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L5 SYSTEM:

Line-Protection Switching

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A new system has been designed to provide protection switching capability for the L5 repeatered line. This line-protection switching system, called LPSS-3, provides one standby line for protection of as many as 10 service carrying lines. Switching equipment is located in terminal, terminal main, and switching power-feed stations. Economic and reliability considerations allow switching spans of up to 150 miles. Either temperature pilot deviations or excessive total signal energy initiates automatic switching. Manual control of all switching functions is provided locally and via telemetry.

A dedicated PCM signaling system maintains interstation switching system coordination. Identical information is transmitted in complementary form over two adjacent L5 channels. Parity and complementary checking as well as automatic retransmission of failed codes enhances error immunity.

I. BACKGROUND

1.1 Motivation for development

The need for new switching capabilities and the desire for a modern switching facility for the L5 Coaxial-Carrier Transmission System have led to the development of a new line-protection switching system called LPSS-3. Several objectives were paramount at the beginning of the new development. One was to design an interstation signaling system that is relatively immune to both line noise and hits (short interruptions of transmission), since a signaling error can cause a service failure because of improper switch activation. Another objective was to provide a design that requires a minimum of effort for the addition of new lines.

A newly installed coaxial-carrier system usually has only one or two of the ultimate regular lines equipped and connected. Additional lines are equipped and connected to the system as traffic growth requires. Thus, the process of adding lines to a working system is important. The LPSS-3 bay is factory-wired and tested for its full capacity of 10 regular lines and one standby line. Equipping switching capability for newly added regular lines on an L5 system requires only replacing dummy plug-in modules with active modules in the LPSS-3 bay and adding a few control leads to the new line bays. No new intrabay wiring changes or connections are involved.

A new series of coaxial switches has been developed using diodes as the switching elements. These switches were designed specifically to comply with the L5 system bandwidth and modulation performance standards.

1.2 Reliability considerations

A reliability analysis of estimated failure rates, mean time to failure, and service outage was made for the L5 coaxial system. This included estimates relating to the L5 line, main-station, and switching equipment. These studies were then projected to estimate average outage times for various types of switching sections through the use of system models. In addition, the probability of cable damage has been analyzed and is included in the overall system outage predictions. An outage is a service loss, i.e., a failure not remedied by protection switching.

The results of this study show that the use of average switching intervals of 120 miles, total system length of 4000 miles, and one protection coaxial line for 10 regular lines will result in adequately small outage times. With this arrangement, service outage time because of individual line failures is significantly less than outage time caused by massive failures such as a man-made fracture of the buried cable. Modification of switching section length and spare-to-regular ratio will not reduce the latter outage time, which is controlling.

II. GENERAL SYSTEM DESCRIPTION

2.1 Switching section layout

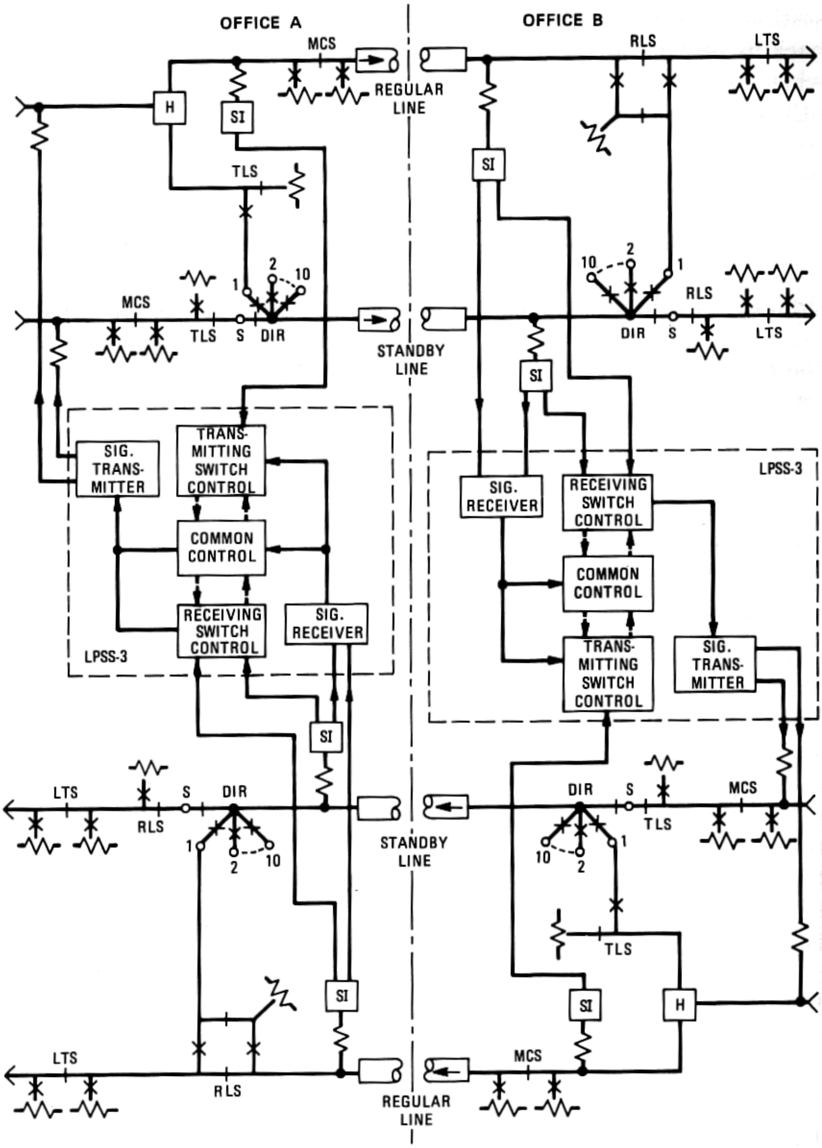
A broadband transmission system such as L5 is composed of two basic elements: the office or main station equipment and the repeatered line equipment. The main station equipment combines and separates the system message content and performs functions such as power feed, equalization, line switching, and fault location. The line equipment provides the transmission equipment required to connect main stations together. The line-protection switching system provides the backup protection to guarantee transmission between main stations when one of the regular lines fails. This is accomplished in L5 by utilizing the LPSS-3 equipment to control and cross-connect the main-station line-connecting equipment to the standby lines provided in the transmission medium. (In the coaxial cable, one unit coaxial is provided for standby or protection use in each direction of transmission, since L5 repeaters are unidirectional.)

