D2 ALARM CONTROL AND ORDER WIRE SYSTEM GENERAL DESCRIPTIVE INFORMATION

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1. GENERAL

A. Scope

1.01 This section describes the D2 alarm, control, and order wire system designed to aid the operating and servicing of microwave radio relay equipment.

B. Functions

1.02 The basic functions of the system include provisions for:

(a) Voice communication between all stations on a voice order wire.

(b) Two-way signaling on the order wire for:

(1) Key calling in the attended main station located near a test board from any unattended substation.

(2) Automatic transferral of alarm information to the main station from all unattended substations.

(3) Semiautomatic remote control of unattended equipment at substation from the attended main station.

1.03 The D2 alarm, control, and order wire system is an expanded version of the D1 alarm and control circuit and order wire circuit. The basic principles employed in the D1 and D2 system are identical. The main differences and improvements are as follows.

(a) An increase in the number of substations per system from 7 to 14.

(b) An increase in the number of orders from 5 to 11.

(c) Means for branching in four directions from the main station instead of the single main path limitation of D1.

(d) Means for adding spurs in two directions from any substation.

(e) Means for extending the order wire circuit but not the alarm and control features on a 2-wire basis from a maximum of two substations or on a 4-wire basis from any number of substations.

(f) Means for extending the order wire circuit but not the alarm and control features to a second D2 system.

The D1 and D2 systems have a limited degree of compatibility. That is a D2 substation may be used in a D1 system as an intermediate, junction, or terminal substation provided the combined D1 and D2 substations do not exceed a total of seven stations. If a D2 substation is provided to add spur paths, all D1 terminal substations must be modified to open their respective signaling loops during all signaling sequences. The compatibility features discussed are available on wiring option basis. The primary application of the D2 system is to TJ radio systems, but it may also be used with other short-haul radio systems including those of non-Western Electric manufacture such as Motorola MR20, Collings MW105, and Lenkurt 74A.

C. Description

1.04 Short-haul radio relay systems are primarily operated on an unattended basis at radio relay stations. It is necessary therefore, for efficient operation of these unattended stations to provide facilities for performing the functions outlined in 1.02.

1.05 Fig. 1 shows a typical geographical layout of a short-haul radio relay system and associated alarm, control, and order wire line circuit. As seen from Fig. 1, the branching and spur features of D2 allow a layout which conforms to actual physical layouts of short-haul radio systems better than the straight line configuration required in D1 systems.

Line Facilities

1.06 The 4-wire line for the order wire can be derived from the voice-frequency part of the radio system base band on a drop-and-reinsert basis, by means of split apart filters. However, 4-wire, physical, or carrier circuits or combinations of these may be used to provide the facilities between stations providing the over-all frequency response of the facilities used is relatively flat to 3 kc. In Fig. 1 branches 1 and 2 are shown from the main station as physical 4-wire paths to illustrate the above point.

Order Wire

1.07 The order wire is essentially a multistation private line circuit which provides a means of voice communication between all stations of a D2 system. Fig. 2 is a simplified schematic representing only the order wire circuit of branch 1 shown in Fig. 1. As indicated, two one-way line channels are looped together at the main station by a 5-arm talk-back bridge. Voice transmission from every station is through this bridge in the direction indicated by the arrows in Fig. 2.

1.08 The order wire shares line facilities and other transmission components with the signaling means. To prevent mutual interference, order wire talking is limited to periods when signaling is not taking place. However, even during nonsignaling periods, the signaling process requires that steady signal tone be present on the line facilities. Thus, speech and tone exist simultaneously during order wire use. The interfering effect of this signaling tone is rendered negligible by band elimination filters in the voice path of the single-frequency signaling receivers. This only slightly impairs the speech quality.

1.09 Voice signaling to a loudspeaker is employed for calling all substations but substations can signal the main station by either an automatic signaling process, or by loud speaker signaling.

1.10 The simple order wire path illustrated in Fig. 2 may branch out in different directions from the main station or junction stations through additional bridging arrangements. Voice communications on these branches, at the point where they are bridged, take the path illustrated. That is, the transmit and receive paths of these branches are also looped together by the main station talk-back bridge.

Signaling

1.11 The signaling means employed in the D2 system is basically the same process used in signaling on toll facilities. It is essentially 2-way inband signaling using standard E and M lead 4-wire type single-frequency signaling units. The information to be transmitted is coded in relay control circuits which in turn pulse the single-frequency signal normally supplied by the main station. The relay control circuits time the presence or absence of this tone to signal the stations. The relay control circuits decode these signals and perform the necessary operations to complete the transfer of information.

1.12 Fig. 3 is a simplified schematic of the signaling paths of branch 1 shown in Fig. 1. The 2-way signaling path is in the form of a party-line loop. In the idle condition of the signaling system, open on the M lead from the main station control circuit to the single-frequency transmitter results in 2600-cycle tone being applied to the ***outgoing*** transmission path. This tone traverses the ***outgoing*** path operating all substation single-frequency receivers bridged across this path. At terminal substations, the loop is normally closed and the signal tone returns toward the main station passing through each substation on the ***return*** path. The return tone operates the main station single-frequency receiver. At intermediate substations, this tone is controlled in two ways.

(a) By insertion of a 2600-cycle band elimination filter which opens the return path to the main station.

(b) By connection of a 2600-cycle bandpass filter which closes the tone reverting path to the main station.

At terminal substations both of these operations are accomplished by inserting or removing a single 2600-cycle bandpass filter. Substations signal the main station by opening the return path as discussed in (a) or by reverting pulses as discussed in (b). The main station signals substations by removing tone and by transmitting dial pulse coded digits. The transmission of alarm conditions from any substation to the main station involves a 2-way signaling process. The transmission of controls from the main station to any substation normally only requires signaling from the main stations to the substation. The signaling paths discussed are shown in Fig. 3.

1.13 In addition to the main signal path described, the D2 system provides for three more branches at the main station. Branches require one SF unit plus relay branching circuits for each additional branch. Main station branching circuits and associated SF units are arranged for common M lead signaling. That is, transmitted tone is applied or removed from all branch paths simultaneously. On the other hand, E lead signaling at the main station is not common. However, the branching circuits at the main station interpret branch path SF E lead indications in a manner such that to the main station all branch paths appear as one continuous loop of the form illustrated in Fig. 3.

1.14 In the D2 system, provisions are also made for a maximum of two additional spurs at any substation. This then is called a junction substation. An additional SF receiver is needed for each additional spur loop required. The SF receiver is bridged across the return path of each spur at the junction substation. The spur unit functions to bridge these spur return paths across the main path only during signaling intervals.

1.15 ***Alarms:*** An alarm condition at any substation, as shown in Fig. 3, interrupts the signal tone normally returned to the main station. This automatically directs the main station to form and send AC tone pulses to all substations. The substation initiating the alarm alert identifies itself by reverting one specific pulse in each of the first two digits sent. The specific pulses reverted correspond to a group and station code unique to the substation. A third, and possibly a fourth digit, are transmitted from the main station to scan the alarms of the substation initiating the alarm alert. For each alarm present, a specific pulse is reverted. The reception of reverted pulses at the main station causes lamps to be lighted which indicate the identified substation and the status of the substation alarms.

1.16 A maximum of 18 alarms may be assigned at each substation. Typical alarm conditions are Primary System Failure East, Engine-Alternator Failure, and Beacon Not Flashing. The alarm system is self-alarming in the event of failure of transmission facilities or substation equipment.

1.17 ***Controls:*** Remote-control signals (orders) are transmitted to a substation by operating keys at the main station which direct the relay control circuit to form and send digits in a manner similar to that described in main station response to an alarm alert. The first two digits select the desired station by sending the exact number of pulses required to select first the group and secondly the substation. Additional digits perform the desired order. Five orders are used to perform functions associated with operation of the alarm, control, and order wire circuit. These orders are Roll Call, Alarm Scan, Indication Scan, Close Loop, and Open Loop. The first three of these orders require pulse reverting by substations to transfer information back to the main station as ordered by the main station. A maximum of 11 additional orders are provided to control various operations at the radio station, such as starting the emergency engine-alternator.

D. Supplementary Information

1.18 The E2B SF unit, which is used in D2 systems, is covered in Section 975-246-100.

2. OPERATING PRINCIPLES

A. General

2.01 The alarm and control system is functionally distinct from the order wire, although there are common circuit and transmission aspects. For simplicity of explanation, in this part, the alarm and control system and order wire are treated as separate entities. Transmission aspects of the over-all system then follow.

B. Alarm and Control System

General

2.02 SF signaling circuits using E2B single-frequency signaling units provide the means of passing signals between stations of the alarm and control system. However, their use in this system departs from standard SF application to intertoll trunks in several important respects. For example, signaling on trunks is primarily between two points. Signaling on the D2 system is between one main station and up to 14 substations on a single line facility. To accommodate this arrangement, the main station will signal all substations on a broadcast basis, but substations in turn must signal the main station individually and sequentially. With this arrangement, the main station must identify or select, as the first step in the signaling process, one specific substation. In addition, unlike signaling on trunks, D2 signaling is not bidirectionally the same. That is, main station signals toward substations are in the form of dial pulse digits preceded and separated by a measured time interval of no tone; whereas substation signals toward the main station are in the form of reverted pulses. Finally, the end result of signaling on toll facilities is the establishment of a specific toll connection. When the talking condition is reached, the signal tone is removed. Speech and signal transmission are not normally required at the same time. In the D2 system, the end result of signaling is the transfer of alarm or control information. Order wire use is secondary to alarm and control system operation. To prevent speech interference with the signaling, order wire use is disabled by relay operation during signaling periods. Additional protection against false operation of the SF receivers, by speech or noise, is provided in the SF receivers.

Signaling Circuits

2.03 Fig. 4 illustrates the signal paths when branching at the main station and spur loops at a junction substation are required. As in the case illustrated by Fig. 3, the basis of signaling operation is closed tone loops in the idle condition. The 2600-cycle signal tone is controlled by common M lead control of each SF transmitter at the main station. In the idle condition, the common 2600-cycle signal frequency traverses each branch loop operating the substation receivers bridged across the outgoing paths. At terminal substations 1 and 4, of Fig. 4, the tone is returned to the main station by connecting the outgoing paths to the return paths through 2600-cycle bandpass filters. The returned tone operates the main station branch SF receivers. The individual SF E lead indications at this time are combined in parallel by the main station relay branching circuits. Since all are operated, the resultant E lead open indicates to the control circuit that the signal branch paths are closed. When the tone is removed by any substation on any branch, the associated main station SF receiver releases. Since the E lead indications are in parallel, the resultant E lead ground to the control circuit is interpreted as an open signal path. Ground on the E lead to the control circuit, at this time, results in the removal of tone from all branch paths. This releases all SF receivers in the system. At the main station, the relay branching circuit now combines the E lead indication in series to the control circuit for the remainder of the signaling period. Thus, subsequent operation of a branch path SF receiver opens the series E lead indication of ground to the control circuit signifying to the control circuit that the signal path is closed and tone is being returned.

2.04 On spur paths, as shown in Fig. 4, the signaling tone is returned to the junction substation at the spur path terminal substation. This tone operates the spur unit SF receiver bridged across the spur return path. Removal of tone by any substation on a spur path, as in originating an alarm alert, releases the spur unit SF receiver. The resultant E lead indication causes spur unit relay operation which removes the spur unit 2600-cycle band elimination filter. This bridges the spur loop return path to the main return path for the remainder of the signaling sequence. The spur relay circuit also disables the junction substation pulse reverting path, inserts the junction substation 2600-cycle band elimination filter, and holds the second spur band elimination filter in its normal position. Thus, at junction substations the spur relay circuit selects the path that requires attention and disables all others. In the event the main station initially removes the tone, the spur unit acts only to bridge the spur path to the main path for the remainder of the signaling sequence.

