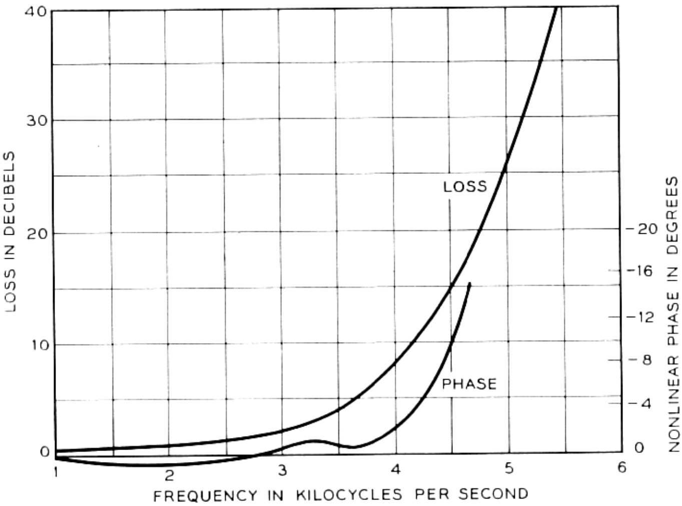


Fig. 18 — Amplitude and phase characteristics of vestigial sideband shaping in the system.

5.4 *Teller's Display Unit*

The signal from the common receiving equipment is applied to several teller's display units. The circuits for carrying out the necessary switching, writing, and display operations are described in the following paragraphs.

5.4.1 *Frame Start and Address Tone Identification*

The line-isolation transformer of Fig. 16 delivers the composite picture signal to a sharply tuned active filter. This filter will respond only to the 50-millisecond address-tone burst of the proper frequency. At the start of a transmission, the appropriate tone burst is superimposed on the composite picture signal. This address tone, as amplified and filtered, is used to trigger a single-shot vertical sweep generator and a gating circuit.

5.4.2 *Vertical Sweep Generation*

The address tone is detected by a voltage-doubler circuit but no smoothing is employed. The detected burst triggers a conventional, monostable, screen-coupled phantastron[8] (Miller run-down). The plate output of this circuit is a linearly decreasing voltage, which is an ideal generator source for a vertical deflection circuit.

5.4.3 *Gate Control of Picture Signal*

Two or more teller's display units may be used in a single installation. It is desirable, therefore, to disconnect the picture signal from all but the display tube for which the message is intended. Also, such switching avoids any possibility of damage to the storage surfaces of vertically undeflected display tubes. A suitable gating pulse is found in the screen-grid circuit of the phantastron vertical-sweep generator tube. This is a positive pulse of the same duration as the sweep voltage. The details of the gating circuit making use of this pulse are described in Section 5.4.6.

5.4.4 *Translation of Received Picture Signal from 3.84 kc to 26.88 kc*

The vestigial-sideband composite picture signal at the input of the receiver may be envelope-detected to regain the baseband frequencies; however, this will result in distortion of the high-frequency components of the picture signal, since accurate resolution of the envelope is impractical at these frequencies. In addition, the writing grid of the direct-view storage tubes is operated at a high dc potential, requiring the application of signals through a capacitor. This capacitive coupling would produce distortion of the reproduced picture if the baseband picture signal were transmitted through it. These limitations are avoided by translating the carrier before detection or display to a frequency considerably greater than the highest baseband frequency.

The picture signal is modulated on a 23.04-kc carrier in a balanced modulator to produce a double-sideband, suppressed-carrier output. The upper sideband produced by this modulation is transmitted and the lower sideband is rejected by a bandpass filter. The picture carrier at 3.84 kc is translated in frequency to 26.88 kc by this modulation process.

5.4.5 *Three-Level Limiting of the 26.88-kc Carrier Picture Signal*

In order to realize the advantages of binary transmission, it is advantageous to insert a threshold detector in the signal path. This slicer separates the signal from average-level noise and also reduces signal distortions caused by delay distortion. The additional requirement for high-frequency coupling to the grid of the direct-view storage tubes led to the adaptation of a slicer which would operate at the 26.88-kc carrier frequency and not contain baseband signal components in its output. Such a slicer circuit is shown in Fig. 19. Both positive and negative alternations of the input signal are sliced at discrete levels between black and white. Fixed-amplitude square waves are produced at the output. The only signal-level values permitted are positive maxima, zero and negative maxima. The ternary-valued output is a completely modulated carrier. This output is suitably amplified and capacitively coupled to the control grid of the display tube. The cutoff characteristic of the grid effects half-wave envelope detection.

