The *Picturephone®* System:

No. 101 ESS

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This paper describes the methods and equipment used in providing Picturephone® *capability to the No. 101 Electronic Switching System. Included are a discussion of the objectives, design approach, transmission requirements, traffic capacity, and operation of the wideband switch unit (WSU) which provides the video transmission path. Also described are the video trunk circuits, junctor circuits, and the physical characteristics of the WSU.*

I. INTRODUCTION

1.1 *General*[1-3]

The No. 101 Electronic Switching System (ESS), an electronic private branch exchange (PBX), has been providing customers with Centrex and other specialized services since the first commercial installation was made in Cocoa Beach, Florida, in November 1963.

The system, consisting basically of a control unit (CU) and one or more switch units (SU), effects the actual interconnections between lines, trunks, and service circuits on a time division switched basis as described in the February 1969 issue of the B.S.T.J.[4] The SUs are connected by means of data links to the CU a common, centrally located, special purpose computer which processes calls in the system by means of a stored program technique.[5,6] Although practical for the handling of voiceband frequencies, the time division circuitry in the No. 101 ESS switch units is not capable of handling the higher frequencies required for transmission of video signals. In order to provide video switching capability, a wideband switch unit (WSU) utilizing space division switching has been designed for use in parallel with the 2A, 3A, and 4A switch units.[7-9]

1.2 *Objectives*

The design objectives for the WSU were based upon the expected low demand for *Picturephone* service during the initial years. It was decided that the WSU must be economical at the 20- to 30-line size and that additional line capacity must be easily administered in the field. The WSU should also be compatible with all No. 101 ESS SUs (2A, 3A, and 4A) and should make as much use as possible of existing SU circuitry.

II. SYSTEM DESCRIPTION

To handle audio telephone traffic, a SU is located on the customer's premises, as shown on Fig. 1, and is controlled by a CU located at the central office. Communications between the CU and SU is provided by means of data links. To add *Picturephone* capability to this complex, an adjunct WSU consisting of a four-wire space division network and a duplicated wideband switch control (WSC), is also located on the customer's premises and is connected to the SU via connectorized cables. The two video pairs from each *Picturephone* extension and trunk terminate on the WSU, while the audio pair terminates on the SU. A complete *Picturephone* connection is composed of an audio connection in the SU and a parallel video connection in the WSU. All translation needed to associate the video pairs with an audio pair is part of the stored program information in the CU, which eliminates the need for directory number changes when equipping an audio line with *Picturephone* service. The WSU adjunct scheme utilizes existing data links, supervisory and signaling circuits, service circuits,

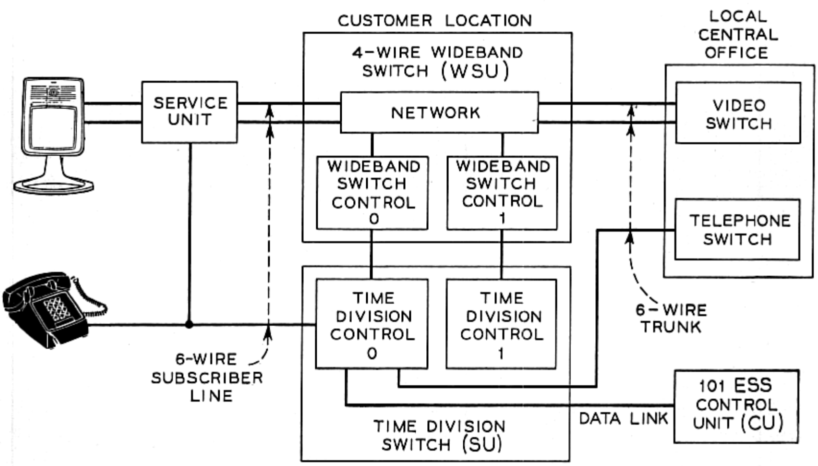

Fig. 1—System plan.

and incoming and outgoing message circuits contained in the SU, as well as all switching functions associated with the audio pair. Messages from the CU to the WSU are transmitted in serial form over an existing data link to the SU and are treated as normal audio messages by the SU until detection of the video address occurs. The message is then converted to a parallel form and gated over a DC bus to the WSU. The circuitry required to detect the video address and gate the video message to the WSU is located in time division controls (TDC) 0 and 1 of the SU. Each wideband switch control in the WSU is directly associated with its respective TDC in the SU. In order for a given WSC to process a video message, the message must be received by the TDC associated with that WSC. When a TDC is disabled by maintenance, the corresponding WSC loses its ability to process video messages.

