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L5 SYSTEM:

Signal Administration and Interconnection

By R. K. BATES and D. J. ZORN

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Each L5 coaxial line is capable of carrying three 3600-channel basic jumbogroup signals that are translated to and from the L5 line spectrum (3.124 to 60.556 MHz) through jumbogroup multiplex equipment. The L5 line signal also includes several line pilots and switching, maintenance, and reference signals. Administration of all these signals is performed by the L5 line connecting circuits, which vary in complexity with the type of main station they serve.

In addition to the circuits required to handle the various components of the L5 line spectrum, signal administration is also required at basic jumbogroup frequencies, before the jumbogroup multiplexing step, to allow interconnection to lower-order multiplex or other systems using the basic jumbogroup frequency format of 0.564 to 17.548 MHz. To perform this function, the basic jumbogroup trunk bay was developed and provides interconnection flexibility hitherto unavailable for direct connections to other long-haul systems, such as L4, LMD, TD, or TH radio, or L5 systems of another route.

I. INTRODUCTION

The L5 coaxial line is a transmission facility with a message capacity of three jumbogroups. These jumbogroups are placed on the line in the frequency format shown in Fig. 1. Each jumbogroup begins as a basic jumbogroup signal, formed by the mastergroup multiplex-2 (MMX-2) frequency-division multiplex or the basic jumbogroup trunk equipment. This basic jumbogroup consists of six 600-channel basic mastergroups and has a frequency assignment identical to that of the L4 line assignment.[1] Each of three 3600-channel basic jumbogroups is translated to the L5 line spectrum through the jumbogroup multiplex

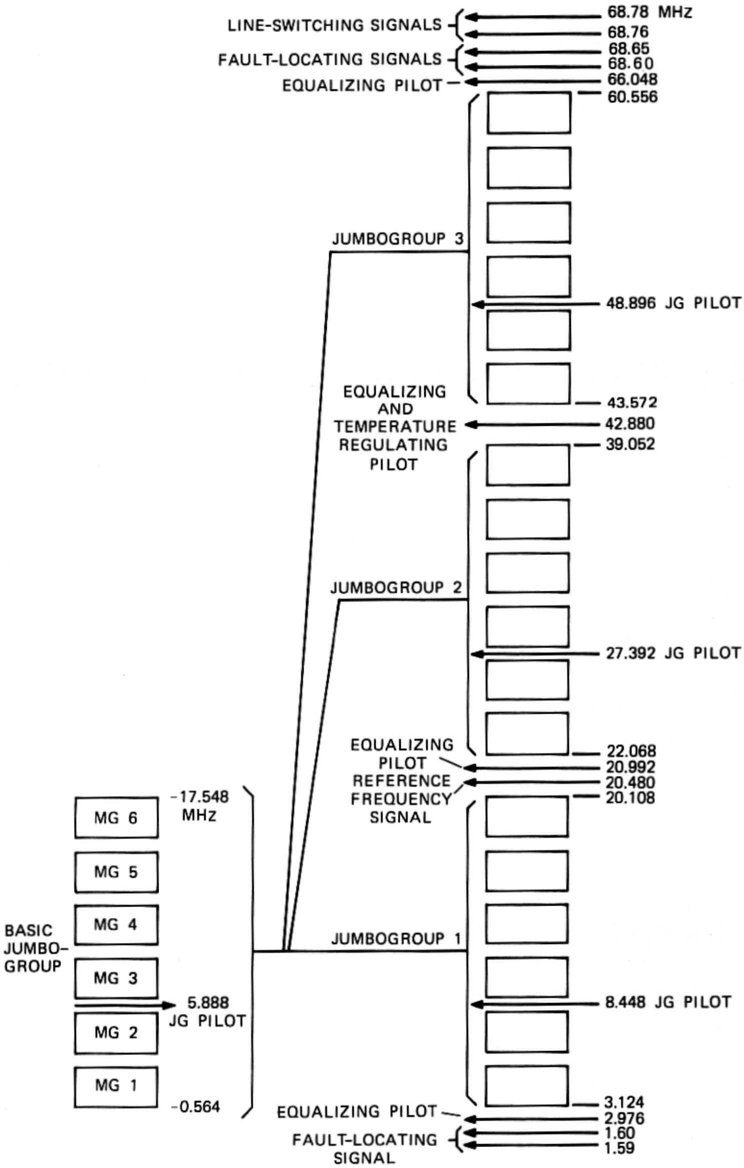


Fig. 1—Three-jumbogroup line frequency spectrum.

(JMX) frequency-division multiplex equipment[2] to form the 10,800-channel line signal.