5.4.6 *Vertical Sweep-Period Gating of Picture Signal*

To insure no response in the unselected teller's display units, as mentioned earlier, the picture signal circuits must be gated.

During the vertical sweep period, the gating pulse available at the screen-grid of the phantastron circuit is applied to adjust the bias of tube V1 in Fig. 19, for proper slicing action. This bias value is such that, with zero signal level input, diodes D1 and D4 are conducting. The voltage difference between the anodes of D1 and D3 is set so that the input signal level corresponding to background is not sufficient to cause D3 to conduct or D1 to cease conduction. The signal level corresponding to signature information is sufficient to cause D3 to conduct on the positive peaks and D1 to cease conduction on the negative peaks. This gives rise to an output waveform at V2 restricted to positive and negative peaks and zero.

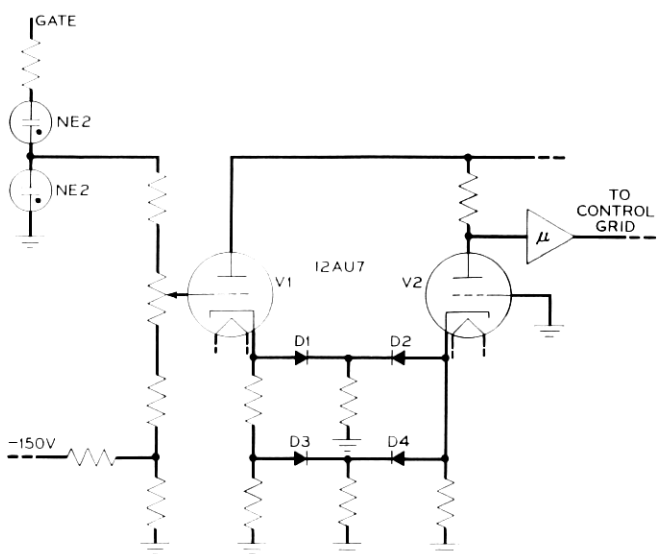


Fig. 19 — Three-level limiter schematic.

Upon completion of the vertical sweep, cessation of the positive pulse reduces the bias on V1 to a negative value and signals are unable to influence further the output of V2.

5.4.7 *Horizontal Sync Pulse Separation*

The composite picture signal, after frequency translation, is envelope-detected and the horizontal sync pulse is derived from the picture signal by the familiar amplitude-separation technique of broadcast television. After separation, the sync pulse is amplitude-limited to remove amplitude components of the transmission-line noise.

5.4.8 *Horizontal Sync Pulse Stabilization*

The limiting of the horizontal sync pulse results in a pulse with fast rise and decay times, but the timing of the leading and trailing edges is perturbed by noise. A further refinement is necessary to minimize the disturbance to sweep timing arising from this cause. The clipped horizontal sync pulses are phase-detected against locally generated pulses and the time difference between these two signals results in an error signal whose value is a function of such difference. This error signal is integrated and applied as a correcting voltage to change the phase of the local pulse source. These locally generated pulses drive the horizontal sweep generator. Therefore, short-term errors, such as are representative of noise, cause only minor perturbations of the horizontal sweep.

5.4.9 *Horizontal Sweep Generation*

The stabilized horizontal sync pulses trigger a saw-tooth generator which, in turn, drives a deflection amplifier. The average voltage with respect to the cathode ray tube gun at the output of both the horizontal and vertical deflection amplifiers is adjustable for optimum focusing of the storage tube displays. Adjustments are also provided for centering the sweeps in the display.

5.5 *Features of the Teller's Display Units*

Three separate display units were constructed for study of the different storage tubes. Each unit provides physical mounting for the tube, and for its operating potential supplies as well as switching and protection circuits.

Fig. 20 — Direct-view storage tubes.