The WSU communicates with the No. 101 ESS control unit via seven supervisory scan points that have been added to the SU scanner. A change of state on a scan point transmits one bit of maintenance information to the CU. All necessary maintenance information regarding the status of both wideband switch controls and the per call transmission checks made on the video pairs is sent to the CU through these seven scan points.

III. NETWORK

3.1 *Transmission Path*

The network, which is shown in Fig. 2 at its maximum size of 192 terminals, is basically a folded three-stage network utilizing standard 8 by 8, four-wire ferreed switches.[10] The network is unduplicated and may be controlled by either WSC.

In order to meet the objectives of being economical at the small line size (20 to 30 lines) and of enabling the network to grow efficiently, the network was modularized. Modules 0A and 0B are identical, each containing four first-stage switches, 16 junctor circuits, and two second-stage switches. Modules 1 and 2 are identical and contain eight first-stage switches each. All interconnections between modules as well as to the wideband switch control are connectorized. The network grows on an add-on basis and allows the addition of modules without disturbing existing customers.

With the provision of two or more modules, the network consists of eight concentrators and four second-stage switches. A concentrator contains a maximum of three first-stage switches with switches 00,

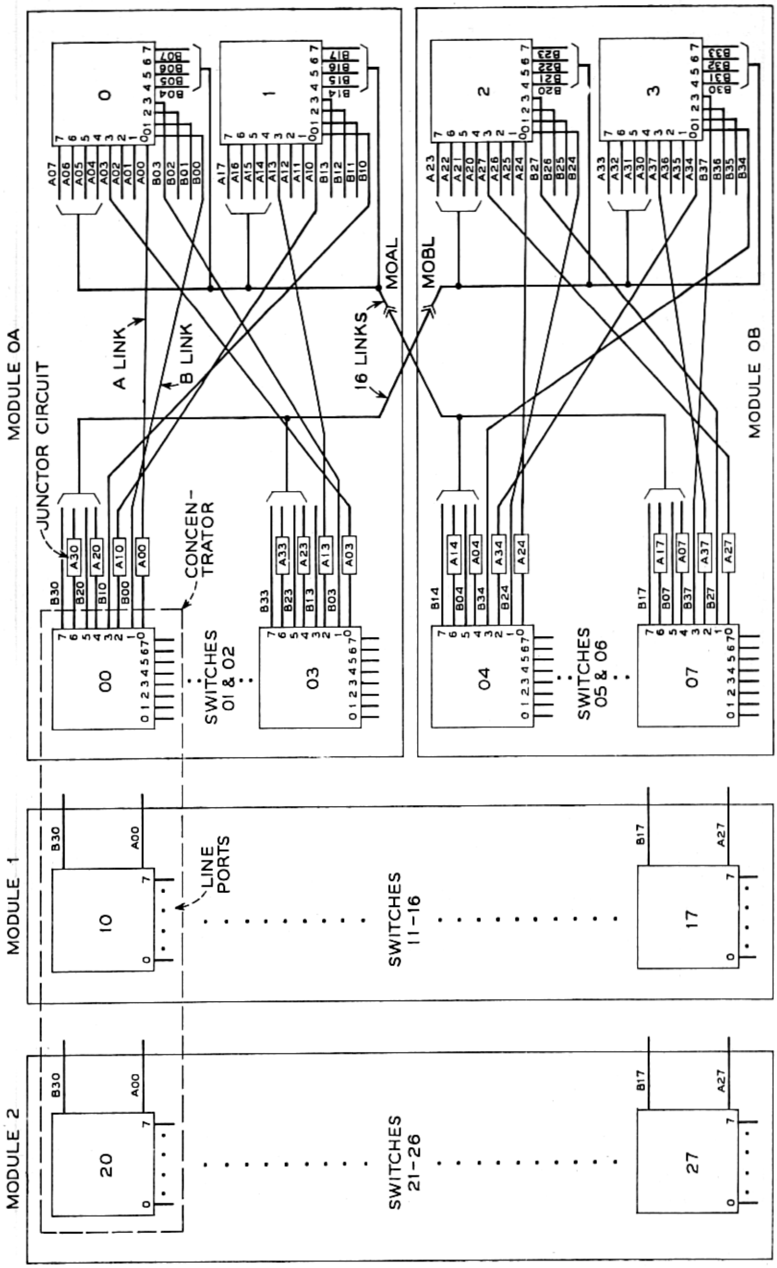

Fig. 2—Fully equipped network.