In addition to the message band, Fig. 1 also shows the placement of several pilots used for the dynamic equalization and temperature regulation of the line,[3] switching signals required for the control of the line-protection switching system-3 (LPSS-3),[4] fault-locating signals used for line maintenance tests in the transmission surveillance system (TSS),[5] and a reference frequency signal used by the jumbogroup frequency supply (JFS).[6] Several rules and administrative functions must be applied to the message and other signals forming the L5 line spectrum which vary under specific situations. The line-connecting circuits described in Section II perform all of these functions.

In the evolution of the various long-haul systems such as the L-carrier and TD and TH radio systems, the need for more direct interconnection between these systems in large channel blocks became increasingly evident. Prior to the development of L5, the predominance of intersystem message interconnection was done on a basic mastergroup basis,* which requires the use of costly MMX terminals and mastergroup connectors. The need for a simpler and less expensive means of intersystem interconnection was recognized early in the L5 development, especially in view of the large 180-mastergroup capacity of this new system.

This need was met with a new bay, designated the basic jumbogroup trunk bay (BJGT), which allows interconnection of single- or multi-mastergroup signals in the basic jumbogroup spectrum; i.e., before the jumbogroup multiplexing step to the L5 spectrum through JMX equipment. Interconnections may be made directly to radio systems (using 3A wire line entrance links), L4 systems, L-carrier mastergroup digital (LMD) terminals, MMX-2 terminals, or other L5 systems. The BJGT circuits are covered in detail in Section III.

II. LINE-CONNECTING CIRCUITS

As mentioned in the introduction, the function of the line-connecting circuit is to process the L5 line signal in accordance with circuit requirements and certain administrative rules. Although many options are required to handle the various conditions that arise, there are only three basic line-connecting arrangements, one for power-feed main (PFM) stations, another for switching power-feed main (SPFM) stations and, finally, one to cover terminal stations or terminal main (TM) stations.†

All line-connecting equipment is located in the line transmit-receive bay. With the exception of line-connecting equipment, transmit-

* The basic mastergroup is the "U600" output of the L-type multiplex terminal (Ref. 7).
† The distinction among the four types of main stations is covered in Ref. 8.

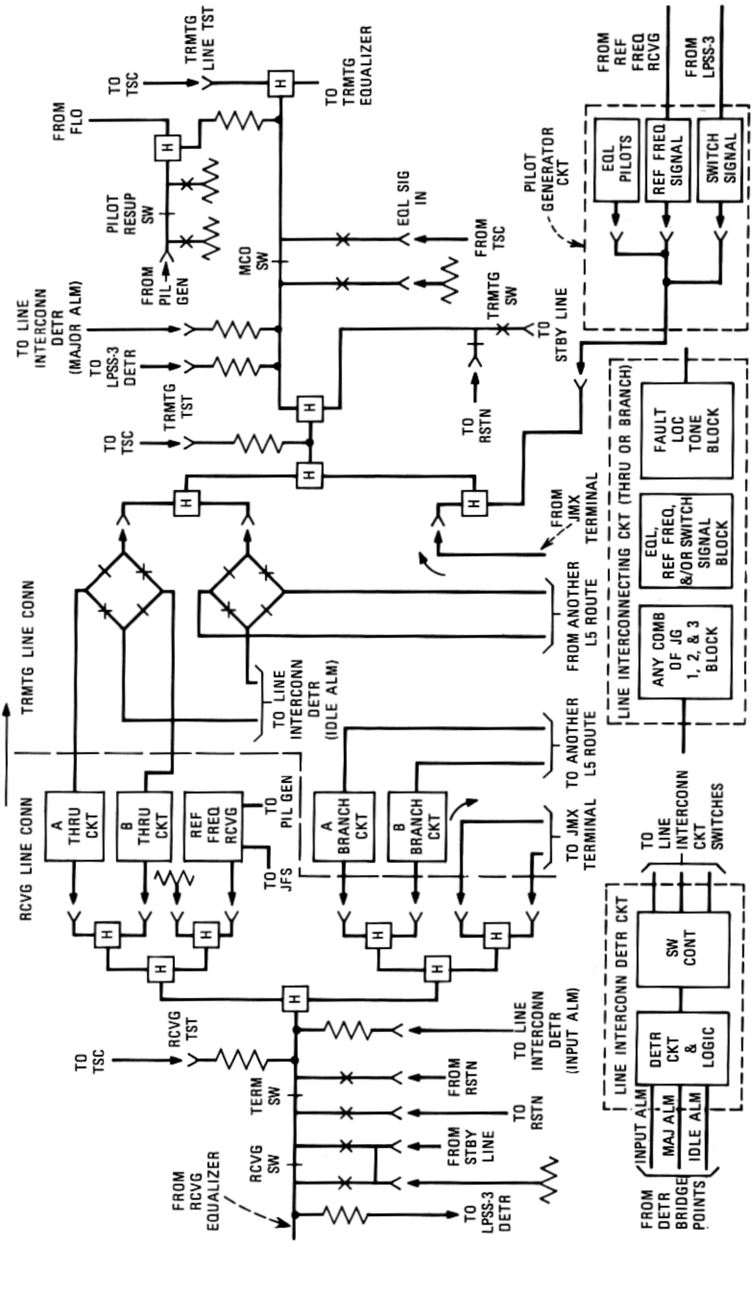


Fig. 2—Simplified block diagram of TM station L5 line-connecting circuits.