Figure 1 is a diagram of an L5 line-switching section. It has been simplified to show only one regular line and the standby line for each direction of transmission. The protection equipment is located within the main stations at each end of the switching section (up to a maximum of 150 miles apart). Within the station, the protection equipment is divided into two basic locations. The line failure detectors and coaxial switches are located in the individual line bays, while the common switching equipment is in the LPSS-3 bay. The inputs to the detector circuits and the access of the interstation signaling commands are derived from the line-connecting circuits.

2.2 Detector circuits

The detector circuits are located in the switch initiator, Fig. 2. These include both transmitting and receiving detectors. The receiving detectors monitor the 42.880-MHz line pilot and the total system average power. If the pilot deviates more than 5 dB from nominal for more than 2.5 ms, a switch request is initiated (whether a switch takes place depends on many conditions and is discussed in detail later). If the average power exceeds its threshold, a switch request is issued, followed 50 ms later by a termination request (as before, the results of these requests depend on other conditions and are covered in detail later).

Transmitting detectors monitor the 42.880-MHz pilot. Each time that pilot exceeds the ±5-dB limit, a 50-ms signal is generated in the LPSS-3 transmitting switch-control circuits, preventing a line switch from taking place during that interval. The assumption is that the failure has occurred in a previous switching section (the probability of such is very high) and that section's protection-switching facility will remove the apparent problem. If both transmit and receive detectors in a switching section persist in the failed state beyond a reasonable switching interval, a switch is completed in that section to obtain the benefit of the independent standby line temperature pilot source.



H HYBRID TRANSFORMER
SI SWITCH INITIATOR
TLS TRANSMIT LINE SWITCH
RLS RECEIVE LINE SWITCH
MCS MESSAGE CUTOFF SWITCH
LTS LINE TERMINATE SWITCH
DIR DIRECTOR SWITCH

Fig. 1—L5 switching section.

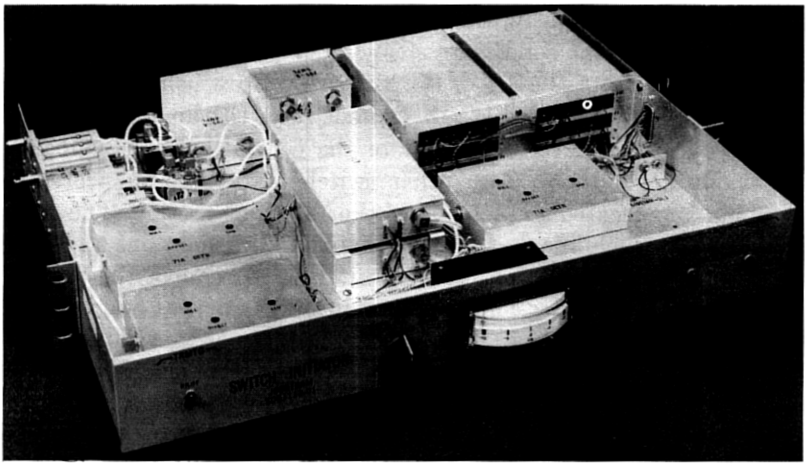


Fig. 2—Switch initiator.

2.3 Coaxial line switches

Two basic types of coaxial switches are used in the protection of L5. One is the director switch, a 1×11 solid-state switch without any control of its own; it is a slave to the switches with which it operates. One director is located at each end of the standby line (Fig. 1). Its common port is connected to the line equipment, and its 11 other ports connect to the line-connecting circuits via line switches. With no protection switch in force, the standby line-connecting circuits are connected to the standby line. With a protection switch in force, the directors route the message from the transmitting line-connecting circuit for the failed line, through the standby line, and on to the receiving line-connecting circuit for the regular line.

The remaining line switches are combinations of the basic solid-state T structure. This structure uses two series elements and a shunt element. In the pass condition, the series elements provide low loss and low distortion, while the shunt element has high loss. The stop condition is just the opposite, with the series elements providing high insertion loss to the signal and the shunt element acting as a short to ground for any signal passing the first series element. The line switches are composed of from two to four T's. In Fig. 1, the T's have been simplified to show only their normally released state. (The straight line across the path indicates the pass condition of a T, while the $\times$ indicates the stop condition.) The transmitting and receiving line switches connect the line-connecting circuits to the standby line via the director switches. As pointed out previously, the director switches are slaves to the line switches. In fact, the solid-state elements of the director switches are the final elements of the T's of the line switch to which they connect. Control of the director is by a dc current from the line switch to the director over the center conductor of the coaxial cable carrying the message between them. Two other switches are used in protection switching, one located at each end of the switching section. The transmitting end of each line, both regular and standby, contains a message cutoff switch. The function of this switch is to remove the message load from the line, under controlled conditions, to permit line measurement for special purposes—equalization and, if necessary under high noise conditions, fault location. The line-terminating switch is located at the receiving end of the section, immediately following the receiving line switch. Its function (detailed in Section 4.9) is to prevent the propagation of system overload conditions.

2.4 Circuit devices

High noise immunity and low power dissipation are more important characteristics than speed of operation in LPSS-3 circuitry. With this in mind, saturated logic integrated circuits have been used in LPSS-3 designs. Timing circuits and NAND logic functions are provided by a family of diode-transistor logic (DTL) circuits. Resistor-transistor logic (RTL) circuits are used in the signaling system to provide NOR and EXCLUSIVE OR logic in addition to clocked flip-flops for parallel-to-serial and serial-to-parallel conversion. Set-reset flip-flops from both families are used as memory elements throughout the system.

2.5 Office arrangements

There are two varieties of L5 offices from an LPSS-3 point of view: switching power-feed stations and terminal or terminal main stations. The physical arrangement of equipment in the LPSS-3 bay is the same for either type station, but the manner in which LPSS-3 interfaces with the line equipment differs. The LPSS-3 bay is mounted in the same aisle as its associated line bays. The reasons for choosing this approach are twofold: it was possible to design one universal arrangement that fits all applications, and the maintenance operation is simplified by always keeping functionally associated equipment in the same aisle alignment. In the terminal and terminal main stations, the LPSS-3 equipment is associated with a line section. In the switching power-feed station, the LPSS-3 equipment is associated with one direction of transmission in two line sections because the line bays are through-transmission units. No message administration is performed at these stations, so the optimum line arrangement is to have the receiving and transmitting circuits all in the same bay.