10, and 20 comprising concentrator 0, etc. It may be seen by looking at concentrator 0 that 24 input terminals have access to eight links resulting in a concentration ratio of 3:1.

At the one module size with only module 0A provided, half of the links (those normally terminated on module 0B) appear to be unterminated. However, the hardware is so arranged that these links may be plugged into the position on module 0A that is normally occupied by links from module 0B. In this way, a full-access network is achieved at the 32 terminal size with no hardware or software modifications. When module 0B is added, the network is full access with a terminal capacity of 64. The addition of module 1 increases the terminal capacity to 128 and the concentration ratio to 2:1. The addition of module 2 increases the network to its maximum of 192 terminals, and the concentration ratio of input terminals to links to 3:1.

Two separate sets of links, termed A and B links, are used to interconnect the first- and second-stage switches. Every connection through the network involves one A link and one B link. The B links provide a straight-through connection between the first- and second-stage ferreed switches. The A links, however, transpose the video pairs via a junctor circuit shown in Fig. 3. The junctor also allows the wideband switch control to access the video pairs for transmission testing, to supply a video supervisory signal to the customer station equipment, and to cut through the video connection after the network path has been established. This latter function assures that the ferreed crosspoints are closed and opened with no current flowing in the network path. With the links interconnecting the first- and second-stage

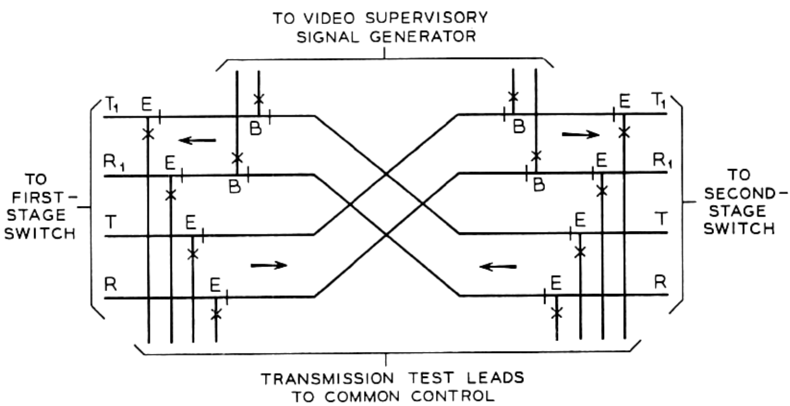

Fig. 3—Junctor circuit.

switches as shown in Fig. 2, there are eight distinct paths between parties located on separate concentrators and four paths between parties involved on an intraconcentrator call.

Lines and trunks are distributed over the switches (as opposed to filling the switches one at a time) in order to balance the traffic load over the links. The first 32 ports of the network, 16 on mod 0A and 16 on mod 0B, are equipped for use as trunk and attendant ports as well as lines. These ports are provided with a loopback circuit and the means of applying the signal for a stationary image to the video transmit pair. The loopback circuit is needed at the WSU on trunk and attendant ports to substitute for the loopback normally provided at the subscriber's station set on line ports. The stationary image is transmitted at appropriate intervals to the distant party on attendant handled calls during the time the call is being processed. Four of the 32 ports are dedicated for attendant use. Since the attendant has the ability to hold up to six calls on the console loops, she must have the capacity to access each party being held. In order to reduce the blocking probability on attendant-handled calls, each console is connected to two ports located on separate concentrators.

3.2 *Pulse Path*

Both the first- and second-stage portions of the network utilize standard 8 by 8, four-wire ferreed switches. The control windings within the switch are series connected along the rows and columns. Eight horizontal leads, eight vertical leads, a common horizontal and a common vertical lead are brought out from each switch (see Fig. 4). By pulsing along a given horizontal and a given vertical via the common horizontal and vertical lead, the selected four-wire crosspoint is closed. A half-select, along either a vertical or horizontal, causes the crosspoint to open.

The horizontal and vertical leads are multipled among the switches associated with a module, so that from any given module only eight vertical leads, eight horizontal leads, one common vertical lead, and one common horizontal lead emerge. In all cases the pulse path exactly parallels the transmission path.