System Operation

2.05 Alarm and control system operation depends on an interchange of information between the relay circuits of the main and substations. The main station relay circuits consist of a control circuit, transfer circuit, alarm and station relay circuits, and branching circuits when required. Substation relay circuits include a control circuit, transfer circuit, alarm and order relay circuits, and at junction substations spur relay control circuits. The branching and spur circuits function as previously described. The major functional operations of the other relay circuits are identification, scanning, registration, and selection.

2.06 During a signaling sequence, these operations are performed in several steps. Each step is associated with the transmission of one or more coded digits from the main station. For example, whenever a change occurs in the status of substation alarms the main station control and transfer circuits act in conjunction with substation relay circuits to automatically identify first the group and secondly the substation initiating the alarm alert. A third and possibly a fourth digit are transmitted to scan the alarms at the identified substation. The scanning process involves receiving the alarm information and registering this information on display lamps at the main station. Alternatively, when orders are sent to a substation, the main station forms and transmits two coded digits which select first the group and secondly the specific substation. Only the substation receiving its group and station code responds to further digits. Additional steps depend upon the type of order. If the order is to control operations in the radio station, a single- or 2-digit order is sent that selects the desired order function by operating a specific order relay or by providing a momentary ground at that substation. Other types of orders, such as close loop, open loop, alarm scan, indication scan, and roll call may be sent. If the order is for the purpose of checking indications at the selected substation, the third digit selects a particular relay that transfers six contacts of the pulse counter from alarm leads to indication leads. A fourth digit is then sent to scan these leads resulting in registration of the indications at the main station on lamps. If the order is alarm scan, a third and possibly a fourth digit is used to scan the alarms of the selected substation. Orders are initiated by manually operating station and order keys which direct the main station relay circuits to form and send the necessary digits to complete the desired signaling sequence.

2.07 ***Identification and Scanning:*** These operations are performed by a pulse reverting technique in the following manner. In response to an alarm alert, the main station control circuit directs the removal of signal tone on all branch paths. The tone is removed for a timed interval to prepare all substations for subsequent reception of coded digits. After this specified time interval, the main station starts to pulse the tone. These pulses step relay pulse counters at each substation in synchronism with the main station pulse counter. When the pulse counter of the substation initiating the alarm reaches a group identifying position, a relay operates closing a pulse reverting path. This causes the next pulse to be reverted to the main station stopping the pulse generator, and also operates a group identifying relay which connects the output leads of the pulse counter to station relays. Substations, whose pulse counter did not stop at group identifying positions, are disabled during the remainder of the signaling sequence. After an interdigital interval of no tone, which restores all pulse counters to normal, a second digit is formed and transmitted by the main station. When the pulse counter of the substation initiating the alarm reaches a position unique to that station, the pulse reverting relay operates closing a pulse reverting path. The succeeding pulse is reverted to the main station operating a station relay and lamp. The station relay operated depends upon the position of the main station pulse counter when the reverted pulse is received. All enabled substations whose pulse counters did not stop on station identifying positions are disabled during the remainder of the signaling sequence. After another interdigital interval of no tone, which again restores all pulse counters to normal, the main station automatically forms and transmits a third digit which scans the first nine alarms at the identified substation. The substation pulse counter, as it advances, looks for ground or open as determined by alarm relay operation. For each alarm condition present, ground through the pulse counter momentarily closes the pulse reverting path so that the succeeding pulse is reverted. At the main station, each reverted pulse received from the output of the pulse counter operates an alarm relay. The alarm relay operated is a function of pulse counter position when the reverted pulse is received. For each alarm relay operated, a display lamp lights registering the alarm condition at the identified substation. A fourth digit may be required to scan a second group of nine additional alarms. After the required number of digits have been pulsed, the main station restores the system to normal by reapplying tone to all branch paths.

2.08 ***Selection:*** Two or more steps of selection are involved in the transmission of orders. The first two steps are used to gain access to the desired substation. Each substation is assigned to one of two possible groups. Each group and each substation within a group has a distinctive code number. In the process of transmitting an order, station key operation directs the main station to form and transmit a digit corresponding to the group code. This drives each substation pulse counter to the position corresponding to this code. When the pulse counters of the substation in the selected group stop at this position, relays operate that prepare these substations for the reception of the second or station selection digit. All substations in the other group are effectively disabled for the remainder of the signaling sequence since their pulse counters did not stop at their group code position. An interdigital interval of no tone restores all pulse counters to normal. Following this, the main station forms and transmits a second digit corresponding to the code of the desired substation. This drives all substation pulse counters, within the selected group, to the position corresponding to this code. When the pulse counter of the desired substation stops at this position, relays operate which prepare this substation for subsequent order digits. All other substations are effectively disabled, for the remainder of the signaling sequence, since their pulse counters did not stop at their station code position. All pulse counters are restored to normal during a second interdigital interval. If an order relay is to be operated after gaining station access, a third step of selection follows. This step is initiated by operating the desired order key at the main station. Operation of this key directs the main station relay circuits to form and send one or two coded digits corresponding to the desired order. If a single digit order is sent, the pulse counter of the selected station stops at a position corresponding to the order code sent. An order relay operates which provides operating ground to the circuit being controlled. This relay optionally supplies steady or momentary ground to the circuit being controlled. After all digits are sent from the main station, relay circuits direct the SF transmitters to resupply the idle signal tone to all branch paths.

2.09 When the main station is called into operation to identify or select a specific substation, as described, the main station SF transmitters are directed to remove tone for a timed interval. This ***off-hook*** or seizure period is recognized by all substations and serves as a signal to prepare all substations for the reception of pulses. The main station pulse generator forms DC dial pulses at the rate of 8 pulses per second. The DC pulses are converted to AC tone pulses by main station SF transmitters and sent to all substations. Substation SF receivers reconvert these tone pulses to DC pulses. The DC form of the pulses step substation relay pulse counters in synchronism with a main station pulse counter. The main station pulse counter is stepped one step behind substation pulse counters. The relay pulse counters are limited to ten steps or positions and since the main station is one step behind, 11 pulses are required to complete a full cycle of all pulse counters. A timed tone-off period is recognized by a substation as the interdigital interval. During this interval, all pulse counters are restored to normal. In addition, during this interval or at the start of the next digit the input and output leads of the pulse counters are switched as required to perform the next operation. After the required number of digits has been sent, the main station relay circuits direct the SF transmitters to reapply tone on all branch paths. This constitutes an ***on-hook*** or disconnect signal that causes all substations to return to normal. If an alarm arises at a substation during a signaling sequence, the substation stores this alarm until the on-hook condition occurs. At this time it interrupts the tone path to the main station and the alarm alert sequence is completed as previously described. This deliberate delay is introduced to prevent interference to any signaling sequence.

C. Order Wire

2.10 The order wire, as indicated in Fig. 2 in its simplest form, consists of two one-way line channels hooked together at the main station by a 5-arm talk-back resistance bridge. The receivers of the 4-wire telephone sets, provided at each station, are bridged across one of these line channels and the transmitters across the other. Voice transmission from any substation goes first to the main station where it is looped back by the talk-back bridge and then to all substation telephone receivers including the receiver of the station originating the transmission. The sidetone path is the same as the direct transmission path; therefore, to insure ample transmission volume without excessive sidetone the net loss between telephone transmitters and receivers is adjusted to 12db. The more complicated order wire arrangement, shown in Fig. 5, extends the simple order wire described to branches and spurs. The additional branches and spurs are joined to the basic order wire by resistance bridges and associated amplifiers. As in the simple order wire described, voice transmission from branch or spur substations is through the main station talk-back bridge. The net loss between all telephone transmitters and receivers of the order wire system is maintained at 12db.

2.11 At all substations, loudspeakers and associated monitor amplifiers are bridged across the telephone receivers. The loudspeakers are provided to permit voice calling between all stations of the order wire. However, normally substations call in the main station by a signaling process similar to the signaling process used in initiating an alarm alert. Loudspeaker volume may be controlled by adjusting the gain of its associated monitor amplifier. If a substation has a 2- or 4-wire extension, the monitor amplifier cannot be adjusted without changing the transmission level to the extension.

2.12 To prevent voice interference to signaling, order wire use is disabled by relay operation during pulsing. At substations this is accomplished by shorting telephone transmitters. At the main station, voice transmission is disabled by SF transmitter relay operation which opens and terminates the voice transmission path during pulsing. This prevents false operation of the SF signal receivers by voice during pulsing. However, even if transmitters were not disabled during signal pulsing, voice communications would be impossible because the 2600-cycle signal tone which is normally on the line during talking is increased 12db during pulsing. The interfering effects of these high-level pulses are too severe to allow order wire use.

2.13 In the event a line fault should interrupt a portion of the order wire, an auxiliary talk-back path may be enabled, at any substation, by operating the line bridging key. This provides a talk-back path for all substations separated from the main station by the line fault. This path bypasses the main station SF 2600-cycle band elimination filter and therefore would decrease the singing margin if the net loss between stations served by this auxiliary talk-back path is not increased. By introducing 6db loss in this bridge path and by bridging the receiving side of the bridge at a lower level point than the transmit side, the net loss between these stations is increased to 21.5db.

2.14 *Two- and 4-Wire Extensions:* The order wire, but not the alarm and control features, may be extended on a 2- or 4-wire basis from substations to other stations off the main order wire route. The receive path from 2- or 4-wire extensions is bridged to the return path to the main station by a 3-arm resistance bridge. The transmit path to the extension is a continuation of the receiver loudspeaker monitor path. Voice transmission from an extension to any order wire receiver is via the main station talk-back bridge. The net loss between extensions and substations is maintained at 12db. To insure adequate system singing margin, 2-wire extensions are limited to two per D2 system. To prevent voice interference to signaling, the receive paths from extensions are opened and terminated in both directions during pulsing.

2.15 *Back-to-back Extensions:* At terminal substations the order wire, but not the alarm and control features, may be extended to a second D2 system by continuing the two one-way line channels as shown in Fig. 5. If this feature is required, 2600-cycle band elimination filters are permanently placed in the return paths of the terminal substations to prevent intersystem signaling interference. Since the D2 systems interconnected in this manner form a loop closed at each end by the main station talk-back bridges, the F pads in the return paths of both terminal stations must be increased 6db over that normally required. This insures at least 12db intersystem return loss, and results in a 6db increase in net loss between intersystem stations. To further insure the minimum return loss, back-to-back extensions are limited to one per system.

2.16 *Singing Margin:* Because of the loop nature of the combined order and alarm circuit, pulse reverting paths of terminal substations, 2-wire extensions, and back-to-back extensions, potential sing paths are formed with the main station talk-back bridge. These paths are individually relatively high in return loss, but since they are in parallel their combined return loss may be low. It is for this reason that the number of 2-wire extensions and back-to-back extensions are limited as previously discussed, and the number of terminal stations per main station branch is limited to three. A more drastic curtailment of terminal stations per branch would be necessary if 2600-cycle complementary filters were not inserted in series with the potential sing paths formed by terminal substations pulse reverting paths. These filters, namely the main station SF band elimination filter and the substation pulse reverting path bandpass filter, insure adequate return loss per individual sing path.

D. Transmission Aspects of Over-all System

General

2.17 An over-all block schematic and transmission level diagram is shown in Fig. 5. As shown, this hypothetical system consists of one main station with two branches, one spur, one 2-wire extension, and a back-to-back extension connected to a second radio system. To illustrate the large range of D2 transmission adjustments, Fig. 5 and Table A are provided as transmission guides. A large number of other transmission adjustments are possible within the gain and loss capabilities of the system.

2.18 The 0db transmission level point is taken as any station telephone transmitter, or the testboard outlet of the main station talk-back bridge. The order wire receiving level is —12db at every station, except when a substation local talk-back path is enabled, in which case the receiving level is 9.5db lower. The 1000-cycle SF receiver input level is —12db. The normal 2600-cycle single-frequency tone level is 7db lower than the 1000-cycle level except during pulsing when this power is increased 12db. In the ensuing discussion, all levels are 1000-cycle levels unless otherwise stated.