III. INTERSTATION SIGNALING

Protection switching operations require coordinated actions at diverse physical locations. Transfer of service from a regular to a standby line, for example, requires properly sequenced operation of line switches separated by up to 150 miles. This interstation coordination is maintained by the LPSS-3 signaling system, a self-contained subsystem that generates and detects digitally encoded carrier signals. The L5 system itself is the medium for transmittal of these signals; the associated frequency band is blocked at each switching main station to eliminate signaling interference among switching sections.

3.1 Encoding and error detection

Thirty-nine digital code words are in active use within the system; each has a specific purpose and consists of seven bits (e.g., 1100101). The digital rate is 2 kilobits per second. When signaling is not taking place, an alternating 1-0 pattern is transmitted to allow immediate alarming whenever interstation signaling continuity is lost. The seven-bit code word is preceded by two successive 1's to mark the beginning of the code word.

The transmitter generates an FSK signal with a 1 bit corresponding to energy at 68.76 MHz and a 0 bit corresponding to energy at 68.78 MHz. The receiver separates and independently detects the two channels. With no transmission or detection errors, the two channel outputs are complementary.

Error-free detection is of prime importance. With this in mind, the 39 code words have been chosen to have even parity to allow detection of errors resulting from the permutation of a single bit. Additional error detection is made possible through complementarity checking of the two channels for each bit of the code word. A transmission medium disturbance must simultaneously permute a 0 to a 1 in one channel and a 1 to a 0 in the other channel in at least two bit positions to cause an erroneous receiver output.

3.2 Automatic retransmission

Error detection at the receiver causes the incoming word to be rejected; no attempt is made at error correction. To prevent switching system lock-up under this condition, the transmitter automatically retransmits the code word every 15 ms until evidence is received that the command has been properly decoded at the remote location. The sequence is as follows: An *originating* command is transmitted to the remote station to cause the change of state of a line switch. With this action completed, the remote signaling transmitter generates an *answering* command that is routed back to the originating location. The proper decoding of the answering command stops the retransmission of the originating command. At the remote location, cessation of the incoming originating command is taken as evidence that the decoding of the answering command has been successful, and the retransmission of the answering command is stopped. Every signaling operation consists of a round-trip operation as described above to verify the completion of each originating command.

3.3 Signaling system test

Special provision has been made to allow in-service exercising of the signaling system to verify proper operation. Local or remote (via telemetry) manual action causes the transmitter to generate a TEST command, which is decoded at the far end of the switching section. A TEST RECEIVED command is then returned, completing the round trip and causing the signaling to return to idle. Failure of any involved circuitry along the route will cause a TEST FAIL lamp to illuminate at the originating point. This test can be performed at any time, even with a protection switch in effect, and checks most of the circuitry involved with signaling.

3.4 Switch signal routing

Each set of up to 11 coaxial lines in a given transmission direction has an associated signaling transmitter and an associated signaling receiver. At the transmitting end, a switch signal distribution unit controls the application of the switch signals to the transmitting coaxial lines. The signals are normally introduced on to all outgoing regular lines but, as explained in Section IV, the signals are sometimes temporarily introduced on to only the standby line or one regular line. The signaling receiver is electrically connected to only one line by the signaling receiver switch unit, which normally provides connection to the lowest-numbered "good" regular line. In this case, "good" implies the line is in service (e.g., not manually switched out of service) and not failed. Under certain conditions, the receiver is temporarily connected to the standby line.

IV. LPSS-3 OPERATIONS

In this section, we examine the operations of LPSS-3 in detail through the use of flow charts. Line switching, termination, and message cutoff operations are discussed after additional preliminary concepts are established.

4.1 Receiving control

A switching section consists of line switches and associated switching-control circuits at both the transmitting and receiving ends of the coaxial lines. The receiving LPSS-3 circuitry has primary control of all switching actions in that switching section. The transmitting LPSS-3 circuitry merely responds to directions from the receiving circuitry. Switching activity, manual or automatic, is never initiated at the transmitting end.

4.2 Priority

In LPSS-3 jargon, the term, "priority," is associated with internal LPSS-3 operations, which establish the right for an operation to take place. There are two types of priority. A failed regular coaxial line attempts to establish *switching priority* as a first step in executing an automatic switch. Any operation requiring the use of the signaling system must obtain *signaling priority* before being given access to the signaling transmitter. In both cases, priority avoids the system confusion that would otherwise result when independent, nearly simultaneous operations take place. The priority circuits in LPSS-3 (Fig. 3) are N-input, N-output logic circuits designed so that a driven in-

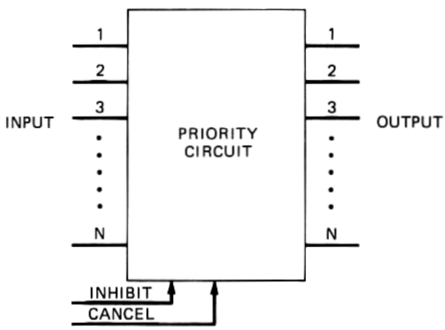


Fig. 3—Priority circuit. Only one output (corresponding to a driven input) may be operated regardless of the input time sequencing. Inhibit prevents new outputs, cancel inhibits new or established outputs.

put will result in the corresponding output going to the operated state. With multiple driven inputs, there will be only one operated output.

If the inhibit input is activated, no new output can become activated; if the cancel input is activated, any previously activated output is cancelled. Consider, for example, the case in which regular line No. 5 fails at approximately the same time as line No. 2. This will result in the No. 2 and No. 5 inputs of the switching priority circuit being driven. Depending on the input sequence, either the No. 2 or the No. 5 output will be driven, but both can never co-exist, even for short intervals. Thus, only one line will obtain clearance to establish a switch. At certain times (e.g., standby line failed) LPSS-3 will refuse to grant new switching priority, but will not defeat established priority. This causes the inhibit to be driven. Both new and established priority may be defeated by the cancel input. Lock normal (Section 4.8) is one such condition.