The establishment of a path through the network may be illustrated using the message contents shown in Fig. 5. The network path is selected by a set of wire spring relay trees that operate directly from the party addresses and the second-stage switch information in the message. The party addresses are composed of three elements which specify the module, switch level, and network concentrator of

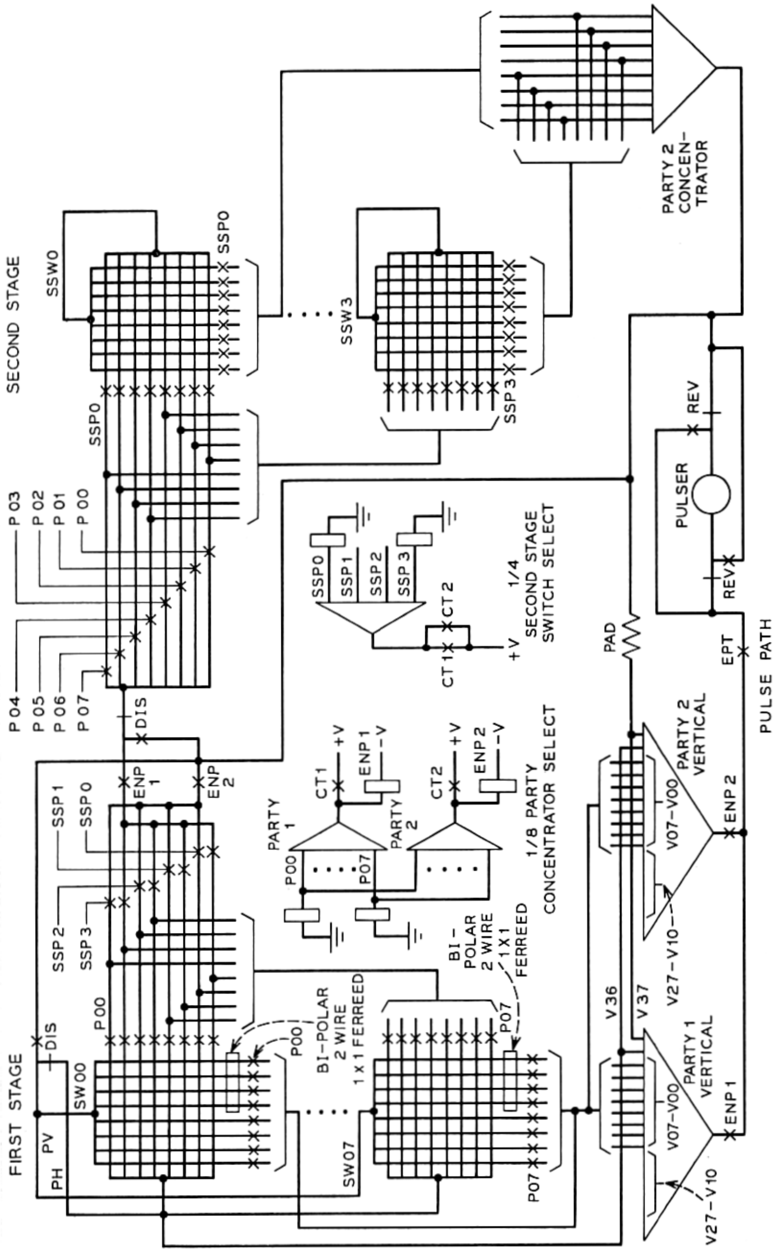

Fig. 4—Pulse path.

the party port. The A and B links to be used in the connection are determined by the second-stage switch bits and the respective concentrator numbers for party 1 and party 2.

The party vertical translators operate from the module and switch level bits to select 1 out of 24 switch vertical leads, and the party concentrator translators operate from the party concentrator bits to select one out of eight network concentrators (Fig. 4). The output of the concentrator translators operates a per switch path select relay for each ferreed switch on the selected concentrator. In a similar manner a path select relay associated with a second-stage switch is operated through the second-stage switch translator.

All translators for both parties operate immediately upon receipt of the message. After the translators have operated, the pulse path is closed across the pulser by relays ENP1 and EPT to fire the pulser. Since a connect order is being performed, the disconnect relay (DIS) will remain unoperated throughout the connect procedure. The first pulser firing simultaneously closes the first-stage switch crosspoint to connect party 1 to the A link, and the second-stage switch crosspoint to connect the A link to the B link. The pulse path runs through the party 1 vertical translator, up the selected vertical lead to the ferreed switch selected by the concentrator translator, around the common vertical (PV) and horizontal (PH) leads, and out on a horizontal level selected by the operated second stage switch path select relay. The pulse then passes through the selected second-stage switch and returns to the pulser. The horizontal and vertical levels on the second-stage switch are respectively selected by the first-stage path select relay and a separate party 2 concentrator translator.