Main Station Levels

2.19 At the main station, the SF signal transmitters, associated with each branch, are inserted at a —29db 1000-cycle level point. The normal signal power at this point is —36dbm. Each main station branch has a transmitting line amplifier and an associated line pad. If the required transmitting line level exceeds —29db, the line amplifier is adjusted to furnish the desired line level and the associated plug-in pad is a zero loss pad. If the required line level is less than —29db, the line amplifier position is bypassed and the associated pad is selected to furnish the desired line level. Each branch also has an associated receiving line amplifier or type 32A pad. If the received line level is lower than −12db, the line amplifier is adjusted to provide −12dbm at the input to the SF receiver. If the received line level is in excess of −12db, the line amplifier is replaced by a type 32A pad and proper plug-in- resistance to reduce the SF input level to −12db. The C amplifier is adjusted for a fixed 24db of gain to make up for the loss of the main station bridges. The A, C, E, and G pads are 5-db plug-in pads which fix the relation between the 1000- and 2600-cycle levels. The monitor amplifier is adjusted to provide adequate loudspeaker volume without allowing excessive accoustical feedback to the telephone transmitter when both the loudspeaker and telephone transmitters are enabled.

Substation Levels

2.20 At substations, three optional amplifiers and six plug-in pads are provided to adjust for transmitting line levels, SF input level, and return tone level.

2.21 Transmitting line level adjustments toward substations away from the main station are made with the A and E plug-in pads when the line facility requires a loss in excess of 3.5db between line out 1 jack and E pad out jack and with the A amplifier and E pad when the loss required is below 3.5db or when gain is required. In the first case, the A amplifier position is bypassed. In the second case, the A pad is a zero loss pad. If an A amplifier is provided, its gain should be adjusted to provide a minimum of —6dbm at A HYB out jack. This level is high enough to allow for bypassing the B amplifier position when an A amplifier is provided. Transmitting line level adjustments toward the main station or toward substations in the direction toward the main station are made with the F and D pads when the line facility requires a loss in excess of 3.5db between line out 2 jack and D pad out jack and with the D pad and C amplifier when the loss required is below 3.5db or when gain is required. In the first case, the C amplifier position is bypassed. In the second case, the F pad is a zero loss pad. In either case, the level at C amplifier out, the point at which the bridge key bridges the return transmission path, must be adjusted to be 3.5db lower than the level at A pad out jack.

2.22 If an A amplifier is not provided, a B amplifier must be provided to adjust the SF input level to —12db with a minimum B pad of 5db. The B pad partially isolates the low 2600-cycle input impedance of the SF unit thereby preventing excessive SF loading to the pulse reverting path. In addition, the B pad should take into consideration bridging loss of the pulse reverting path to the SF unit. This loss is 1.5db when a B amplifier is provided and 1db when the B amplifier position is bypassed.

2.23 The C pad is selected so that reverted 2600-cycle tone to the main station maintains the previously defined level relation between signal tone and 1000-cycle reference. Because of impedance deviation of filters at 2600 cycle, this value should be calculated rather than measured. The total 2600-cycle loss of the pulse reverting path when bridged across the return transmission path is 18db.

C Pad Value = (1000-cycle Level at B Amp Out) — (1000-cycle Level at Telephone Bridge Out) — 18

C Pad Value = —30 + B Pad Value — (1000-cycle Level at Telephone Bridge Out)

The solution of this equation must be positive. If it is not, the level at B amplifier out must be increased.

2.24 The telephone transmit level at a substation is adjusted to obtain the required 1000-cycle level at the telephone bridge out jack by adjusting the level potentiometer with 0.22-volt rms applied to the tips of the telephone jack.

2.25 At terminal substations, the E and F pads are not provided unless a back-to-back extension to a second D2 system is required.

Spur Unit Levels

2.26 One or two spurs may originate at any intermediate substation or at any terminal substation arranged for a back-to-back extension. When spurs are part of a substation installation, the substation is known as a junction substation. The transmission adjustments of a junction substation are the same as described in 2.21. The transmission level adjustments on the associated spur units are based on the levels established for the junction substation and on the transmit and receive spur line levels. If the required transmitting line level to both spurs is 6db or less than the established spur input level at equipment out jack, the E amplifier is not required and the transmitting line level to the first or second spur is adjusted by selecting the correct G and K pads. If the required transmitting line level to either spur is such as to require the E amplifier, the E amplifier is adjusted to supply the correct level to the transmitting spur line requiring the highest level. In the other spur, the transmitting line pad (G or K) is adjusted to supply the correct line level. In the receiving direction, a separate amplifier is provided in each spur to adjust the spur SF input level to —12db with a minimum J or M pad of 4db. The minimum pads partially isolate the low 2600-cycle SF input impedance. The H and L pads are adjusted to equate the spurs and main line levels at the inputs of the A bridge. The G amplifier is adjusted to 9.5db of gain to compensate for the loss in the A bridge.

Two- or 4-wire Extension Level

2.27 Transmission level adjustments on 2-wire extensions are made by plug-in pads (transmitting and receiving) in the 4-wire terminating set. The transmitting pad should be selected to provide 12db net loss between all order wire telephone transmitters and the extension receiver. This adjustment should be made with the D (monitor) amplifier set at maximum gain. The receiving pad should be selected to adjust 0db 1000-cycle level from the extension transmitter to be equal to the established 1000-cycle level at the telephone bridge out jack. If gain rather than loss is required for this latter adjustment, it may be provided external to D2 or the established 1000-cycle level may be lowered by increasing the F pad. If a 2- or 4-wire extension is required, the C amplifier must be provided to compensate for the 6db loss of the 3-arm resistance bridge which is needed to derive the extension. In addition, the C pad must be increased 6db over that normally required if an extension were not furnished. Transmission adjustments for 4-wire extensions must be made external to D2.

3. EQUIPMENT ELEMENTS

A. General

3.01 The three major divisions of equipment comprising the D2 alarm, control, and order wire system are the main station unit, the substation unit, and the spur unit. The main station unit is located at an alarm center, which is an attended office. It provides the equipment required to transmit orders to and receive alarms from a maximum of 14 substations. It also provides equipment for talking and monitoring on the order wire. A substation unit is located at each of the radio stations along a radio route. This unit provides the equipment required to receive orders from and transfer alarms to the main station. In addition, it provides the equipment required for talking and monitoring on the order wire. A spur unit may be located at any substation. It provides the equipment required to derive one or two spur loops as required.

B. Main Station Unit

3.02 As shown in Fig. 6, this unit consists of a number of individual panels mounted on 19-inch duct-type framework. The equipment occupies forty-two 1-3/4-inch mounting plate spaces. The framework shown is 7 feet high. It may be 9 or 11-1/2 feet long, as required. The main station bay is factory wired and it is furnished fully equipped for the maximum number of stations and alarms. Terminal strips are provided at the top of the bay from which all external connections are made to office battery and ground supplies, to office major and minor alarm circuits, to toll testboard, and to line facilities. All components are fixed in position except the E2B SF signaling units. These units are arranged for plug and socket mounting to facilitate removal for testing and maintenance.

3.03 The principle functional elements of the main station are shown in Fig. 8. The control and transfer circuit consists primarily of relays. The control circuit includes a relay pulse generator and a number of relays which indirectly control the operation of this generator. The control circuit is joined to the branch SF units by E and M leads. A separate Fig. 8B is required for each main station branch circuit. In addition, if more than one branch is required, E lead branching circuits are provided to combine the branch E lead indications. The transfer circuit consists of a relay pulse counter and a number of transfer relays which transfer the input and output leads of the pulse counter, as required, to complete various phases of the signaling sequence. Alarm and station relays are provided to register identified stations and alarms or indications. This information is displayed on lamps shown in Fig. 7. Fig. 7 also shows the station and order function keys, plus miscellaneous lamps, jacks, and keys required at the main station. Major and minor alarm leads from alarm relays, control circuit relays, and auxiliary relays connect to office alarm circuits, as required.

3.04 An additional jack panel, not shown, must be provided if more than one branch originates at the main station. This panel includes the transmission jacks indicated in Fig. 8B for branches 2, 3, and 4.

3.05 If the main station is located at a radio station and if it is desired to alarm and control this radio station, it may be done on a dc basis without providing a substation unit. This feature is available by providing a local radio alarm circuit per SD-50025-01. This unit is not an integral part of the D2 system, and from a signaling point of view, its operation is independent of D2 system operation. However, mounting space is provided at the main station for the relays, alarm and indicating lamps, and the order keys associated with this circuit. In addition, SD-50025-01 provides a transmission panel, which essentially duplicates the transmission arrangement of a substation, that may be used to derive a 4-wire order wire appearance at the radio bay location. This unit is wired in series with the main order wire transmission path and thus in effect from a transmission point of view, is the near end substation.

3.06 A transistorized 2600-cycle signal frequency supply is provided at each main station unit. It supplies a maximum of four SF transmitters. Normal signal power at the output of the SF transmitter is —36dbm. A plug-in pad permits adjusting the order wire transmission level in relation to the fixed signal frequency level at the output of the SF transmitter.

3.07 The order wire talking and monitoring circuit consists of three 5-way resistance bridges, a telephone set circuit, two amplifiers, and a loudspeaker. The A bridge provides a 2-wire extension of the order wire to the toll testboard in addition to the main station unit 4-wire telephone appearance. The B and C bridges provide the necessary bridging arrangements required to extend the order wire when more than one main station branch is required. C amplifier is provided to adjust the receive transmission level to —12dbm at jack "bridge out 3". The loudspeaker may be turned on or off with a key as desired, and in addition, it is automatically enabled whenever a line-open condition occurs. This latter feature insures that any substation not separated from the main station by a line fault will still be able to call in the main station even though the normal means of calling in the main station is disabled.

C. Substation Unit

3.08 As shown in Fig. 9, the substation unit consists of apparatus mounted on a 14-1/4- by 19-inch panel and box assembly adopted for mounting on 19- or 23-inch framework. The unit is equipped with slide assemblies to allow single side maintenance from the front of the bay.

3.09 When the substation unit is used in conjunction with TJ radio equipment, it is mounted on the TJ auxiliary bay. The substation is powered by rectifiers located on the TJ auxiliary bay, but it may be powered by office battery, when available. All external connections are made througn plug-ended cables, provided by the auxiliary bay to sockets mounted on the substation unit. Through the plugs, the external leads run either directly to associated units on the auxiliary bay such as rectifiers and diversity switches or to terminal strips at the top of the bay from which connections are made, as required, to radio failure alarms, external alarm sensing equipment, external equipment requiring orders, office alarm circuits, external speaker, 2- or 4-wire extensions, transmitting and receiving lines, and to the first and second spurs. Space is provided on the auxiliary bay for a 4-wire terminating set if a 2-wire extension is required.

3.10 When the substation unit is used with other than TJ radio equipment, a connection panel consisting of terminal strips is provided in addition to the substation unit. The connection panel is factory wired through plug and socket arrangements to the substation unit. The connection panel and substation unit are mounted on mounting bars to keep the two parts together for handling. They occupy ten 1-3/4-inch mounting plate spaces on a 19-inch duct-type framework. All external connections, as described in 3.09, are made from terminals on the connecting panel.

3.11 Substation circuits have options that differ according to locations of the unit in the system. That is, since signaling is on a selective basis, each substation is wired to respond to a different number code. In addition, substations 1 through 7 are wired to respond to group 1 code; substations 8 through 14 are wired to respond to group 2 code. Options are also provided to enable substation use as an intermediate, junction, or terminal substation. Finally wiring and equipment options provide for adding 2- or 4-wire extensions and for back-to-back extensions at terminal substations.

3.12 The principal functional elements of the substation are shown in Fig. 10. The control and transfer circuits consist primarily of relays. The control circuit connects to an SF receiver by an E lead. The transfer circuit includes a relay pulse counter and a number of transfer relays which switch the input and output leads of the pulse counter as directed by main station operation. In addition, the substation unit provides 18 alarm relays, 5 order relays, a major and a minor alarm relay, plus miscellaneous lamps and keys as shown in Fig. 9. Transmission apparatus includes four V3 plug-in amplifiers and six plug-in pads by which transmission level adjustments are made to the associated line facilities, the substation SF unit, the substation pulse reverting path, and the substation loudspeaker. A hybrid is provided to derive relatively low loss transmission paths to the SF receiver and pulse reverting circuit and to the bridge key circuit without incurring a large loss to the through transmission path. The return transmission path includes a 2600-cycle band elimination filter, a telephone bridge which provides an outlet for connection of the telephone transmitter to the line, and a bridge key which enables a local talk-back path. The pulse reverting path contains a 2600-cycle bandpass filter. A loudspeaker is provided for monitoring purposes with options for connecting a second loudspeaker remote from the substation unit.