5.5.1 *Direct-View Storage Tubes*

Fig. 20 is a photograph of the direct-view storage tubes as manufactured by (from left to right) the Farnsworth Electronics Company, the Radio Corporation of America and the National Union Electric Corporation, as a licensee of Skiatron Corporation. Fig. 21 shows a representative tube mounted in its housing. These frameworks are designed for mounting in a teller's desk. For demonstration purposes, they are fitted with covers and mounted on mobile carts.

5.5.2 *Switching Circuits*

Switching circuits are required for properly cycling the operations of the direct-view storage tubes. Some means must be provided to maintain these tubes in a state of readiness to store an incoming signal. This is achieved by maintaining the storage mesh at erase potential during any period when there is no signal stored and being viewed. Additional switching disables the phosphor-screen high voltage during all but the viewing period. One further switching circuit is provided to permit either manual erasure of the stored information or automatic erasure after a total viewing time of two minutes. The automatic feature is provided to insure readiness to store new information in the event of a teller's failure to erase a previous message.

The switching functions required for the dark-trace cathode ray tubes are somewhat different. Upon completion of the short cycle of erasure performed by heating the scotophor with an internal filament and then permitting the surface to cool, this tube is in a condition to record another message, and will continue in such a state indefinitely without further manipulation. In order to conserve power, the high voltage supply is enabled only during the writing process, as it is only during this period that the electron gun of the tube is active. Again, both manual and automatic erasure are provided.

The erasure filament must be maintained at high voltage (13 kv) during the writing cycle for proper beam focus. Consequently, erasure is carried out by disconnecting the high voltage from the erasure filament before the heating power is applied to it. Vacuum switches were used in this equipment, but the need for switching would be eliminated if a suitable isolation transformer were used for the heating power.

5.5.3 *Tube Protection Circuits*

A circuit is provided to protect the storage tubes against excessive beam current density in the event of a horizontal sweep failure. This

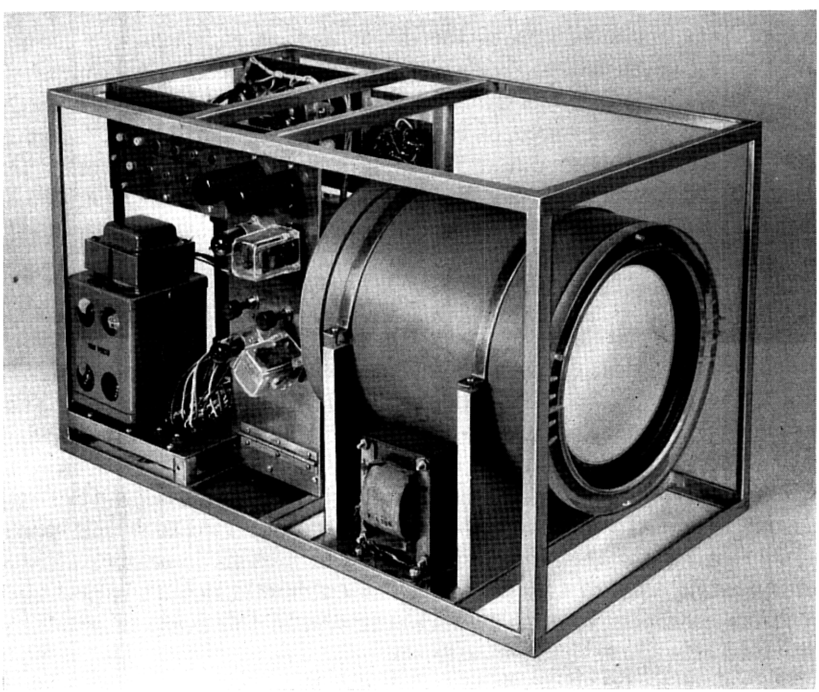


Fig. 21 — Display unit employing a Farnsworth Electronics Company 7-in. direct-view storage tube.

circuit is also self-protecting against the most common types of vacuum tube failures.

5.5.4 *Operating Potentials for Display Devices*

Potentials for the critical anodes of the direct-view storage tubes are provided through cathode followers to improve the voltage regulation. The writing gun and screen voltages are provided by separate supplies for independent operation and switching.

The dark-trace cathode ray tube may have all required potentials supplied by a single 15-kv high-voltage power pack. Separate anode potentials are derived from taps on a resistive voltage divider.