4.3 Automatic switch

The major steps in accomplishing an automatic transfer of service from a regular line to the standby line are diagrammed in Fig. 4. The line bay switch initiator detects a line failure and automatically causes an LPSS-3 switch request for that line. Switching priority will be established if LPSS-3 can provide switching. Action will stop if another line has switching priority, if the standby line is failed, or if lock normal is in effect. Signaling priority is established next. If another operation is in the process of using the signaling transmitter, another delay is encountered until the transmitter is available. At that time, a specific digital code word called the ID (there are 10 such code words, one for each regular line) is sent to the transmit end of the switching section over all regular lines in that direction. The ID is decoded by the signaling receiver, causing the appropriate transmit switch to operate. An LPSS-3 indication TSO (transmit switch operated) is illuminated. The message is now being introduced to both the regular and standby lines. Signaling priority is sought at the transmit end so that the answering command verifier may be sent back to the receiving end. This one command is used in common by all 10 lines. Receipt of the verifier is taken as evidence that the transmit switch has operated properly. The receive switch is operated, completing the switching sequence. An LPSS-3 indication OSA (out of service automatic) is activated.

The route of the verifier command from transmitting to receiving ends of the switching section deserves special attention. The verifier is

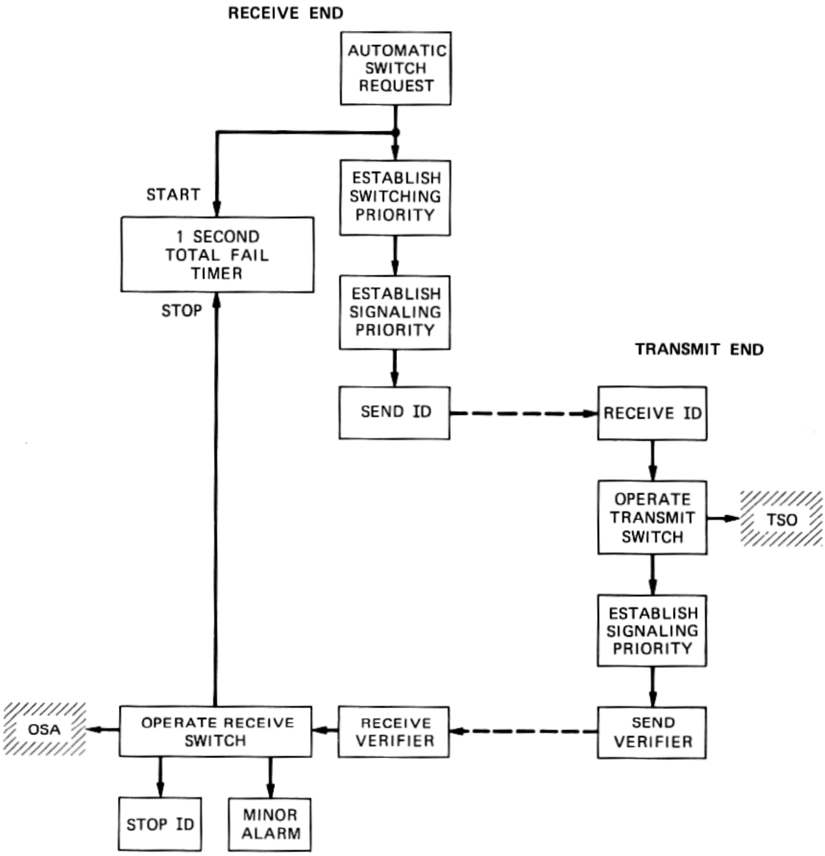


Fig. 4—Automatic line switch.

introduced into the transmit line-connecting circuit of the line to be switched. The verifier then propagates through the operated transmit switch on to the standby line. Meanwhile, at the same time that the ID was sent out from the receiving end, the signaling receiver was connected to the standby line in anticipation of the verifier returning from the transmit end of that line. This routing gives an added measure of confidence in the serviceability of the path to which the message is to be transferred. If the verifier is not successful in traversing this path, the receive switch will not operate.

Elapsed time from failure to switch complete is typically less than 12 milliseconds:

2.5 ms	Recognize pilot failure
2.2 ms	Signaling, ID (zero length system)
0.8 ms	ID propagation (150 miles)
3.0 ms	Delay at transmitting end
2.2 ms	Signaling, verifier (zero length system)
0.8 ms	Verifier propagation (150 miles)
0.3 ms	Delay at receiving end
11.8 ms	

Completion of an automatic switch results in a minor office alarm, since switching protection has been automatically used. If, for any reason, a switch request does not result in a completed automatic switch within 1 second, an LPSS-3 TF (total fail) indication and accompanying major office alarm result, since service is presumably lost.

4.4 Switch blocking

In many cases, the 42.880-MHz pilot that is detected for switch initiation traverses more than one switching section. The switch blocking feature prevents several tandem sections from switching on a single failure.

The temperature pilot level in the regular transmitting line-connecting circuits is detected by the switch initiator. When the pilot exceeds limits, the initiator so informs the LPSS-3 transmitting switch control circuitry. The transmitting switch is then inhibited from operation for the next 50 milliseconds. The receiving switch initiator circuits at the next office will also detect the failure, causing an ID to be sent back to the transmit end. Since a block is in effect in the transmit switch control circuitry, the transmit switch will not operate. Under this condition, the BLOCK ON command is sent back to the receive end of the switching section instead of the verifier. At the receive end, the apparently failed line is deprived of switching priority for 100 ms. During this interval, the switching system is free to execute other operations. After the 100-ms interval, the involved line is allowed to seek switching priority if it is still failed. Note that the section with the actual failure is allowed to switch, since its transmitting detector experiences no failure. Subsequent switching sections undergo a 12-ms failure (typical) at both transmitting and receiving detectors and try to switch, but are blocked. After the 100-ms lockout, the lines are no longer failed because of the completed switch in the failed section, and no further action results. If the switch does not complete in the failed section, the next section will switch after the 100-ms interval.

4.5 Automatic switch release

When a failed line that has an automatic switch in force returns to a nonfailed condition as indicated by the switch initiator, an automatic switch release sequence starts. Figure 5 summarizes the operation.