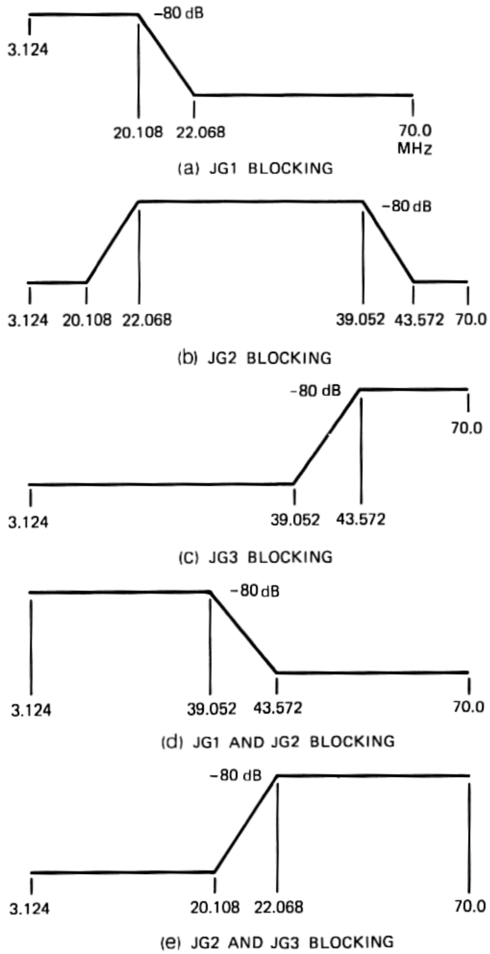


Fig. 3—Jumbogroup blocking filter requirements (frequency in MHz).

receive bays are virtually identical for all types of stations.[3,9] The line-connecting circuits are simplest at PFM stations where no signal processing is performed, and all message continues through the office. A pad and hybrid, for fault-location oscillator (FLO) access to the line, are the only apparatus in the line-connecting circuit. At SPFM stations, all message is again connected through; however, switching apparatus, filtering, and additional access to the transmission surveillance center (TSC) are added to the line-connecting circuits for system administration.

Terminal or TM stations require similar basic equipment units in the line-connecting circuits, but the terminal station options within that equipment are simpler. Each TM station transmit-receive bay requires six basic circuits to perform the line-connecting functions: the receiving line-connecting circuit, transmitting line-connecting circuit, pilot generator circuit, line-interconnecting circuits, line-interconnecting detector circuit, and, optionally, the line-branching circuit. These circuits are shown in the block diagram found in Fig. 2, and are discussed more thoroughly below.

The signal administration role of the line-connecting circuits in TM stations may be reduced to six major functions:

(*i*) *Message Administration:* Provides routing of the message signal for any combination of the three jumbogroups.

(*ii*) *Pilot Administration:* Introduces equalizing and temperature pilots to the line and provides pilot blocking when required.

(*iii*) *Switching Administration:* Provides line switches, introduces switching signals to the line, and provides detection access and signal blocking when required.

(*iv*) *Transmission Surveillance Administration:* Provides access to the line at strategic points for TSC analysis, and furnishes signal blocking when required.

(*v*) *Reference Frequency Signal Administration:* Introduces a reference frequency signal to the line, and provides signal blocking when required and a distribution network for circuits requiring the use of a reference frequency.

(*vi*) *Restoration Access:* Provides access to the regular transmitting and receiving lines for restoring L5 over other facilities and access to the standby transmitting and receiving lines for restoring other facilities over L5.

2.1 *Message administration*

The simplest of the TM station line-connecting circuits is required when all message passes through the office; i.e., no jumbogroups are branched to other L5 lines or are dropped to JMX equipment. In such a case, the line signal entering the line-connecting circuit from the receiving equalizer (Fig. 2) would only connect (via splitting hybrids) to the A and B THRU CKT modules at the output of the receiving line-connecting circuit. No message blocking filters are required in the THRU CKT modules for this application.*

* Although no message blocking filters are required, other circuitry may be required for other line-connecting functions at TM stations, as described below.

In the example shown in Fig. 2, the message administration is arranged to split the jumbogroup signals into three directions: one jumbogroup connected through, one branched, and one dropped to JMX. Assuming JG1 is connected through, JG2 branched, and JG3 dropped, blocking filters would be assigned to block JG2 and JG3 in the THRU CKT and JG1 and JG3 in the BRANCH CKT. No blocking filters are required in the drop circuit, since the JMX circuitry selects that jumbogroup for which it is equipped.