D. Spur Unit

3.13 The spur unit, as illustrated in Fig. 11, consists of a frame, chassis, and box assembly that has provisions for mounting one or two spur panels, as required. The spur unit is the same size as the substation unit, and it too is equipped with slide assemblies to allow single side maintenance. It has the same mounting features as the substation unit, but mounting space must be provided. One or two spur loops may be provided by a single spur unit at intermediate or at terminal stations arranged for back-to-back operation. All external connections, to the spur unit, are made by a plug-ended cable which connects at one end to either of the terminal strip panels discussed in 3.09 and 3.10 and at the other end to a socket mounted on the box assembly. This socket is wired by cable to two plugs which in turn connect to sockets mounted on the back of the spur unit chassis. These sockets are wired by cable to two more sockets mounted on top of the chassis. The first and second spur panels connect to these sockets by plug-ended cables. If the second spur panel is not required, a bypass plug is inserted in the second spur socket. The external connections include control and transmission leads from the substation unit, power leads from the substation unit, and transmission leads for connecting to spur line facilities.

3.14 The principal functional elements of the first and second spur panels are shown in Fig. 12. The relay circuits consist of basic relays which operate under control of the substation control circuit and the spur SF units. Transmission apparatus for the first spur includes three V3 amplifiers and three plug-in pads by which transmission level adjustments are made to the substation unit, to the spur lines, and to the spur SF units. Three resistance bridges are provided to derive the spur loops. If the second spur is not required, one outlet of each bridge is terminated in 600 ohms. The second spur panel includes one V3 amplifier and three plug-in pads by which the same adjustments indicated for the first spur are made. The first and second spur have 2600-cycle band elimination filters in the spur return transmission paths to the main station.

4. METHOD OF OPERATION

A. General

4.01 This part describes the method of operation of the alarm and control signaling. Operation of the order wire requires no detailed explanation except for the process of signaling the main station from a substation for service calls on the order wire, which is essentially the same as alarm signaling and therefore is covered herein.

4.02 For purposes of description, the following distinction is made. Operations in which the action of the control and transfer circuit is initiated by depressing keys at the main station are described in ***B. Orders.*** Operations in which control and transfer circuit action is initiated automatically are described in ***C. Automatic Identification and Scanning.*** The first category includes not only functions that are purely for the purpose of remote control from the main station, but also those that are for the purpose of checking trouble or supervisory indications. The second category covers all operations that begin with interruption of the alarm loop, and includes detection of a change in status of the individual alarms at a remote station, a fault in the line facilities or substation circuits, and signaling for service calls on the order wire. Table B shows the alarm and control features and the operational characteristics of each.

B. Orders

4.03 The operation of two keys is required to send any order. The first key is associated with the gaining access to the wanted station, the second with a particular order function.

Gaining Station Access (First and Second Digit)

4.04 The first step in transmitting an order to a particular substation is gaining access to the station; that is, making the selected substation responsive to further signals, while at the same time preventing all other stations from responding by locking them out. An exception to this procedure is the roll call, which is performed by signaling all substations within a group simultaneously, as discussed under Roll Call. Except for this special case, the first two digits of an order are used to give station access.

4.05 To gain access to a particular substation the corresponding station key is operated. This results in the main station removing tone for a timed interval as a seizure signal, which prepares all substations for reception and counting of pulses. Then, two digits consisting of a variable number of tone pulses, separated by an interdigit interval of no tone, are transmitted. The first digit is a group code and consists of either two or four pulses corresponding to group 1 or group 2 codes, respectively. The second digit consists of a variable number of pulses from two through eight, depending upon the substation concerned.

4.06 Fig. 13A is a functional block diagram of main station operation during group and station selection. The group code is formed at the main station in the following manner. Station key operation results in control circuit relay operation which removes signal tone from the line as a seizure signal. After the seizure signal, the pulse generator is started. The pulse generator advances the local pulse counter and at the same time causes the SF transmitter to key the 2600-cycle tone, thereby applying tone pulses to the line. The operated station key places ground on a specific output of the relay pulse counter which corresponds to the group code. When the read-out lead of pulse counter finds this ground, the pulse generator is stopped, ending the digit. Since the main station pulse counter does not count the first pulse generated, if the selected substation is in group 1 the pulse counter would find the ground at position 1, although two pulses are transmitted. After an interdigital interval of no tone, the pulse counter is returned to normal and the pulse generator is restarted advancing the local pulse counter and again keying the SF transmitter. The initial ground applied by the station key is transferred by relay operation at the start of the second digit to an output of the pulse counter which corresponds to the station code. When the pulse counter finds this ground, the pulse generator is stopped, ending the second digit. The pulse counter is again returned to normal in approximately 400 milliseconds which corresponds to the time between digits. A red guard lamp lights at this point to signify that a second key must be operated to complete the call. The second or order function key must be operated within 5 seconds or thermal relay operation will restore the control and transfer circuit to normal, thereby causing 2600-cycle tone to be reapplied to the line.

4.07 Fig. 13B is a functional block diagram of the substation operation. Tone pulses received at the substation are translated by their SF receivers to dc pulses, which cause their relay pulse counters to advance to a position corresponding to the number of pulses sent. After the pulses stop, during the interdigital interval and prior to normalizing the pulse counter, ground applied from an output lead of the pulse counter corresponding to the group code causes group A relay operation at all substations in the group being selected. At all other substations, a lockout circuit operates making these substations nonresponsive to further pulsing. During the interdigital interval, all substation pulse counters are returned to normal. At the start of the second digit, all substations in the selected group operate their group B relays which transfers the outputs of their pulse counters from the group A relays and a lockout circuit to their station relays and their lockout circuits. The pulse counters of the stations in the selected group follow the incoming pulses of the second digit. Since the station relays of the various substations are connected to their respective pulse counters at different positions, when the pulses stop only the station relay of the wanted substation operates from ground at the output of the pulse counter. At all other substations, the lockout circuit operates. The operated station relay establishes access to the substation for subsequent operations. Following the last pulse sent and during the interdigital interval, all pulse counters are restored to normal to prepare for counting additional digits.

Third and Fourth Digits of Orders

4.08 To complete the transmission of an order after gaining access to the wanted substation, a second or order function key is operated. This results in the main station pulsing one additional digit for some orders and two digits for others. During the third and fourth digits, the system functions in either of two different ways. If scanning and registration are involved, pulses are reverted by the selected substation to transmit alarm or indication information back to the main station. If selection is involved, to either operate an order relay or provide a 400-millisecond ordered ground, the signaling is unidirectional. Pulses may be reverted in this case, but they are ignored by the alarm receiving circuits of the main station.

4.09 A close-loop order will be discussed as typical of all single digit orders in the unidirectional category. This order is used in the following manner. The alarm loop is normally closed at all terminal substations through their tone-reverting paths. In the event of failure that opens the loop at some point in the system, the location of the trouble may be determined by a roll call. To alarm the substations between the main station and the point of failure, the order ***close loop*** is sent to the appropriate substation. The alarm system then functions on a shortened basis until the failure is corrected, at which time the system may be restored to normal by sending the order ***open loop*** to the appropriate substations. In the event the failure should occur on a spur loop between the junction substation and the first substation on either spur path, the system is restored by closing the loop at the substation preceding the junction substation.

4.10 After the desired substation has been selected as described, the close loop key is operated. Fig. 13A and B are functional block diagrams of the operations at this time. The operated close loop key, indirectly by relay operation, starts the pulse generator. The sequence of operation continues at the main station as described for the first two digits, however since the ground applied by the operated close loop key is on output 7 of the pulse counter eight pulses are generated. Therefore, the pulse counter of the selected substation in counting the pulses stops at the position corresponding to a count of eight. During the interdigital interval, the alarm to order transfer relay operates prior to pulse counter normalizing thereby providing ground through the pulse counter and transfer relay to operate the close loop relay which locks up. This causes the alarm loop to close via the substation pulse reverting path and causes this substation to function as a terminal substation. The main station begins to restore to normal at the end of the interdigital interval by reapplying tone to the line and finally by restoring direct E lead control of the main station control circuit. The red guard lamp extinguishes to signify completion of the signaling sequence.

4.11 When other orders in this category are transmitted, the third digit will contain the number of pulses required to drive the substation pulse counter to a position to which the corresponding order relay is connected or in the case of an open loop order to the position which provides a momentary ground which releases the operated close loop relay. Otherwise system operation is identical to that described for a close loop order. Orders in this category are as follows; close loop, open loop, and numbered orders one through four.

4.12 Numbered orders 5 through 11 are 2-digit orders. In this case, the third digit consists of six pulses, which drives the selected substation pulse counter to a position corresponding to a count of six. During the interdigital interval the alarm-to-order transfer relay operates, prior to the pulse counter normalizing, thereby providing a ground through the pulse counter and transfer relay to operate an order transfer relay which locks up and transfers the output of the pulse counter to 2-digit order leads. After the interdigital interval, which again normalizes all pulse counters, a fourth digit is generated automatically, at the main station which drives the substation pulse counter to a position corresponding to the order code transmitted. During the interdigital interval, the alarm-to-order transfer relay operates prior to the pulse counter normalizing. The output of the pulse counter provides a momentary ground through the alarm-and-order transfer relay and the order transfer relay to operate an order relay or to apply momentary 400-millisecond ground to any one of six order leads. The momentary grounds, associated with orders 6 through 11, may be used to operate external circuits or to unlock order relays 1 through 5. The normalizing sequence is the same as described for a close loop order.

Alarm Scan

4.13 The main station operation during the th· and (if required) fourth digit of an alarm scan is illustrated in Fig. 14A. The corresponding diagram for the substation operation is Fig. 14C. Let it be assumed that access to the substation has been obtained with the first two digits. The alarm-scan key is then depressed, causing an 11-pulse digit to be generated. Dial pulses are transmitted to the selected substation, where they are converted to dc pulses that step the pulse counter. Nine different alarm circuits are connected to nine of the ten outputs of the pulse counter. The existence of an individual alarm causes a ground to be applied to a specific one of these nine outputs. As the pulse counter advances, it connects each of the outputs in turn to the pulse reverting circuit, operating it every time a ground is encountered. Operation of the pulse reverting circuit closes the tone loop through the substation for approximately 125 milliseconds, so that the next pulse is returned to the main station. That is, if there is a ground on output 3 for example when the third pulse steps the pulse counter to this output the reverting path is enabled; but because of delay in the SF receiver and the operate time of the pulse counter and the relay that enables the reverting path, the loop is closed too late for the third pulse to be reverted. The fourth pulse will be reverted, however, and will be received at the main station when its pulse counter is at position 3, since this pulse counter is one step behind.

4.14 The reverted dial pulses are received at the main station and converted to dc pulses used to operate alarm registration circuits. The main station pulse counter, by virtue of prior releases of station-order transfer relay and operation of the station-alarm transfer relay, has connected to nine of its ten output alarm registration circuits corresponding to the nine individual alarms of the substations. Each time a reverted pulse is received, while the pulse counter is being driven locally by the pulse generator, an alarm-register relay operates and the associated lamp lights. The particular relays operated depends on coincidence of the received pulse as the pulse counter pauses on the output to which the relay is connected. In this manner, the alarm information is registered and displayed on lamps. Alarm identification is provided by individual alarm lamps, one for each alarm condition. The main station begins to restore to normal at the end of the interdigital interval by reapplying tone to the line and finally by restoring direct E lead control of the main station control circuit. The red guard lamp extinguishes to signify completion of the signaling sequence. When lighted, alarm lamps remain on under control of a common release key.