For the first 30 seconds after the line has returned to normal, no action takes place. If the line momentarily fails during this interval, the full 30-second count is restarted. After the line has been nonfailed for the full interval, the receiving switch is released. This transfers service back to the regular line, since the operated transmit switch did not remove the message from the regular line, but merely caused a dual feed of message on the regular and standby lines. The remaining steps are taken to clear the switching system for the next operation. Signaling priority is obtained to send the RELEASE command to the

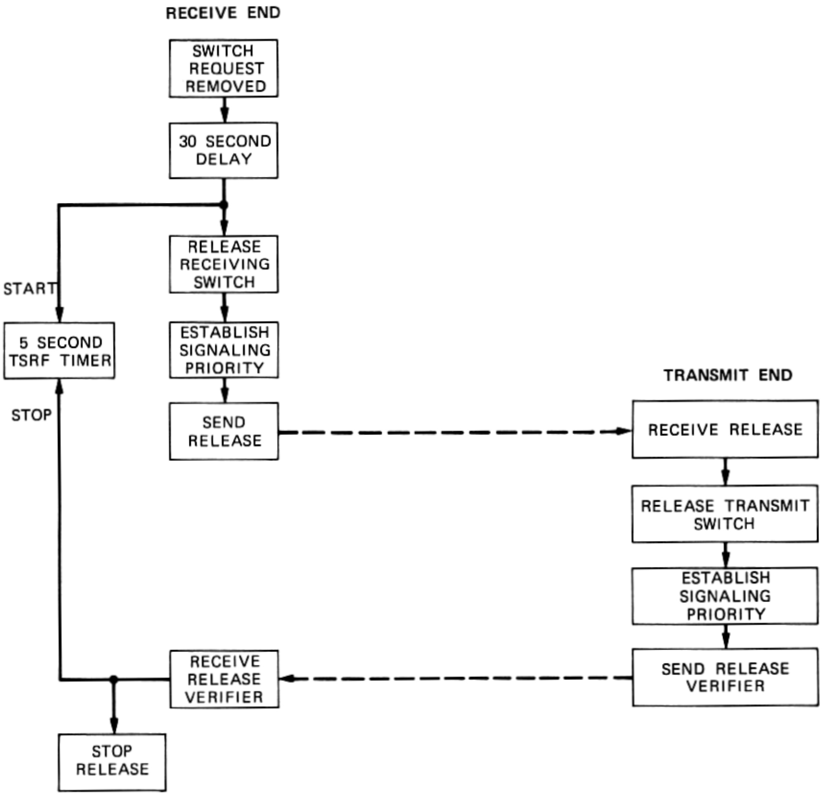


Fig. 5—Automatic switch release.

transmit end of the section, causing the transmitting switch to be released. The release verifier is then sent back to the receiving switch control circuitry to verify the successful release of the transmitting switch. If the release verifier fails to return within 5 seconds of the receiving switch being released, the transmit switch release fail (TSRF) indicator is activated, and the minor office alarm is sounded in the receiving office. With this condition in effect, the system will not attempt to establish another protection switch, since a transmitting switch may still be operated. The TSRF condition is cleared by the successful completion of a manual release (Section 4.7).

4.6 Manual switch

Manual switching capability is provided by LPSS-3 so that nonfailed regular L5 lines may be taken out of service for equalization, maintenance, or measurement. The steps taken to establish a manual switch are identical to those summarized in Fig. 4 for automatic switching, except that the action is started manually rather than automatically, the resulting indication is OSM (out of service manual), not OSA, and no office alarms result.

In general, manual operations on LPSS-3 override automatic operations. A manual switch may be executed on one line while another has an automatic switch in force. The manual switch initiation causes the established automatic switch to be released before the manual switch is executed. This capability allows operations personnel to control which of several failed lines is to be switched to the standby line. If the manual switching procedure is executed on a line that has an automatic switch in force, the control of the protection switch is made manual (OSA extinguishes, OSM lights), and the line switch will not release automatically after the failure clears.

4.7 Manual release

The release of a manual switch is identical to the automatic release sequence of Fig. 5 and Section 4.5, except that the action must be started manually and the 30-second delay is bypassed. If a manual switch on a nonfailed line is released with another regular line failed, an automatic switch on the failed line will result. The release of a manually switched line that is failed results in a transfer of control to the automatic mode (OSM extinguishes, OSA lights), but does not cause a release. A manual release may be performed at any time, not only when a manual switch is in effect. This allows operations personnel to clear the TSRF condition, should it occur (Section 4.5).

4.8 Lock normal and restoration lock normal

The lock normal condition is manually initiated to prevent the use of the standby line for service. This feature is used while the standby line is being equalized, for example. The essence of lock normal is that switching is inhibited. Restoration lock normal also prevents switching, but is intended for use when the standby line is being used to carry service from a failed facility that is not normally associated with that standby line. Unlike lock normal, restoration lock normal is activated and released from the restoration patch bay and not from the LPSS-3 bay.

Lock normal may be activated at any time that neither a manual switch nor restoration lock normal is in effect. Restoration lock normal is inhibited by a manual switch, lock normal, or a standby line termination (Section 4.9).

Activation of either lock normal or restoration lock normal results in the release of any automatic line switch that may be in force. Release of lock normal or restoration lock normal allows the failed line to again complete an automatic switch.

4.9 Line termination

The line termination capability of LPSS-3 provides a check against the propagation of overloads on the L5 lines. Each line has a terminate switch located on the output side of the receiving switches (Fig. 1). Each regular line terminate switch may be set in the manual or automatic mode. Under the normal automatic control, any terminate switch that is connected to an overloaded line by the receiving switch matrix is operated, thereby removing the overload from subsequent system components. As previously discussed, an overload on a regular line will cause an attempt to switch that line out of service. The automatic line termination will result only if the switching action (or lack of it) results in a persistent overload condition at the output of the receiving switch matrix. When the manual termination mode is selected, the particular terminate switch involved may be manually operated at any time that the terminate switch is connected to a failed line, where the failure may be due to either pilot deviation or system overload. *Automatic* terminations *result* when switching action cannot stop an *overload*, while *manual* terminations are *enabled* when switching action cannot remedy a *failure*, either pilot or overload.