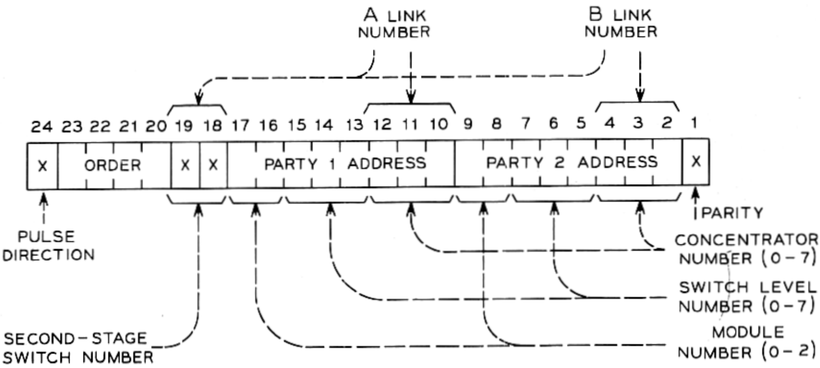

Fig. 5—Message contents.

The second pulser firing connects party 2 to the B link and occurs after relay ENP1 is released and ENP2 is operated. The pulse path is similar to that of the party 1 connect but does not include the second-stage switch.

The REV relay is operated from the pulse polarity bit in the message and controls the direction of the pulser firing. The direction of the pulse is used on trunk and attendant ports to operate or release the bipolar ferreeds for application of the metallic loopback or stationary video-image signal on these ports.

On the termination of each talking connection the link crosspoints are opened to prepare the link for the transmission tests which will be conducted on the next connection. The order is processed in two stages which resemble a connect order except in the following respects. The DIS relay is operated causing a half-select along the verticals of the first-stage switches thereby releasing party 1 and party 2 from their associated links. The second-stage switch crosspoint remains operated, but will be released by the next connection made to either the horizontal or vertical lead associated with it.

For maintenance and initialization purposes, it is desirable to modify the disconnect order so that any connection on a link is released without specifying a port address. For this purpose a disconnect message is formed in which an octal 36 is substituted for the module and level bits in either or both party addresses. This substitution causes the disconnect pulse to be transmitted along the link specified by the second-stage switch and concentrator numbers in the party address.

It is also essential in certain call processing situations to execute an order that affects only one port appearance. An octal 37 substituted for the module and level bits in the party address will cause the pulser to fire into a resistive load leaving the first-stage crosspoints associated with that party unchanged.

3.3 *Transmission Tests*

Since the transmission requirements of the video facilities are stringent and charging takes place upon completion of the audio path, it is imperative that the integrity of the video loop be checked before billing takes place. This is accomplished (Fig. 6) in the WSU on a per call basis at the time the intial connection between two parties is being established. On subsequent connections, during call transfers for instance, the transmission checks are omitted from the connect orders. As explained previously, the establishment of a path through the network occurs in two stages. On each stage of an initial connection a false ground test is made from the junctor circuit on each lead of the video pairs looking toward the party being connected to the link. This test is made in order to detect the presence of stubs attached to the link through stuck network crosspoints. After all network crosspoints have been closed, a test is made on the total video path to check continuity through the network crosspoints and over the video loop to the station apparatus.

The false ground test relies on a 50Ω ground that is placed on each lead of the video pairs by either the station set equalizer or the equalizer located at the WSU. This ground should not be present on any lead of a link within an idle junctor circuit since each party is disconnected from its link when a talking connection is terminated. Therefore, a stuck crosspoint may be detected by looking for grounds on the video pairs in the junctor circuit before the network crosspoints are closed. All transmission tests employ a 12-kHz tone source and a 12-kHz tuned detector located in the WSC of the WSU. On the first stage of the connection, before party 1 is connected to the A link, the E relay of the junctor circuit is operated to bring the video pairs from both parties into the WSC. The FCG1