4.15 If more than nine alarms are required at a substation, the system does not restore to normal after the third digit, and a fourth digit will be transmitted automatically to the substation to scan the additional alarms. Operation takes place in the same way as for the third digit (first scan digit). The main station pulses the number of digits required for scanning as determined by the station key operated. At substations so equipped, nine additional alarm circuits will be switched to the pulse counter when the third digit ends, in preparation for acting on the additional scanning digit.

Indication Scan

4.16 An indication scan is performed by depressing the indication scan key after gaining station access as described in 4.04. A third and fourth digit are required with this scan. The third digit serves to set up the substation for the scan of the indication leads by driving the substation pulse counter to position 7. This operates a transfer relay that switches pulse counter output leads to the indication leads. Main station and substation operation during this digit is illustrated in Fig. 13A and C, respectively. This operation is similar to the third digit of the close-loop order covered in 4.09, except for the final circuit energized by the pulse counter.

4.17 At the end of the third digit, the selector restores to normal and the fourth digit is then generated automatically. Main station and substation operation during this digit is shown in Fig. 14A and C, respectively. Each indication lead at the radio station will supply either a ground or no ground to its position on the pulse counter, depending upon its status. The system now functions as it did for alarm scan, with pulses reverted when the selector encounters grounds, thus lighting indication lamps at the main station. Up to six indication lamps are used at the main station, one for each binary function. Two alternate conditions are indicated by a lamp on or off, respectively. The lamps may be extinguished by operating a common release key. The system restores to normal as described in 4.14.

Roll Call

4.18 The roll call is made in response to a line open alarm or when it is desired to check the internal operation of each substation or determine the location of a line fault. If the alarm loop is initially closed when the roll call key is operated, the line open alarm sounds. This alarm is silenced by operating the line open key. Two roll calls, one per each group, is required if it is desired to check the status of the entire system.

4.19 Roll call of group 1 is initiated by operating the roll call 1 key. This causes the system to function as described in 4.06 for group selection by the first digit. A second digit, consisting of ten pulses, generated automatically, is applied to the line and is used to step the pulse counters of group 1 substations to position 10. This position applies operating ground to a relay which operates and connects the pulse path enabling relay of each substation in group 1 to an output lead of its pulse counter corresponding to its station code. Each substation makes this connection at a different output of the pulse counter with substation 1 connected to output 1, substation 2 to output 2, and so on up to output 7. Station identification access has now been obtained as shown in Fig. 13E. At the end of the second digit, all pulse counters return to normal and at the main station the red guard lights signifying an alarm scan key must be operated to complete the roll call sequence.

4.20 The alarm scan key is now operated. This, by relay operation, causes an 11-pulse scanning digit to be generated and applied to the line. Operation during this time is illustrated in Fig. 14A and B. The received pulses advance the group 1 substation pulse counters. When the pulse counter of substation 1 reaches output 1, its pulse reverting relay is operated thereby enabling the pulse reverting path and the succeeding pulse is reverted. At substation 2, the reverting path is enabled when the pulse counter reaches output 2, and the third pulse is reverted, and so on. Each substation that receives pulses and is capable of responding, and that is not prevented by a line fault from reverting a pulse to the main station, will be identified by the main station. The process of identification results in the lighting of corresponding station lamps. If a reverted pulse is not received from a given substation, the corresponding station lamp will not be lighted indicating that either there is a trouble in the equipment or that a line fault exists between the substation and the main station. Operation of the main station during this third or scanning digit is similar to that described for the alarm scan in 4.13. For roll call however, the main station pulse counter outputs are connected through transfer relays to station relays and in this case when a reverted pulse is received a station relay operates, which lights a station lamp corresponding to the station that reverted the pulse.

4.21 System operation for a roll call of group 2 substations is identical to that described for roll call of group 1 substations with the following exception. The first digit consists of four pulses rather than two pulses. This digit is used to gain access to group 2 substations and it locks out group 1 substations. It should also be noted that group 2 substations report on group 1 substation lamps. That is, substation 8 reports on station 1 lamps, substation 9 on station 2 lamps, and so on.

C. Automatic Identification and Scanning

4.22 *Automatic Alarm Scan:* An automatic alarm scan is brought about by the onset or the clearing of an alarm condition at a substation. To report the onset of an alarm, the substation must perform the following three functions.

(a) Signal the main station to start a scan.

(b) Cause the main station to form the correct digit codes to gain station access.

(c) Cause the main station to scan the alarms.

The first function is performed by blocking tone to the main station; the second and third by reverting pulses.

4.23 Main station and substation operation for the first two digits of an automatic alarm scan caused by the onset of an alarm at a substation is illustrated in Fig. 15A, 15B, 16A, and 16B. When the alarm arises, an associated alarm relay operates at the substation reporting the alarm and is locked up, to assure that if the alarm is transitory it will still be reported. At the substation reporting the alarm, the pulse reverting circuit is then switched to the pulse counter at a position reserved for group identification. The main station is then signaled by the insertion of a 2600-cycle band-rejection filter in the return line, toward the main station. At the main station, the SF receiver detects the loss of tone. This results in the SF transmitter removing tone from the outgoing line as a seizure signal, to prepare all substation relay circuits for the reception and counting of pulses. At the end of the seizure signal the pulse generator starts, and dial pulses are applied to the outgoing line. The dial pulses advance the pulse counters at all substations.

4.24 When the reporting substation pulse counter reaches the position preceding the group identifying position, the reverting circuit is enabled so that the next pulse is reverted to the main station. This stops the pulse generator, thereby forming the correct group digit. In a manner similar to that described in 4.07, all substations in the group associated with the substation reporting an alarm operate their respective group A relays during the interdigital interval. At the main station during this interval, group relays operate which transfer the outputs of the pulse counter from the group identifying relays to the correct group of station relays. After all pulse counters return to normal, a second digit is generated automatically. At the start of the second digit, all substations in the identified group operate their group B relay which transfers the outputs of this pulse counter from a group A relay and a lockout circuit to a station relay and a lockout circuit. When the reporting substation pulse counter reaches the position preceding the station identifying position, the reverting circuit is enabled so that the next pulse is reverted to the main station. This stops the pulse generator, thereby forming the station code of the reporting substation. After the pulses stop, but prior to the pulse counter returning to normal, the station relay of the substation reporting operates thereby enabling access to this substation for subsequent operations. All other substations are locked out as previously described. At the main station when the reverted pulse is received, the station relay of the substation reporting the alarm operates and locks up under control of a common release key. The operated station relay lights an associated station lamp thereby identifying the substation. After all pulse counters return and after the interdigital interval separating the second and third digits, the third digit consisting of 11 pulses is generated automatically. Subsequent operations at the main station and substation are essentially the same as that described in 4.13 through 4.15 for the third and fourth digit of an ordered alarm scan. The operation is shown in Fig. 17.

4.25 As an option, the ***clearing of an alarm*** may be reported to the main station in a manner similar to the ***onset of an alarm.*** The only difference in the method of operation in this case is that when a particular alarm clears, a pulse is not reverted when the pulse counter passes the position associated with this alarm, and the corresponding alarm lamp does not light. If a transitory alarm occurs that drops out during the initial alarm scan, a second scan takes place immediately to report the clearing of the alarm. Under these conditions, the alarm lamp is on after the second scan since the attendant has not released the lamps during the scanning process. To inform the attendant that a second scan has occurred, an alarm check lamp lights during this scan. The alarm check lamp also lights when a second alarm is reported by any substation before the first alarm registration is canceled. If the alarm check lamp is lighted, the attendant executes a manual alarm scan to determine the status of the alarm.

Line Open

4.26 A line fault that causes a break in alarm-loop continuity is reported to the main station through a line-open scan. The action that takes place is illustrated in Fig. 18. Initially, the operation is the same as that occurring for an automatic alarm scan. That is, the main station SF receiver detects the loss of tone, the SF transmitter is therefore directed to remove tone, and pulsing starts. For an alarm scan, a pulse is reverted to identify the group and stop the pulse generator. Since the alarm alert in the case of the line-open scan is due to the line fault rather than to a change in individual alarm status at the substations, no pulses will be reverted, so the main station continues to produce pulses until the pulse counter is driven to its top position. The pulse generator stop circuit then operates and a line-open lamp lights. The SF transmitter then reapplies steady tone to the line to normalize the substations. Before the main station restores completely, a major office alarm is brought in to announce the line-open condition. Operating the line-open key will silence the alarm. When the line-open condition clears, tone is received at the main station and the major office alarm is again brought in. Releasing the line-open key silences this alarm and returns the system to the idle condition.

4.27 To obtain information as to the location of the line fault, a roll call is made as covered in 4.18 through 4.21. If the system is a single branch system without spurs, a line fault will produce a pattern of consecutively lighted and consecutively dark station lamps. The fault then may be presumed to exist between stations indicated by the last lighted lamp and the adjacent dark lamp; or in the case of failure in radio line facilities the trouble may be in either of the radio stations indicated by these two lamps. If the system contains branches and/or spurs, the numbering of the substations may be such as to preclude the above type pattern of consecutively lighted and consecutively dark lamps on a roll call response. In this case, the lamp pattern must be analyzed on the basis of known substation layout to localize the trouble.

Substation Equipment Failure Alarm

4.28 The alarm system is self-alarming in the event of failure of certain major equipment elements of a substation. Such a failure manifests itself by a 10-second interruption of the alarm-tone loop, which is recognized at the main station by a line-open scan as covered in 4.26 and Fig. 18. Subsequently, when a roll call is made from the main station as is the normal procedure, all station lamps light except the one representing the substation in trouble, since that substation does not respond by reason of failure of local equipment.

4.29 The alarm alert as a result of equipment failure is produced as follows. Substation relay circuits are equipped with two thermal slow-release relays whose release times differ by 10 seconds. These relays are normally operated; but in the event of SF rceiver failure, failure of the VF amplifier preceding the SF receiver, or failure of 48-volt C fuse or 130-volt battery, these relays will be de-energized. As a result, one relay releases after about 20 seconds and in so doing shunts a 2600-cycle series-resonant trap across the line incoming to the main station. After an additional 10 seconds the other relay releases, removing the trap. These operations result in about 20db reduction in the tone received in the main station for 10 seconds. This acts as an alarm alert to which the main station responds with a line-open scan and major office alarm.

Signaling on Service Calls

4.30 Signaling from the unattended substation to the alarm center for service calls on the order circuit is accomplished by methods similar to automatic alarm reporting. The essential difference is that the operation is key-initiated at the substation and regardless of the substation concerned, it reverts the ninth pulse on the first digit. This pulse is received at the main station when its pulse counter is at position 8. Position 8 of this pulse counter is connected to a signal register circuit, which in turn is connected to an answer lamp on the main station bay and to the answer lamp and night alarm arrangements of the toll testboard.

4.31 The main station and substation operation for signaling on order wire service calls is illustrated in Fig. 17A and C, respectively. Operation of the signal main station key at the substation inserts the band-elimination filter in the line incoming to the main station and connects the reverting path enabling circuit to output 8 of the substation pulse counter. This causes the ninth pulse to be reverted. Since the main station pulse counter is on output 8 when the pulse is received, the signal is registered as a calling-in signal at the main station and at the toll testboard. The call may be answered at either the main station or at the toll testboard. If answered at the main station, the release key is operated which releases the signal register circuit, which in turn extinguishes both answer lamps. Answering the call by plugging into the toll testboard order wire jack also releases the signal register circuit. If ringing is provided, it is released when the signal register circuit is released. The alarm system is restored to normal by main station thermal relay operation approximately 5 seconds after the sequence started. This prepares the system for subsequent receipt of alarms.

5. MAINTENANCE

A. Transmission Circuits

5.01 A number of jacks are provided in the main station unit, the substation unit, and the spur unit as shown in Fig. 6, 7, and 8. These jacks permit access to the transmission circuits for test and adjustment and for over-all system line-up and maintenance. A 21-type transmission measuring set, or equivalent, is used for transmission measurements.