4.10 Message cutoff

The L5 manual equalization procedure is accomplished out of service, with the message removed from the line facility. A message cutoff switch is therefore located in each transmit line connect panel. Since untimely operation of this switch while the particular line is in service would cause a service loss, activation of a regular line message cutoff switch is enabled only when the line is manually switched or manually terminated. The normal procedure for removal of the message from a regular line for equalization or measurement is to manually switch the line, then operate the message cutoff control. Enablement of the message cutoff feature for a manual termination is intended to allow the removal of an overload condition from a line to facilitate measurement of that line. Message cutoff capability for the standby line is also provided. Enablement of the feature is caused by lock normal or standby terminate.

Whenever the message cutoff feature is in force, none of the preconditions for message cutoff can be released. For example, if a regular line is manually switched and the message cutoff is activated, the line would be isolated at both transmitting and receiving ends. If the manual switch is inadvertently released, service would be lost. To prevent this, the manual release is inhibited while the message cutoff and manual switch conditions exist on the same regular line.

The steps taken for a regular line message cutoff operation are shown in Fig. 6. Provided one precondition is met when the control is activated, signaling priority is established and the appropriate command is sent to the transmitting end. The command is decoded, causing the operation of the message cutoff switch and the illumination of an indicator MCSO (message cutoff switch operated). Signaling priority is then sought to return the answering signal (message received) to the controlling receiving end of the switching section. When this command is decoded, the MCCO (message cutoff control operate) lamp for the involved line is illuminated, and the release of a manual switch or a manual termination on that line is inhibited.

Release of a message cutoff condition is also executed from the receiving end of the switching section. The message cutoff release operation is never inhibited and may, in fact, be exercised without a message cutoff in effect.

4.11 Pilot resupply

Switching activity often has a direct effect on the presence or absence of pilots on the L5 system. The most critical pilot is the 42.880-MHz temperature pilot. Resupply of the temperature pilot is always provided when that pilot is disrupted by switching, specifically for any regular line message cutoff and for a regular line termination

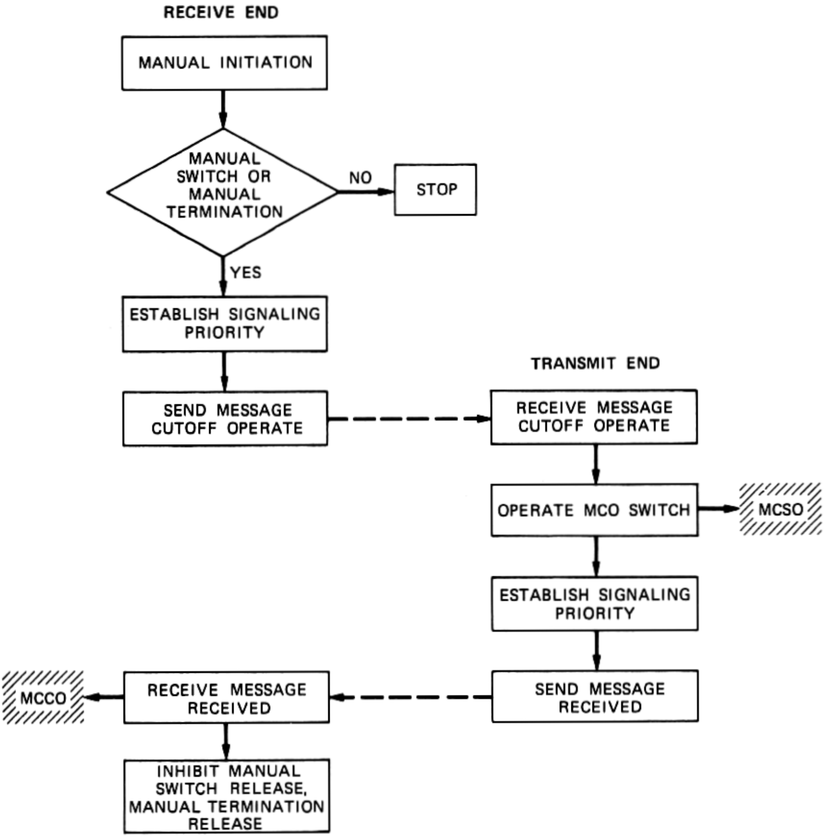


Fig. 6—Message cutoff operation.

at offices where the pilot is not blocked and reinserted in the line-connecting circuit. The temperature pilot is always blocked and reinserted on the standby line on the line side of the message cutoff switch. This eliminates the need for standby line temperature pilot reinsertion. The other three E3 equalization pilots are often passed through the office. Without special provision, these pilots would be lost in the transmitting switching section on the standby line each time a receiving section switch is completed. Because of the relatively high activity of such occurrences, the three E3 pilots on the standby line are reinserted whenever disrupted by receiving switching activity. Except for the 42.880-MHz temperature pilot, E3 pilots are not reinserted on the regular lines, since a line termination is the only means by which they are disrupted. The combination of the lack of necessity of constant presence of the three E3 pilots and the relative infrequency of line terminations allows this mode of operation.

4.12 Key line feature

One of the 10 regular lines in each direction of transmission may be designated the key line. The key line is different from all others in that a failure on the key line causes the release of an automatic switch on another line, so that the key line may be switched out of service automatically. The key line reacts as do the other lines in all other ways. The key line will not automatically overtake a manual switch, can itself be overtaken by manual action, and will not attempt to switch to a failed standby line. The circuit module with the key line feature is provided only if specifically ordered by the customer. When provided, the capability may be easily disabled by using a switch on the module or transferred from one line to another by simple module interchanging. Figure 7 illustrates the key-line-switching process. If switching priority is available when the key line fails, the line switch to the standby line is executed in the conventional manner. With switching priority unavailable, a release operation will be executed if the standby is not failed, no manual switch or lock normal is in effect, and another line has completed a line switch. When the release is complete, the key line is allowed to establish a line switch. Typical time for a key line switch with another line previously switched is 21 ms from time of failure to key line switch complete.

V. FUNCTIONAL DESCRIPTION

5.1 Subsystem functions

The LPSS-3 bay is illustrated in Fig. 8; one bay is required per coaxial cable end at each office.