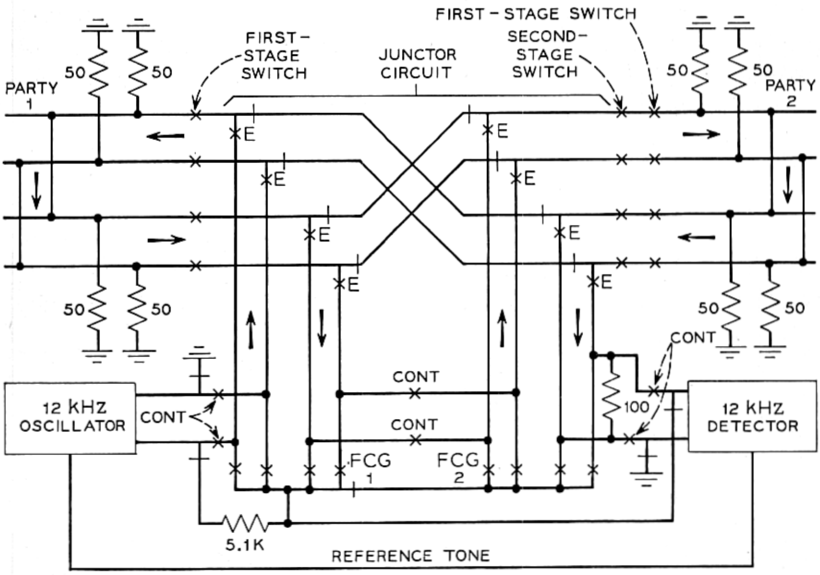

Fig. 6—Transmission tests.

relay is then operated to interconnect the leads of the video pairs for party 1 and to connect them to the 12-kHz tone source. The 12-kHz signal on the video pairs is connected to a tuned detector together with a reference tone from the 12-kHz source. The detector compares the tone level on the video pairs with the reference tone and sends a pass or fail signal to the WSC. If an impedance ground of 3K ohms or less exists on any lead of the party 1 pairs, the signal level will be low enough to cause the tuned detector to transmit a failure signal to the WSC. If no stub is detected on the A link, party 1 is connected to this link and the second-stage switch crosspoint is closed thereby connecting the A link to the B link being used for party 2. On the second half of the connection procedure a similar false ground test is made through the junctor circuit looking toward party 2 through the closed second-stage switch crosspoints. If no stubs are found on the B link, the connection is completed by connecting party 2 to the link.

The continuity test is performed after the network path has been established and utilizes the same 12-kHz oscillator and detector used in the false ground tests. To start the test the CONT relay is operated in the WSC to transmit the 12-kHz tone through the junctor circuit, through the loopbacks at the party 1 and party 2 station sets, and back through the junctor circuit to the tuned detector. If the received tone at the detector is 4 dB less than the reference tone, a failure signal is given to the WSC. A failure on any one of the transmission tests prevents the WSC from completing its sequence of operations for the order and causes a FAIL scan point to be sent to the No. 101 ESS control unit. Upon receipt of the FAIL scan point, the CU will clear the WSU of any effects of the failed order and will attempt to remove possible stubs on the transmission path. The order will then be resent. If the failure persists, the CU will remove suspected faulty equipment from service and cause reorder signal to be returned to the calling party.

IV. TRAFFIC HANDLING CAPABILITY

Traffic calculations at three stages of growth were made assuming a blocking probability of P(0.01) (see Fig. 7). These calculations were made at the equipment break points and assume that all terminals are equipped at a given network size and generate equal traffic. It may be observed that terminal capacity can be traded for increased traffic handling capability in a very high traffic situation.

V. WIDEBAND SWITCH CONTROL

Each of the duplicated WSCs is fully equipped to handle the maximum network capacity of 192 terminals and is intimately associated with a TDC in the SU (see Fig. 8). The WSC to be used in processing a message is selected by sending the message to its associated TDC. The WSC is an asynchronous circuit which performs the timing, sequencing, and transmission tests necessary for the operation of the switch network. The order repertoire was designed to complement the operation of the SU as closely as possible so that a minimum number of WSU orders are required to complete a connection. This is necessary to prevent excessive loading of the SU data link and to minimize the time required to complete a video connection.

Receipt of a start bit from the SU initiates a sequence of events which leads to the establishment of a four-wire transmission path through the network and leaves the A link junctor circuit in the proper state. The start bit causes the relay tree translators to operate directly from the party and second-stage switch bits in the message. The order is decoded by solid-state translators and, after the relays have settled down, a parity check is made on the 24-bit message. The WSC then operates the E relay in the proper junctor circuit to gain access to the transmission leads for the transmission tests and to open the trans-