5.02 All amplifiers used are of the plug-in type. In general, it will be advantageous to remove a unit suspected as faulty, substituting a spare amplifier. Standard test facilities and procedures exist for these amplifiers, as covered in other sections.

B. Signaling Circuits

5.03 The plug and jack mounting of the SF signaling units permits their removal for maintenance. Although means have been provided and procedures set up for certain in-service adjustments or checks of these units, the maintenance philosophy for the D2 system calls for signaling units to be removed for maintenance and replaced by a spare kept on hand for this purpose. This is particularly applicable to substations at remote radio locations. It is expected that one spare signaling unit will be adequate for a system. It is intended that maintenance of the SF units of the system be accomplished at locations where the standard test facilities are provided. These facilities and test adjustment procedures are covered in the sections on SF signaling.

C. Relay Circuits

Substation and Spur Units

5.04 Operation of substation and some spur relay circuits may be checked locally by use of a No. 52B test set. This set includes a switch and a dial by means of which on-hook and off-hook signals or dc dial pulses may be applied to the substation or spur unit line relays that are normally connected to their associated SF receiver via E leads. Access to these relays is provided by associated E test jacks. By this means, most operations that would normally take place in conjunction with the main station may be simulated locally.

Main Station

5.05 Only one local test of the main station relay circuits is practicable. This is adjustment of the per cent break and pulsing rate of the pulse generator in the sending director circuit. A J94723A pulse checking test set is required for these tests. Access to the pulse generator by the test set is provided by P and BATT GR jacks in the jack field.

5.06 In general, the proper functioning of the main station relay circuits is ascertained by actual operation in conjunction with a substation, since no means of local testing is provided for this purpose, except for initial adjustment of the pulse generator as covered in 5.05.

6. GLOSSARY

Alarm Alert — The means by which the unattended station invites the attention of the main station when a trouble either occurs or clears. Interruption of the alarm-tone loop constitutes an alert.

Alarm Center — A fully attended station at which alarms are received from and control orders transmitted to an associated group of unattended radio stations of a radio relay system. Ordinarily, an alarm center also serves as a maintenance center for a group of nearby radio stations.

Branches — The 4-wire line facilities that provide transmission paths from the main station to associated stations in a maximum of four different directions from the main station. Each transmission path from the main station is called a branch.

Dial Pulse Code Digit — The signal consisting of a train of pulses having characteristics, such as per cent break or repetition rate, similar to those generated by a telephone dial. In the D2 system, each of the ten number symbols, 0 through 9, corresponds to an item of information, such as a particular substation or alarm condition. These digits are in turn represented by a pulse code, wherein the number of equal length pulses is the same as the numerical value of the digit represented.

Main Station — The D2 equipment, located at an alarm center, that provides for sending control orders to and receiving alarms from an associated group of substations, and for talking and monitoring on the order wire.

Maintenance Center — The home station of the force concerned with the maintenance of a group of nearby radio stations, usually coincident with an alarm center. If not located at an alarm center, a maintenance center is notified of trouble conditions by the alarm center, since the maintenance center does not receive alarms.

Scanning — The process by which the status of individual alarm conditions at a substation is examined in succession by the main station.

SF Signaling — The signaling system used to pass supervisory and dial pulse signals on trunks by use of a single ac signal frequency (in a given direction) within the speech channel frequency band.

Spur Loops — The 4-wire line facilities that provide transmission paths from a junction station to stations off the main branch route.

Substation — The D2 equipment located at an unattended radio station, used to transfer alarms to and receive control orders from a main station, and to provide order wire talking and monitoring facilities. In D2 there are three types of substations; intermediate, junction, and terminal substations.

	LINE FACILITIES	TRANSMIT RECEIVE LEVELS		AMPLIFIER GAINS						PAD VALUES									Pot. Lev.	TRANSMISSION LEVELS AT TEST JACKS									
		Xmt	Rec	A	B	C	E	F&H	G	A	B	C	D	E	F	G&K	H&L	J&M		A Pad Out	B Pad Out	Tel Brdg. Out	D Pad Out	E Pad Out	G&K Pad Out	F&H Ampl. Out	J&M Pad Out	M Net. A&B	M Net. Out
SUBSTATION LINES ALIKE ON BOTH SIDES	TJ Radio	—36	—32.5	—	33.5	—	9	31	9.5	0	5	11	0	0	0	0	25	4.5	36	—32.5	—12	—36	—36	—36	—36	—1.5	—12	—32.5	—32.5
	Motorola MR20	—38	—33	—	34	—	7.5	31	9.5	0	5	11.5	1.5	1.5	0	0	25	4.0	36.5	—33	—12	—36.5	—38	—38	—38	—2.0	—12	—33	—33
	Lenkurt 74A	—28	—12	—	27	—	5	12	9.5	8.5	10.5	4.5	4	4	8.5	0	14.5	6	24	—20.5	—12	—24	—28	—28	—28	0	—12	—20.5	—20.5
	Collins MW105	—30	—30	31.5	—	31.5	—	31	9.5	0	6	9.5	28	28	0	19	25	7	33.5	+1.5	—12	—33.5	—30	—30	—30	+1	—12	—30	—30
	Carrier	—16	+7	—	25	—				19.5	16.5	2.5	0	0	19.5				16	—12.5	—12	—16	—16	—16					—12.5
	Wire Line (See note)	—8	X	—X+.5	—	27				0	5	5	5	5	—X—26.5				—30	+.5	—12	—30	—8	—8					—26.5
MAIN STATION				B, D, F&H	A, E, G&J	C				A, E, G&J 32A Pad	B, D, F&H	A, C, E&G								A Brdg Out 1	A, C, E&G Pad Out	B, D, F&H Ampl Out	A, E, G&J Ampl Out	A Brdg Out 3	Toll T Bd				
	TJ Radio	—36	—32.5	—	20.5	24				—	7	5								—12	—29	—36	—12	—12	0				
	Motorola MR20	—38	—33	—	21	24				—	9	5								—12	—29	—38	—12	—12	0				
	Lenkurt 74A	—28	—12	9	—	24				0	8	5								—12	—29	—28	—12	—12	0				
	Collins MW105	—30	—30	—	18	24				—	1	5								—12	—29	—30	—12	—12	0				
	Carrier	—16	+7	13	—	24				19	—	5								—12	—29	—16	—12	—12	0				
	Wire Line (See note)	—8	X	21	—X—12	24				—X—12	—	5								—12	—29	—8	—12	—12	0				

Note: X is the received level. Provide gain for + or loss for — results.

TABLE A

D2 TRANSMISSION TABLE —

1000-CYCLE TRANSMISSION LEVEL GUIDE

ORDER	NUMBER OF PULSES PER DIGIT				DIGITS OF REVERTED PULSE	VISUAL REGISTRATION (LAMPS)	KEY DEPRESSED			
	1st DIGIT	2nd DIGIT	3rd DIGIT	4th DIGIT			1st DIGIT	2nd DIGIT	3rd DIGIT	4th DIGIT
Alarm Scan	2 - 4	2 - 8	11	*11	3rd & 4th	Alarm	Station 1 - 14		Alarm Scan	
Close Loop	2 - 4	2 - 8	8				Station 1 - 14		Close Loop	
Open Loop	2 - 4	2 - 8	9				Station 1 - 14		Open Loop	
Indication Scan	2 - 4	2 - 8	7	11	4th	Indication	Station 1 - 14		Indication Scan	
Orders 1 - 4	2 - 4	2 - 8	2 - 5				Station 1 - 14		Order	
Orders 5 - 11	2 - 4	2 - 8	6	2 - 5 7 - 9			Station 1 - 14		Order	
Roll Call 1	2	10	11		3rd	Station	Roll Call 1		Alarm Scan	
Roll Call 2	4	10	11		3rd	Station	Roll Call 2		Alarm Scan	
AUTOMATIC IDENTIFICATION AND SCANNING										
Automatic Alarm Scan	2 - 4	2 - 8	11	*11	1st, 2nd, 3rd, 4th	Station, Alarm				
Equipment Failure	11					Line Open				
Line Open	11					Line Open				
Service Call	9				1st	Answer	Signal main Station			

* This digit generated for substations requiring more than 9 alarms.

TABLE B

ALARM AND CONTROL FEATURES AND THEIR CHARACTERISTICS

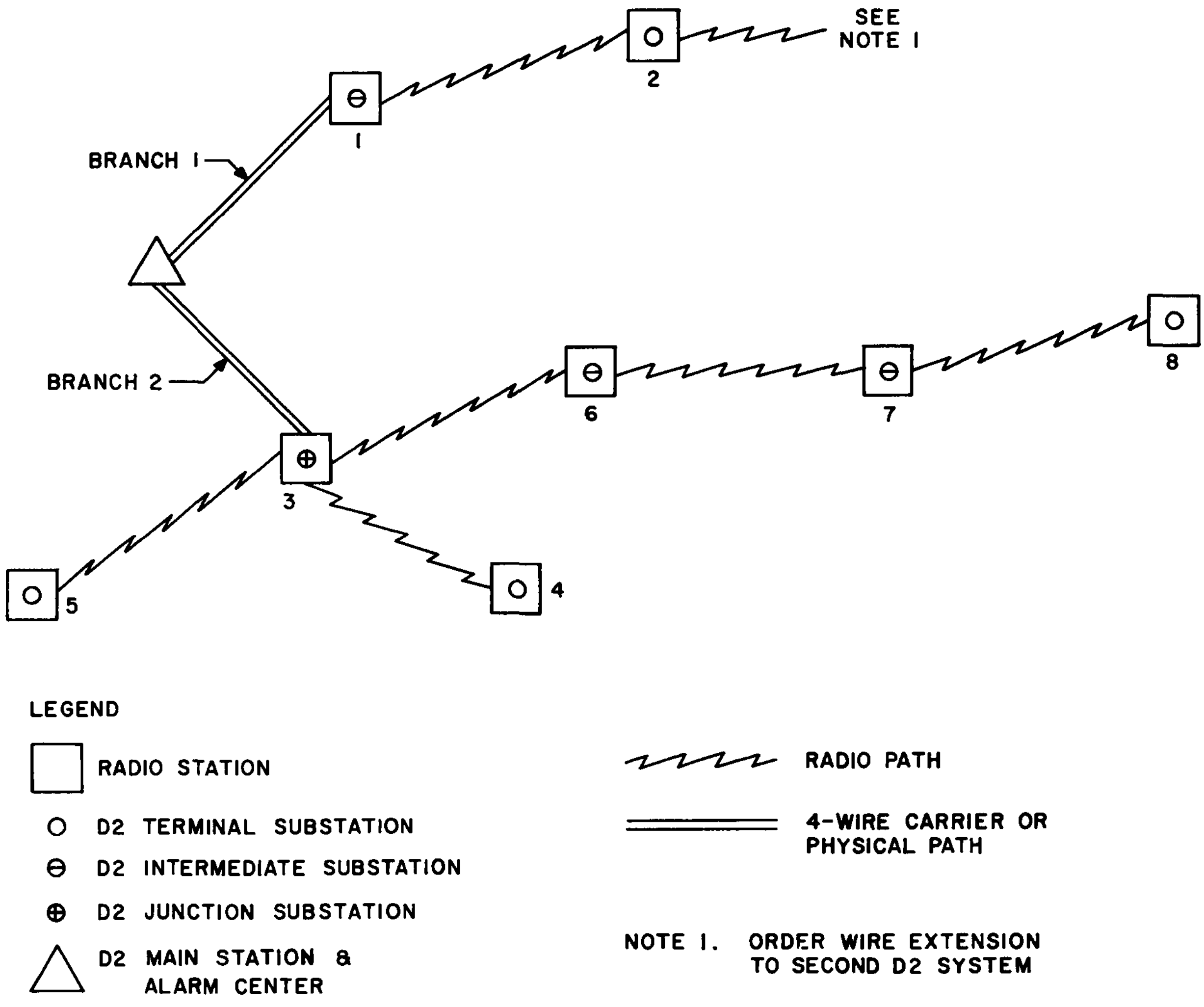


Fig. 1 — Typical Geographical Layout of Alarm, Control and Order Circuit Facilities of a Radio System