Powering equipment is provided in the form of regulated dc-to-dc converters, fuse panels, and power alarm circuits. The converters provide regulated outputs of +25, +12, and +6 volts dc using the −24 volts dc office supply as a source. The various logic circuits throughout the bay have decentralized voltage regulators to provide the proper voltage levels for the integrated circuits.

Signaling circuitry is housed in four shelves; terminal strip and signaling receiver switch unit, switch signal distribution unit, signaling transmitter, and signaling receiver. These components contain all the high-frequency circuitry associated with the generation and distribu-

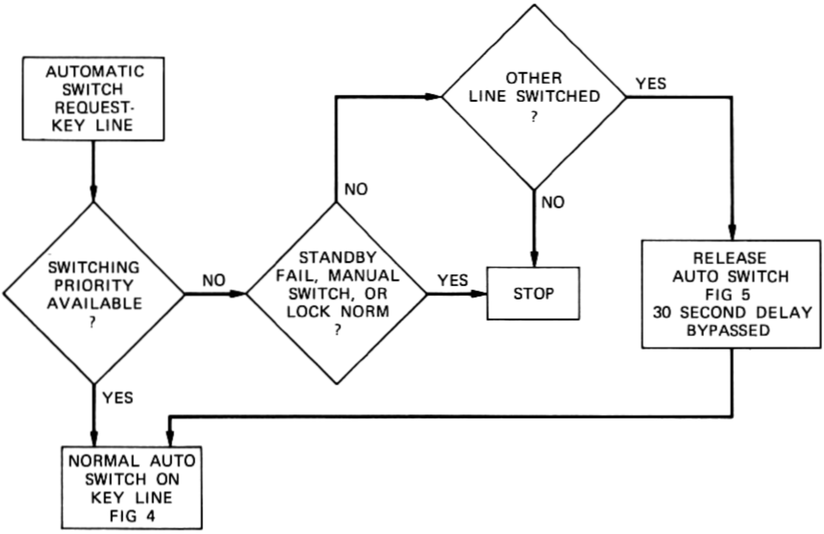


Fig. 7—Key line switch.

tion of the signaling commands and also contain modular logic circuits for the control of signaling.

The *indicator and control* panel provides a centralized input-output capability for routine switching activity. Section 5.2 provides additional discussion of this important panel and associated operations.

Per-line circuits are located on the three shelves directly below the indicator and control panel. The lowest of these three shelves is associated with receiving operations, the middle shelf is associated with transmitting operations, and the top shelf provides interfacing for both receiving and transmitting circuits with the indicator and control panel, the office alarms, and the telemetry systems. Whenever a new regular line pair is added to an existing route, a new working module is added to each of these shelves. Positions for lines not yet equipped are filled by special modules that allow proper switching operation for the equipped lines. Both the transmitting and receiving per-line modules have logic disable circuits with the associated control key and indicator on the module face plate. Activation of this feature prevents LPSS-3 from responding to the normal stimuli that cause automatic line-protection switching. The intended use is for cases in which automatic switching is to be prevented on a per-line basis for switch initiator maintenance or repair and for lines equipped but not yet in service.

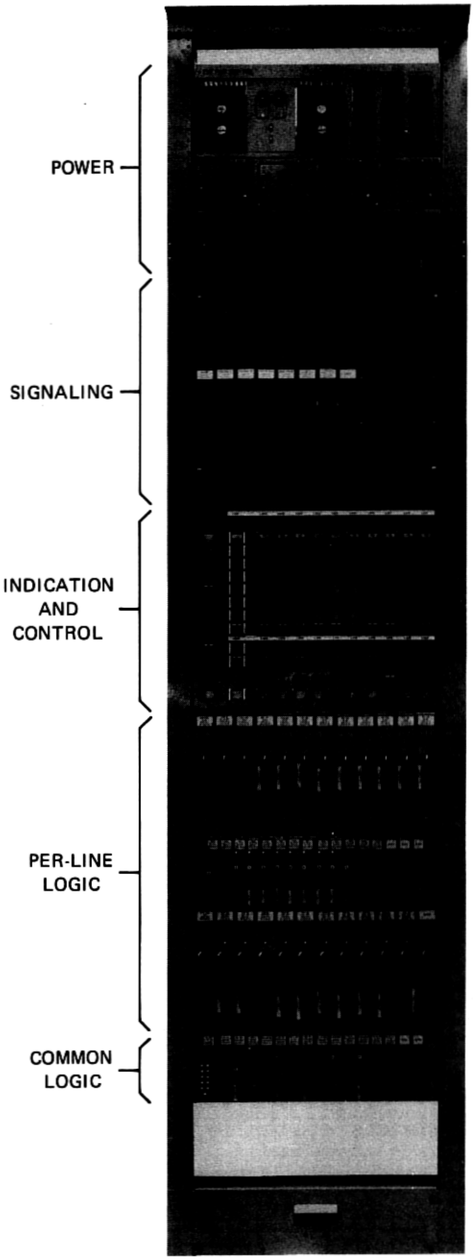


Fig. 8—LPSS-3 bay.

Common control circuitry is located in the bottom panel in LPSS-3. The coaxial line to be connected to the signaling receiver is selected by circuitry on the left-hand module. A set of 11 lamps provides visual indication of which line is being accessed. Other functions performed by the common control include switching priority, signaling priority, receive switch timing, release control, standby line receiving control, signaling retransmission, and signaling system test control.

5.2 *Indicator and control panel—description*

The indicator and control panel (Fig. 9) is the focal point of LPSS-3 manual switching activity and visual indications. The controls and indications are organized in rows and columns by functions. The top eight rows are associated with receiving functions, and the next two rows are associated with transmitting functions. The next-to-last row provides for signaling system control and visual displays. The bottom row is a set of lamp test keys that allow a rapid check of the lamps in the panel.