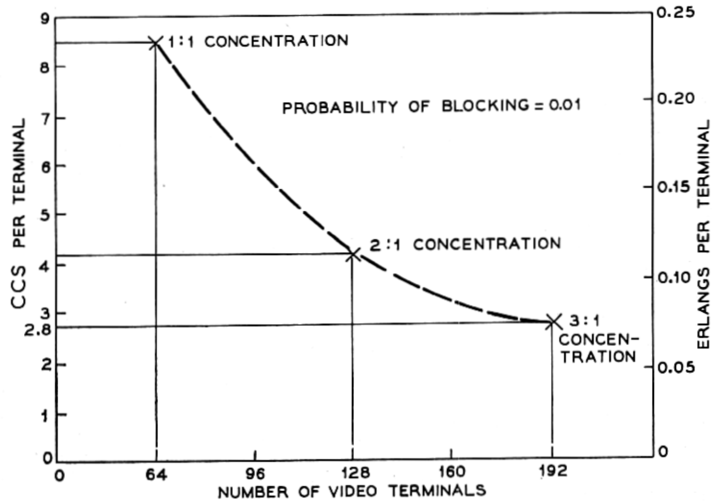

Fig. 7—Traffic estimates. (Notes: 1. X = calculated points. 2. Traffic calculations assume all terminals equipped at a given network size. 3. All terminals generate equal traffic. 4. P(0.01).

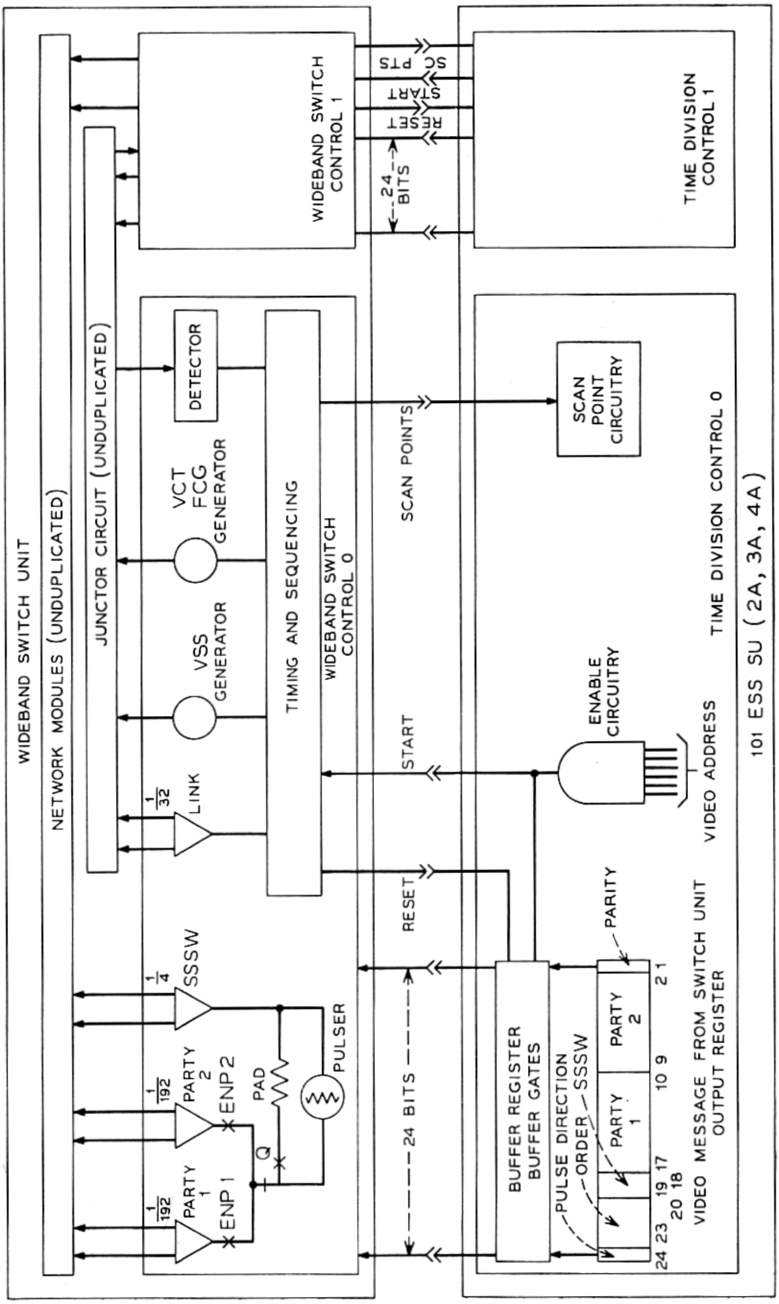

Fig. 8—Common control.

mission leads during the pulser firing. The network path is completed with the required transmission tests as previously described. During the period in which the WSC is setting up the network connection, the junctor circuit is placed in its proper state. Upon completion of the network connection, the junctor relays are checked to verify their operation. If all indications are proper, the buffer register in the SU is reset and an OK scan point is returned to the CU. If the operate time of an order is greater than 85 ms or if any WSC test has failed during processing of the message, a FAIL scan point is returned to the CU.