Any combination of jumbogroups can be passed in the through, branched, or dropped path. The blocking is accomplished through the use of five arrangements of filter designs developed for L5 use. The requirements for jumbogroup blocking are outlined in Fig. 3.* In all but jumbogroup 2 blocking, single high-pass or low-pass filter designs are used; however, in the case of jumbogroup 2, filters *d* and *e* are paralleled with a "split-apart" filter at the input and output of the paralleled pair. The advantage of split-apart filters, as compared to hybrids, allows better return loss with lower in-band loss.

A minimum of 80-dB out-of-band discrimination for each blocking arrangement is required. Return loss is approximately 26 dB (75 ohms). Maximum insertion loss is less than 4.0 dB.

2.2 *Pilot administration*

Four full-time pilots are required for the administration of the L5 line: 2.976, 20.992, 42.880, and 66.048 MHz. The 42.880-MHz pilot is used for dynamic equalization and temperature regulation as well as the switch initiation described below, whereas the remaining pilots are used for dynamic equalization only (see Fig. 1).

Ideally, it is desirable to maintain continuous-line pilot continuity throughout a frogging[8] section (approximately 800 miles). Two factors, however, preclude this possibility. When jumbogroup blocking filters are required at TM stations, one or more line pilots are attenuated to some degree because they fall within the attenuation region of the filters. In addition, the stability of each line pilot is adversely affected as the number increases of regulating repeaters or dynamic equalizers through which they must pass. Therefore, the pilots are blocked and reinserted at specific intervals.[3]

Since the administration of individual pilot blocking and reinsertion would be unwieldy, all pilots are blocked when any pilot or jumbogroup signal is blocked. Thus, rules for pilot blocking were established such

* A more detailed description of filter design techniques for L5 is given in Ref. 10.

that all pilots are blocked when either (*i*) jumbogroup blocking is provided or (*ii*) pilots will otherwise pass through more than four E3 equalizers.

Minimum requirements for the pilot band-elimination filters are as follows:

Frequency ($\pm 1/10^5$ from nominal)	Discrimination (dB)
2.976	50
20.992	50
42.880	80
66.048	50

Return loss requirements are 26 dB (75 ohms) and insertion loss is less than 4 dB.

2.3 Switching administration

The line-connecting circuits provide several functions for the administration of the LPSS-3. A bridged access point is provided at two locations, (*i*) on the line side of the receiving switch and (*ii*) on the line side of the transmitting-line switch hybrid (Fig. 2). The switch-initiator circuit monitors the 42.880-MHz pilot at these points for LPSS-3 operations.

Unlike L3 and L4, the L5 line switches are located within the line-connecting equipment to reduce the cable length in the through signal path. This was made possible through the use of parallel switch cabling, as opposed to the series arrangement in L3 and L4 systems.[4]

Two switches are provided in the receiving line-connecting circuits, designated the RCVG SW and the TERM SW. The RCVG SW furnishes access from the standby line when the associated regular line is out of service for any reason. This switch also provides a termination to the out-of-service line. The TERM SW is either automatically operated as a result of a line overload condition, thereby preventing noise propagation to other systems, or manually operated under certain abnormal line conditions.[4] The transmitting line-connecting circuit also includes two switches, the TRMTG SW and the MCO (message cutoff) SW. The TRMTG SW provides access to the standby line when the associated regular line is out of service. The MCO SW, also controlled by the LPSS-3, provides a means for opening the transmitting end of a regular line, primarily as an access for line equalization.

As indicated in Fig. 1, the line-switching signals occupy the bandwidth between 68.76 and 68.78 MHz. These signals are blocked in the line-interconnecting circuit at every switching station to prevent interference with switching functions between switching sections.

In addition to those switches described for the regular bay, the standby transmit-receive bay line-connecting circuits use a receiving and transmitting line director switch (see Fig. 4).* These switches provide inputs and outputs to the 10 regular lines for switched access to the standby line.

2.4 Transmission surveillance system administration

Each transmit-receive bay at TM and SPFM stations has six measurement points which can be accessed by the TSC for automated remote measurements of the L5 line status.[5] In addition to the measurement points, an input access is also provided in the transmitting line-connecting circuit so that out-of-service frequency characteristic measurements may be remotely performed by the TSC on a switching section. This point, equalizing signal in (EQL SIG IN), is also used for line equalization described in an earlier section.

Another transmission surveillance system administrative function performed by the line-connecting circuits is that of fault-locating signal blocking. Fault-locating signals at 1.59, 1.60, 68.6, and 68.65 MHz must be blocked at each switching section to avoid interference with fault-location routines in other switching sections. A high-pass filter blocks the low-frequency fault-locating tones a minimum of 50 dB. An alternate high-pass filter design will also block the 2.976-MHz equalizing pilot (Section 2.2) when required.