VI. EXPERIMENTAL RESULTS

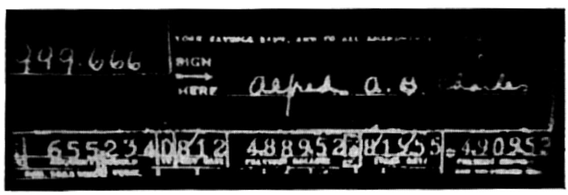
By constructing separate receivers for each of the three storage tubes subjective evaluation was accomplished. All three tubes performed adequately to accomplish the desired purpose and, fortunately, there is no need to designate a "best" tube, since this equipment was not intended for Bell System manufacture.

Graphic presentation of the over-all results in the form of photographs of the storage tube viewing screens is given in Fig. 22. The signals shown stored in these photographs were transmitted over a 40-mile loop of a 5-kc program channel. It is evident from Fig. 22 that the system design produced the desired results. It is also evident that all elements of the system have been taxed to their limits of performance. If the time-bandwidth product were appreciably increased the available storage tubes could not adequately display the increased information. Similarly, if the quality of the storage tubes were significantly better only marginal improvement of the system would result. Only an increase in both the time-bandwidth product — by appropriate changes in the transmitting equipment — and an improvement in the resolution and quality of the storage tube can improve the net results.

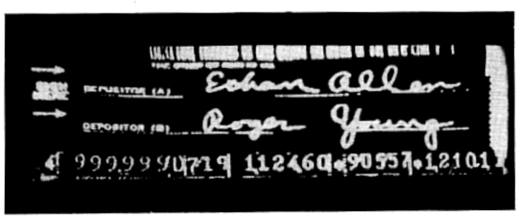
The most serious distortion of the transmitted signal resulting from transmission was found to be delay distortion. The delays encountered, however, were well within tolerable limits for program use. Noise introduced by typical long circuits was found to have little effect on the picture in the presence of the larger distortions produced by delay distortion. A series of tests was run to show the transmission distance limit of some representative forms to Bell System 5-kc program circuits without additional delay equalization.

Fig. 23(a) shows the output of the transmitter to the program line after the half-filter has partially shaped the vestigial sideband. Fig. 23(b) shows the same signal after transmission from Murray Hill to Philadelphia via New York and return over a 5-kc program circuit on an audio-frequency cable system. Fig. 23(c) shows the same signal after frequency translation and limiting. It is seen that the limiting process was capable of separating the delay distortion components from the desired signal. Fig. 23(d) is a storage-tube viewing screen photograph of a sample transmission.

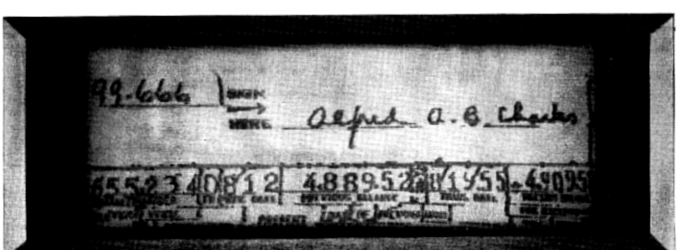
Similar data also are shown in Fig. 23 for various other loops. An audio-frequency cable channel to Washington, D. C., and return showed no loss in picture detail. The doublet and triplet output of the three-level limiter resulting from circuits with large amounts of delay distortion produce unusable results at some threshold level. All lines with less distortion produce no visible distortion in the display.



MANUFACTURER A



MANUFACTURER B



MANUFACTURER C

Fig. 22 — Photographs of storage tube viewing screens with stored signal.