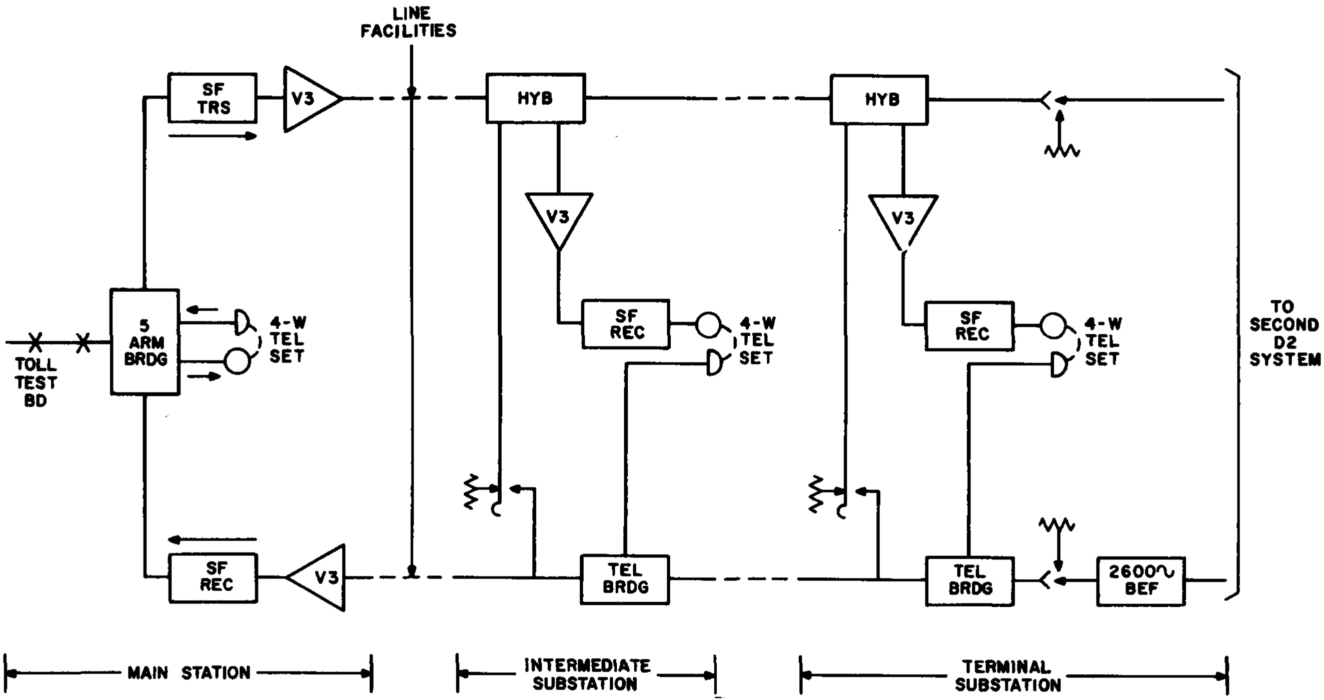


Fig. 2 — Symplified Schematic of Order Wire

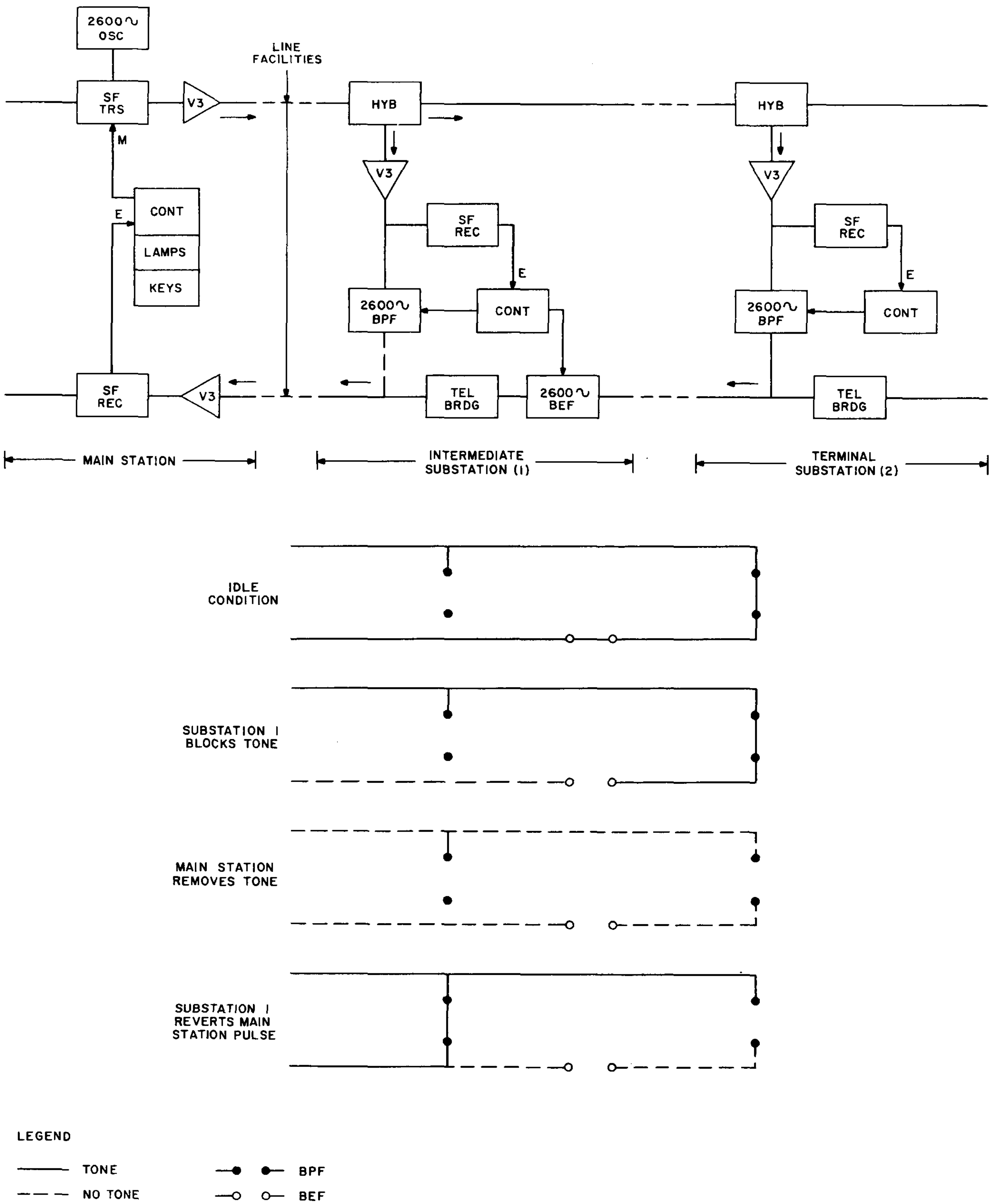


Fig. 3 — Simplified Schematic of Alarm and Control Signaling

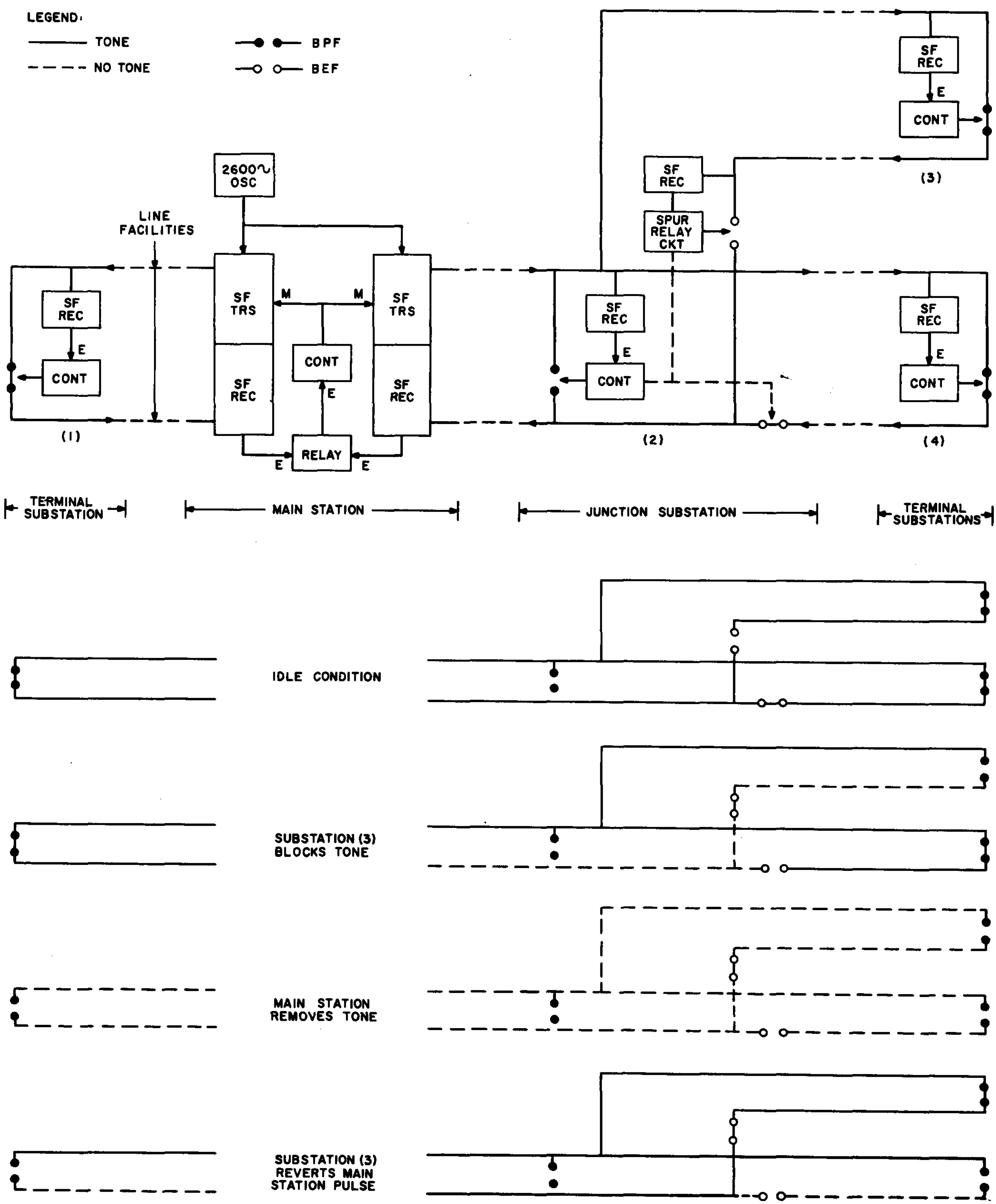


Fig. 4 — Simplified Schematic of Alarm and Control Signaling With Branches and Spurs

Fig. 5 — Block Schematic and Level Diagram of D2 Alarm, Control, and Order Wire System