Since switching (Section 2.3) and fault-locating signals are always blocked at each switching station, a single filter accomplishes both functions. Because of the relative closeness of the 66.048 equalizing pilot—which is not always blocked concurrently with the switching and fault-locating signals—a low-pass filter was not a practicable design. Instead, a band-elimination filter with a minimum of 50 dB of suppression was developed for this purpose. In those cases where the 66.048-MHz pilot is also blocked (Section 2.2), a low-pass filter is furnished to block all signals above the message band.

2.5 Reference frequency signal administration

The JMX requires a very stable frequency for the synchronization of its carrier supply circuits. This frequency, 20.480 MHz, is generated by the Bell System Reference Frequency Standard (BSRFS) located at

* Figure 4 represents a simplified block diagram of the line-connecting circuits for a SPFM station. The circuitry is essentially similar to the TM station, with the exception of the line-interconnecting circuits, which are much less complicated.

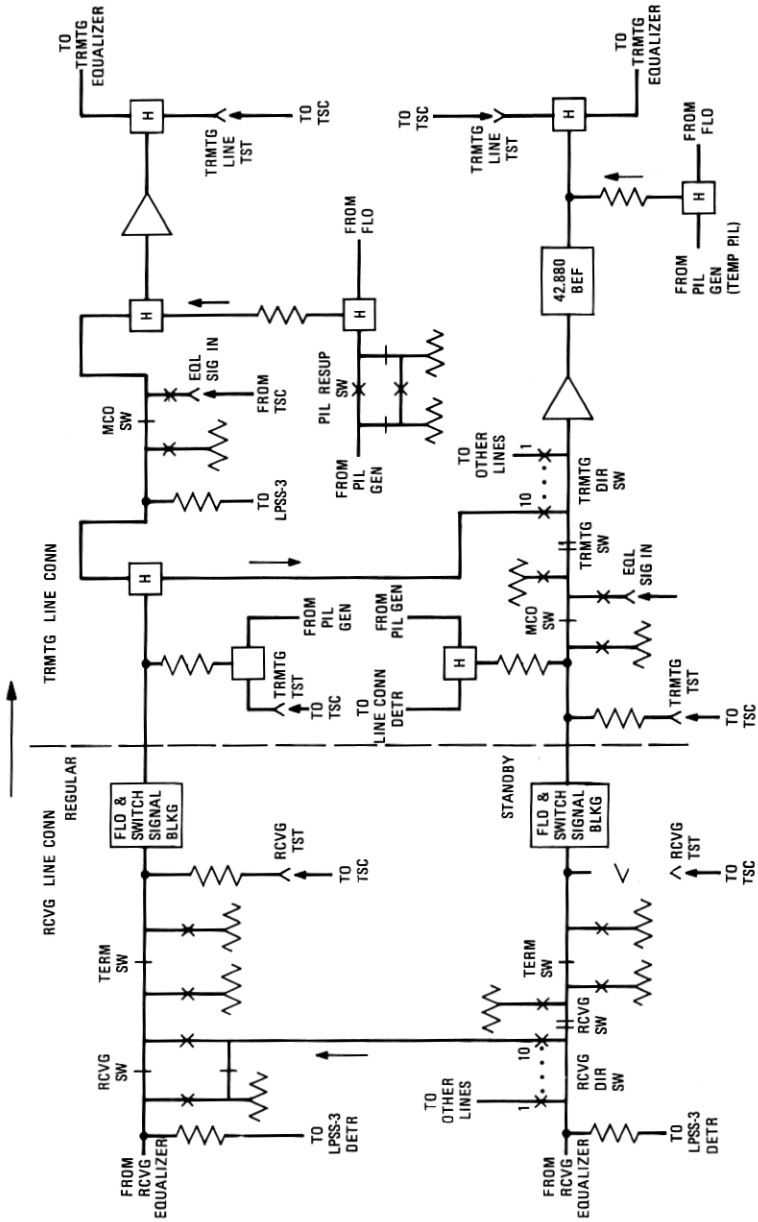


Fig. 4—Simplified block diagram of SPFM station line-connecting circuits.

Hillsboro, Mo.[6] The BSRFS will supply the reference frequency signal for all L5 systems, either directly, as in the case of the initial L5 Lillyville–Hillsboro route, or indirectly via other long-haul systems in subsequent routes.