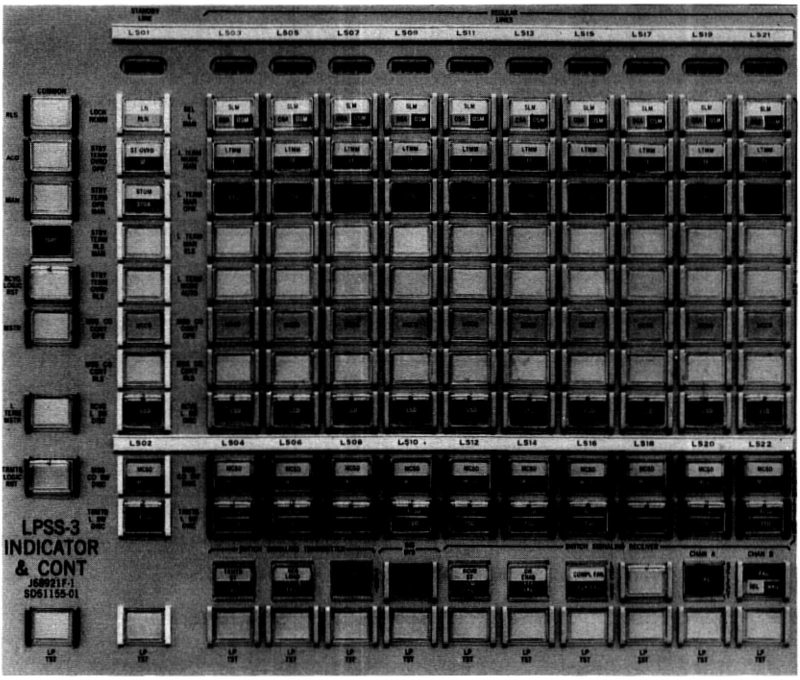


Fig. 9—Indicator and control panel.

The columns contain per-line functions, with the exception of the signaling system row and the left column, which provide common functions. The second column is associated with the standby line, while the next 10 identical columns are associated with the regular lines. Each position on the panel contains a key, a lamp, or a key and a lamp. The key designations are stamped on the panel to the left of the key position, with the exception of LP TST (lamp test), which is below the keys. The designations on the plastic covers are for the lamps under the covers. To illustrate this, the top position in the third column is the SEL L MAN key; the position also contains three distinct indicators, SLM, OSA, and OSM. The upper left position contains the RLS key but no indicator, while the fourth position in the left column contains the TSRF indication but no control key. The control identifications are not repeated for the regular lines. Table I defines the indicator and control panel abbreviations.

5.3 Indicator and control panel—switching functions

The indicators provide office personnel with information regarding the present state of the switching system, while the keys allow the state of line switching, termination, and message cutoff to be manually controlled, as discussed in Section IV. Disconnect keys and corresponding indicators are provided for receiving, transmitting, and message cutoff line switches (e.g., TRMTG L SW DISC and TLSD—third row from the bottom). When a disconnect key is activated, the associated indicator is illuminated and the corresponding line switch is forced to its normal nonoperated state. This allows LPSS-3 maintenance to be carried out without concern for loss of service resulting from improper line switch operation under abnormal switch control bay conditions, such as having circuit modules removed. A message register at the top of each per-line column indicates the number of completed line switches for each regular line and the number of failures for the standby line. These registers are nonresettable, so that the change in readings over a time span is an accurate measure of switching activity.

Two control panel design features reduce the probability of service loss because of accidental manual operations. Particularly sensitive controls, such as the switch disconnect keys, are mechanically inhibited from accidental operation. In addition, manual operations that could interrupt service require simultaneous operation of the involved key and a master key, or the sequential operation of two keys, depending upon the operation.

Table I — Indicator and control panel abbreviations

ACO	alarm cut off
CLK FAIL	clock fail
COM FAIL	command fail
COMPL FAIL	complement fail
DISC	disconnect
DR ENAB	decoder enable
L	line
LN	lock normal
LP TST	lamp test
LSD	line switch disconnect
LTMM	line terminate mode manual
LTO	line terminate operated
MAN	manual
MCCO	message cutoff control operated
MCSD	message cutoff switch disconnect
MCSO	message cutoff switch operated
MSTR	master
OSA	out of service automatic
OSM	out of service manual
OSC A FAIL	oscillator A fail
OVRD	override
PTY FAIL	parity fail
RCVG	receiving
RCVR ST	receiver start
REG LOAD	register load
RLN	restoration lock normal
RLS	release
RST	reset
SEL	select
SF	standby fail
SLM	select line manual
STBY	standby
STOA	standby terminate operate automatic
STOM	standby terminate operate manual
ST OVRD	standby terminate override
TERM	terminate
TF	total fail
TLSD	transmit switch disconnected
TRMTG	transmitting
TRMTR ST	transmitter start
TSO	transmit switch operated
TSRF	transmit switch release fail
WKG	working

5.4 Indicator and control panel—signaling functions

The signaling system control and indication appearances are in the next-to-last row. The first three positions are associated with the signaling transmitter. A normal operation of the transmitter results in a momentary flash of the two diagnostic lamps, TRMTR ST and REG LOAD. An alarm lamp is associated with each oscillator, one for each of the two signaling channels. An alarm lamp is also provided for the clock signal that times the pulsed high-frequency output of the transmitter.

The fourth position contains the signaling system test key and the TEST FAIL lamp. Depression of the key causes the signaling test operation to start; if the operation has not completed in 1 second, the TEST FAIL lamp is illuminated.

Positions 5, 6, and 7 in the signaling row are associated with the signaling receiver. The alarm lamp COM FAIL indicates that the receiver was unsuccessful in decoding the last command. COMPL FAIL and PTY FAIL indicate a command lacking those properties. Loss of timing ability in the receiver is indicated by CLK FAIL. RCVR ST and DR ENAB are the diagnostics for the receiver that flash momentarily with each normal operation. The last two positions indicate failures of either signaling channel and provide indication and control of which channel is being decoded by the receiver. The channel not being decoded is used for the complement check.

VI. SUMMARY AND CONCLUSION

The LPSS-3 switching system provides protection against service loss because of line failures and protection against overload propagation from any source. Line maintenance is aided through manual switching controls, including service transfer and message cutoff capabilities. One switch control bay provides switching capability for 10 regular lines and one standby line, both transmitting and receiving.

The LPSS-3 bay is modular in design and utilizes a PCM signaling system to maintain interstation switching coordination. Several design features, both electrical and mechanical, minimize the risk of inadvertent service loss from untimely or accidental control activation.