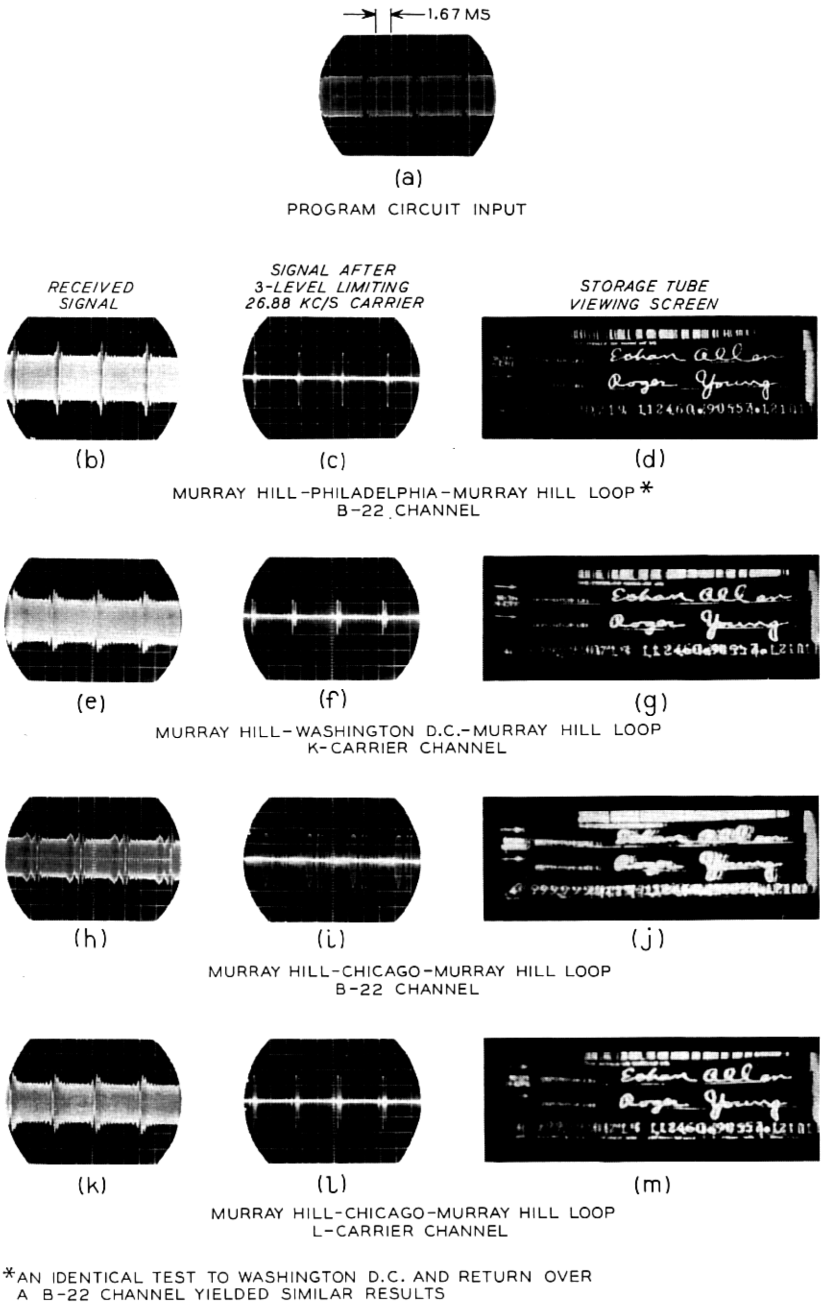


Fig. 23 — Results over various transmission loops.

VII. CONCLUSIONS

It has been shown that it is indeed feasible to build a visual communication system combining to advantage features of television and facsimile. While the results represent a solution of a particular communication problem, it is apparent that the techniques used may be applied to many similar problems in the business field. It should be obvious that the physical form of equipment for use in any specific application would differ in many details from that used in our experiment.

In considering the results of this experiment, the reader must keep our goals in mind. One aim was to demonstrate the use of a system intermediate between facsimile and television and providing features of both types of visual communication facility. Another aim was to demonstrate that, for some purposes, the product of transmission bandwidth and time could be reduced to a minimum without impairing the readability of the reproduced image. It is obvious that the resulting images have very little esthetic appeal; the use of a larger over-all time-bandwidth product coupled with display devices capable of increased resolution would result in more pleasing images.

VIII. ACKNOWLEDGMENTS

It is impossible to give individual credit to all of our associates who have contributed to this experiment. We do wish, however, to express our appreciation of the enthusiastic liaison carried on with the New York Savings Bank by M. B. Long, since retired from the Laboratories; and to Albert F. Kendall of the New York Savings Bank for his patient explanations of the workings of a banking house. Furthermore, we are indebted to John W. Smith and his associates of the Hogan Laboratories for their cooperation in producing the mechanical scanner employed in our experiment.

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