Since the reference frequency signal is only required on the first regular working line and in only one direction, the line-connecting circuit administration of that signal is limited to that line. As in the case of the equalizing pilots, it is desirable to maintain the integrity of the reference signal throughout the route without restriction; however, if jumbogroup 1 or 2 is blocked in the through route, some attenuation of the signal occurs that requires that a 20.480-MHz band elimination filter be added to the receiving circuit of the through route to block the signal sufficiently to prevent its interfering with the reference signal reinserted in the transmitting line-connecting circuits of that route. In such cases, the 20.480 signal is bypassed around the through-line-connecting circuit, as described in the next paragraph. The characteristics of the filter are similar to those of the 20.992-MHz band-elimination filter described in Section 2.2.

In those offices requiring a reference signal for JMX terminals (via the JFS circuitry), for reinsertion in a through route or for insertion on an L5 branch route, a synchronizing receiving panel is provided. This panel, which accepts the entire line signal from a port in the receiving line-connecting splitting-hybrid circuit (Fig. 2), is furnished with a 20.480-MHz bandpass filter, amplifiers, an adjustable attenuator, and a hybrid tree that provides eight outputs for distribution as required. The bandpass filter provides a minimum of 80-dB discrimination approximately ±75 kHz from the reference frequency signal.

2.6 Restoration access

The line-connecting circuits provide access for message service restoration both for L5 restoration and for the restoration of other long-haul systems over standby L5 lines.

Access to restore a failed L5 facility is provided at each regular line at the TERM SW (Fig. 2) in the receiving line-connecting circuit and the TRMTG SW in the transmitting line-connecting circuit. These access points connect—via the restoration patch bay—to the standby L5 line of another facility or, through idle JMX terminals, to spare equipment of other long-haul facilities. Another access point is provided at the TERM SW to allow monitoring of the failed lines at the restoration patch bay. Similar points are provided with the standby line connecting equipment to allow direct restoration access to other failed L5 facilities or other types of long-haul systems through idle JMX equipment.

2.7 Line-interconnecting modules

During the early development of the L5 line-connecting circuits, it was recognized that considerable gain would be required at TM stations to offset the loss of the filters required for specific administrative functions. Since as many as 18 mastergroups may be served on each line-connecting circuit, redundancy was provided to assure reliability consistent with the overall L5 system. Although without redundancy the reliability of the amplifiers in isolation was considered adequate, the associated power, fusing, and related cabling associated with the active elements made redundancy necessary.

A beneficial byproduct of the redundancy in line-connecting circuits is the ability to provide all optional equipment in a modular package, thereby allowing in many cases in-service rearrangements of circuit assignments with less danger of service outages.

The line-interconnecting circuit modules are depicted in Fig. 2 as the *A* and *B* THRU CKT or *A* and *B* BRANCH CKT. The *A* and *B* paths terminate in a coaxial switch that provides the automatic protection for the *A* or *B* unit, whichever is serving the line. Jumbogroup pilots control the switch logic circuitry, which can be rather complex because of the wide number of options available in the line-connecting circuits. Three points of detection are required to satisfactorily implement the switching logic: (*i*) beyond the output of the switch to indicate a major alarm* at loss of pilot; (*ii*) at the output of the alternate leg of the switch to monitor the condition of the idle line-connecting circuit; and (*iii*) at the input of the modules to assure that the jumbogroup pilots are present at the proper level. Since as many as three sets of line-interconnecting modules may be required, i.e., one through circuit and two branch circuits, up to nine detector circuits are required as a maximum for monitoring the three jumbogroup pilots at the three points of detection. The simplest case, of course, is when all jumbogroups are "through," in which case only one jumbogroup pilot need be detected (at the three points) for the full message load.

Line-interconnecting circuits for the standby line are considerably simpler than the regular lines, since no jumbogroup blocking or synchronization administration is required. All intermediate stations are therefore "through routes" on the spare line for an entire frogging[8]

* All line-connecting alarms and status indications may be connected to remote alarm systems.