A faulty WSC may be removed from service or quarantined by the maintenance program. In the quarantined state, the pulser will be made to fire into a dummy load instead of through the network, and the junctor translator will translate to a dummy junctor circuit. If a continuity test or a false cross test is required, the oscillator and detector are interconnected in a manner to allow the test to pass. All other functions of the WSC are performed normally. Responses from the WSC, OK, or FAIL scan points are still received by the CU so that a quarantined WSC may be fully tested without endangering network operation.

VI. PHYSICAL DESCRIPTION

Figure 9 is an artist's rendition of a fully equipped wideband switch unit plus the equalizers necessary to give *Picturephone* capability to the No. 101 ESS. The equipment shown is housed in existing No. 101 ESS 3A switch unit frames measuring 90 cm wide by 213 cm high by 50.8 cm deep.

The wideband switching frame is used to mount the equipment modules with no electrical connections actually made to the frame. The solid-state circuitry used in the wideband switch controls is mounted on circuit packs 14.2 cm high by 28 cm deep. Nine such packs are needed per wideband switch control.

At the 32-line size the high current pulser unit, wideband switch control unit, and one 32-port network module (0A) are supplied. If it is necessary to grow beyond this terminal capacity, additional network modules are added by mounting them on the frame and making the appropriate connections via connectorized cables.

When the WSU is used in a *Picturephone* application, a cable equalizer is needed for each line or trunk terminal used. For transmission reasons, the equalizers must be physically located near the WSU. The basic equalizer bay provides equalization for the first 64 video ports.

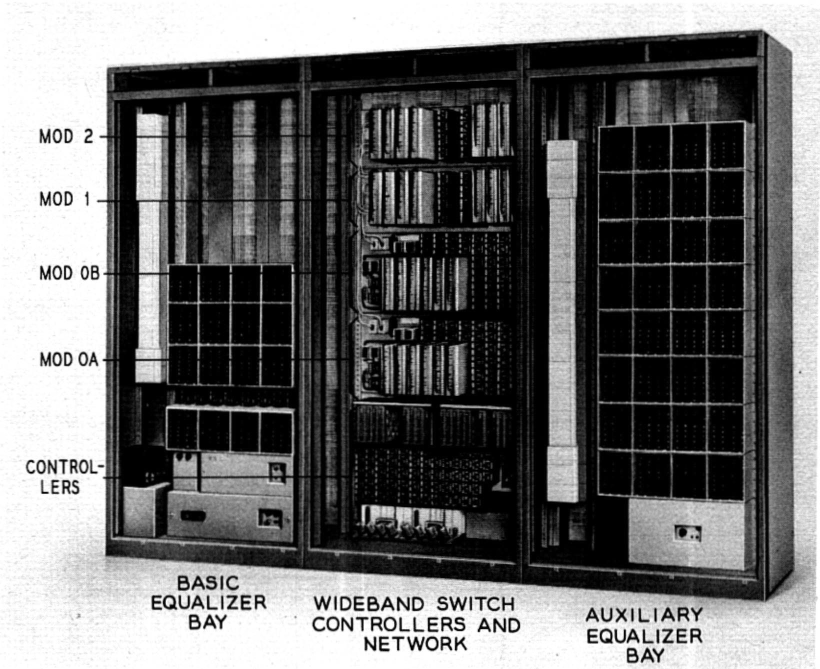

Fig. 9—Wideband switch unit and equalizer bays.

In addition, it houses the power supplies needed by the equalizers and wideband switching frame.

The auxiliary frame is added to the lineup if a terminal capacity greater than 64 is desired. The additional equalizers and their associated power supply are housed in this frame.

VII. SUMMARY

In order to handle the higher frequencies required to transmit the video signals required for *Picturephone* service, a WSU was developed for No. 101 ESS. System operation of the No. 101 ESS with the WSU is given and the processing of a typical video message is described, indicating the manner in which a network path is established for the video portion of a call.

Laboratory testing of the hardware and software has thus far demonstrated the validity of the overall objectives and philosophy used in the design and operation of the WSU.

VIII. ACKNOWLEDGMENTS

A number of persons have been involved in the design of the No. 101 ESS wideband switch unit. The authors wish to acknowledge in particular R. M. Averill and M. L. Larson for their contributions to the WSU circuit design and R. V. Gillingham and R. D. Wiese for the WSU physical design.

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