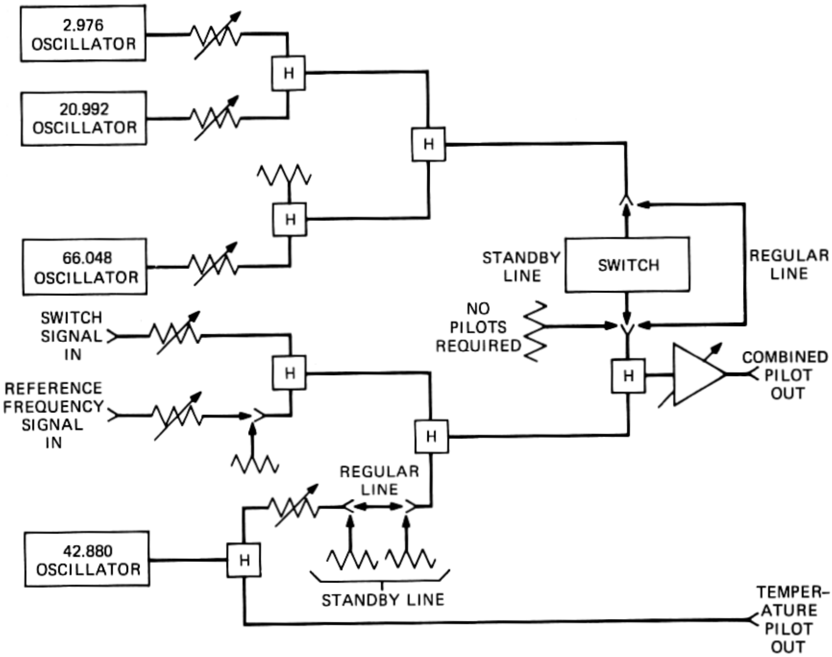


Fig. 5—Pilot generator circuit.

section. Although active circuitry is furnished with the standby line-connecting circuits, no automatic protection is required, inasmuch as service does not normally traverse an office on the standby line. An alarm is provided, however, to monitor continuity through the standby line-interconnecting module, and a spare module furnished may be manually patched in to replace it.

2.8 Pilot generator circuit

As shown in Fig. 2, the pilot generator circuit combines all the pilots and maintenance signals so that only one input port is required for their application to the transmitting line-connecting circuit. Several options within the generator, as noted in Fig. 5, are consistent with the various options required for line-connecting circuit administration.

The pilot-generator circuit provides the means for combining the switch signals from the LPSS-3 system, the reference signal from either the local standard or the receiving reference circuit (Section 2.5), and the four locally generated equalizing pilots. The four pilots are derived from free-running crystal oscillators mounted within the generator panel, which are designed to maintain a frequency accuracy of approximately one part in 10^6 per year under normal office temperature variations. Harmonic distortion is required to be at least -40 dB relative to the fundamental.

In all SPFM and TM stations,* the minimum options required are the 42.880-MHz oscillator and the switch signal combining circuits. The 42.880-MHz signal is required for regular lines to connect to the pilot resupply switch (Fig. 2), which automatically reinserts the pilot should (*i*) the pilot be lost in the through path, or (*ii*) the MCO switch be operated for equalization or TSC measurements, thereby sustaining temperature regulation of the line during out-of-service conditions. Since the 42.880-MHz pilot for standby lines is always blocked and reinserted (Fig. 4), the oscillator is always required with standby transmit-receive bay pilot generator panels.

Another feature provided for standby lines is a switch for reinserting three of the equalizing pilots. This switch is provided at SPFM and TM stations where pilots are not blocked in the through path. Since there may be times when the standby line is being used for protection for sustained periods, the stations with through pilots would otherwise be without dynamic equalization; thus, when a receiving line switch occurs, three equalizing pilots are automatically reinserted for the duration of the switch.

III. BASIC JUMBOGROUP TRUNK CIRCUITS

As discussed in the introduction, the basic jumbogroup trunk bay design is unique in long-haul system development in that it provides a direct standard interconnection between the JMX and certain multiplex terminals and systems of multi-mastergroup capacity. Any combination of contiguous mastergroups in the basic jumbogroup format may be interconnected from L4 lines, MMX-2 or LMD terminals, radio systems using 3A wire line entrance links, or other JMX terminals as indicated in Fig. 6a.

Actually, a maximum of four inputs per jumbogroup is available to the BJGT bay, so that a more practical arrangement with contiguous mastergroup assignments is shown in Fig. 6b. Through judicious planning of the mastergroup assignments, line engineering personnel can more economically engineer facilities; however, there will still be cases where some interconnecting systems will carry identically

* PFM stations are not furnished with pilot generator panels; however, a special portable, equalizing-pilot generator unit is available for installation and maintenance tests.

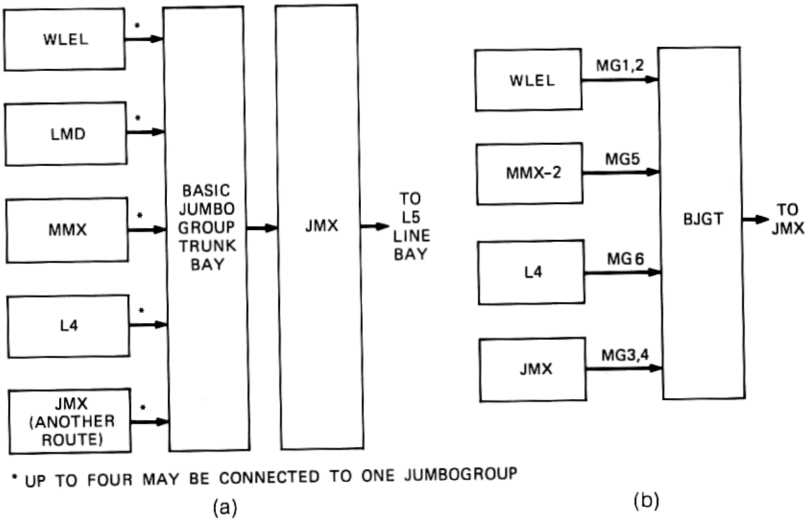


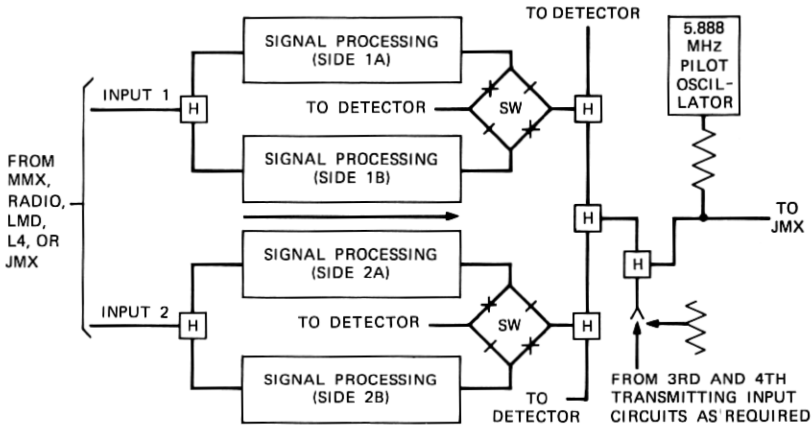
Fig. 6—(a) Basic jumbogroup trunk function. (b) Example of basic jumbogroup trunk arrangement with four-system input.

numbered mastergroups, thus requiring multiplex equipment to reassign their frequency allocations.

The BJGT bay is required whenever a JMX terminal is furnished, since it provides not only the transmitting and receiving trunk circuits for interconnecting the JMX to the various terminal arrangements, but also the 5.888-MHz jumbogroup pilot. The BJGT bay provides more than 250 different list structures to accommodate all combinations of contiguous mastergroups to associated systems.

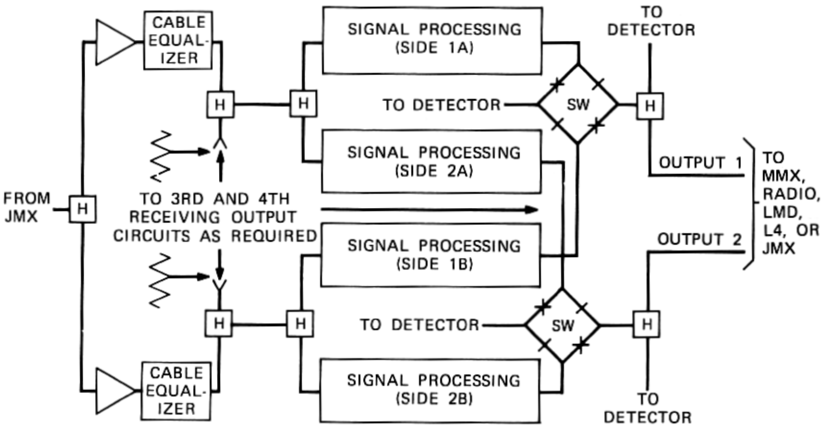
The transmitting and receiving trunk circuits consist of signal-processing panels and switch and logic panels. An example of the transmitting trunk circuit (transmitting to JMX), shown with a two-input circuit arrangement, is given in Fig. 7a. The signal from MMX, radio, LMD, L4, or another JMX terminal is split into two paths to identical, redundant signal processing circuits consisting of filters,* amplifiers, cable equalizers, and, in the case of L4, de-emphasis. Each processing circuit connects to a coaxial switch controlled by the logic circuitry in the switch and logic panel. The logic circuitry is activated when the mastergroup pilot level associated with the highest-numbered mastergroup in that particular circuit arrangement changes by a

* The filters are low-pass, high-pass combinations, similar to those used in L4 blocking and branching arrangements,[1] and are required for removing unwanted signals in the various spectra of interconnecting systems.



(a)

Fig. 7a—Transmitting basic jumbogroup trunk circuit.



(b)

Fig. 7b—Receiving basic jumbogroup trunk circuit.

predetermined amount. In addition, the logic circuitry provides local and remote alarming.

The transmitting trunk circuit also contains the 5.888-MHz basic jumbogroup pilot oscillator. The insertion of the jumbogroup pilot at the BJGT bay allows the interbay trunk to the JMX bay to be alarmed, thereby offering further protection against personnel error or cabling problems.

The receiving basic jumbogroup trunk circuits are very similar in design to the transmitting circuits, as shown in Fig. 7b; however, in addition, a 5.888-MHz band elimination filter is provided to prevent interference with connecting systems, and pre-emphasis is furnished when connecting to L4.

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