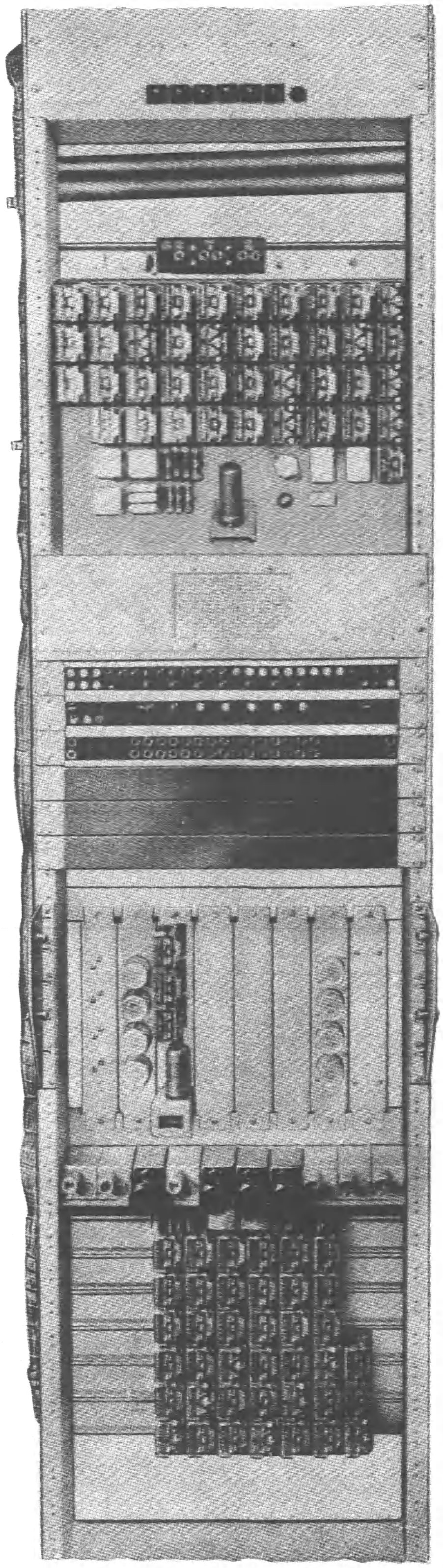


Fig. 6 — Main Station Unit — Front View

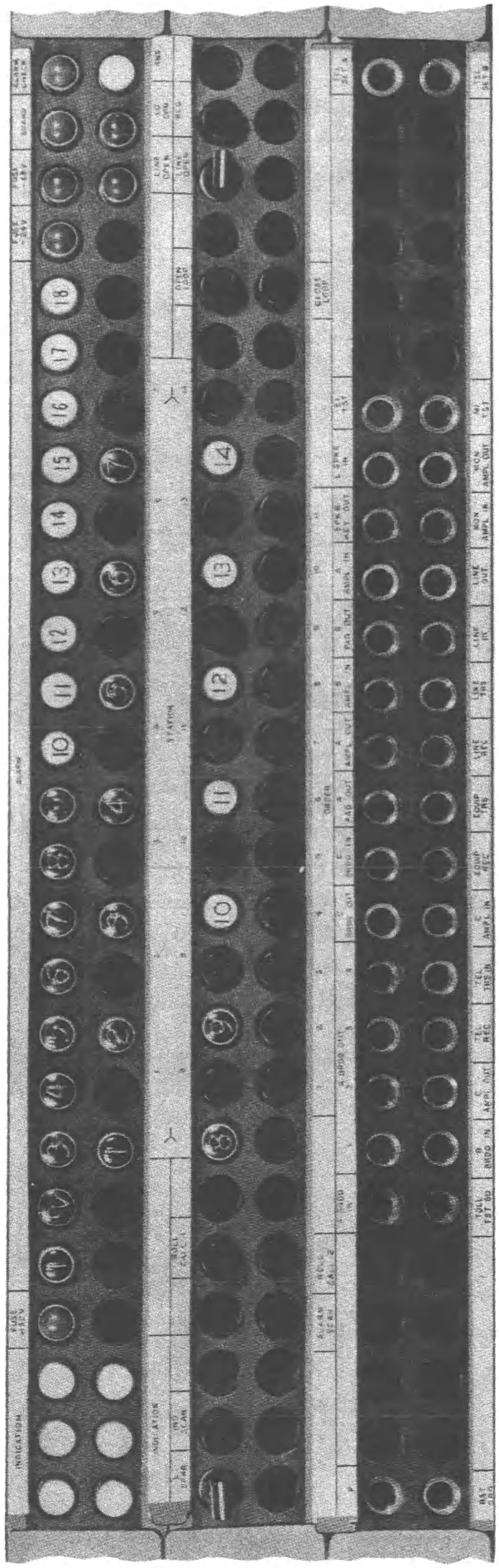
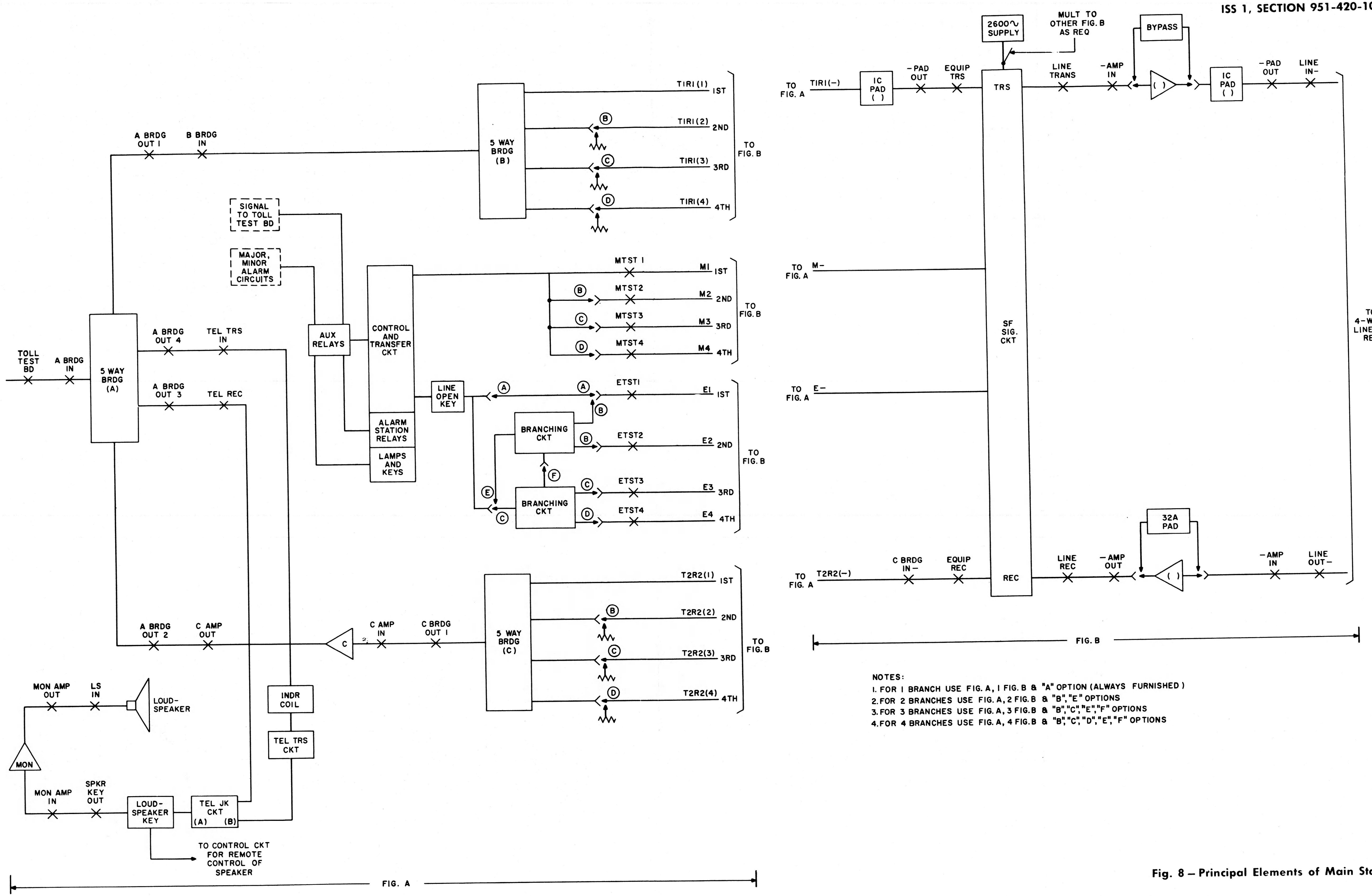


Fig. 7 — Main Station Key, Lamp and Jack Field



NOTES:

1. FOR 1 BRANCH USE FIG. A, 1 FIG. B & "A" OPTION (ALWAYS FURNISHED)
2. FOR 2 BRANCHES USE FIG. A, 2 FIG. B & "B","E" OPTIONS
3. FOR 3 BRANCHES USE FIG. A, 3 FIG. B & "B","C","E","F" OPTIONS
4. FOR 4 BRANCHES USE FIG. A, 4 FIG. B & "B","C","D","E","F" OPTIONS

Fig. 8 – Principal Elements of Main Station

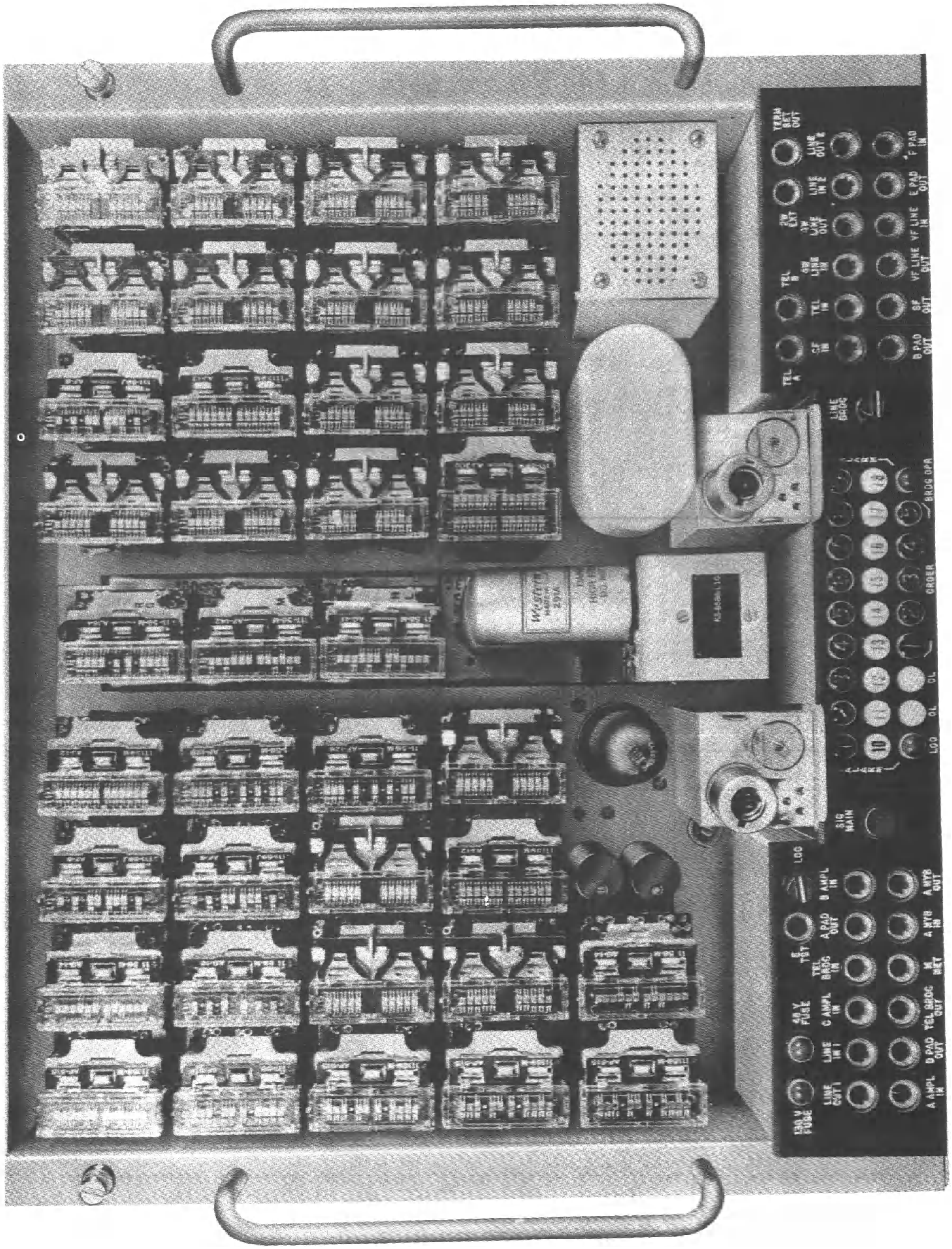


Fig. 9 — Substation Unit — Front View

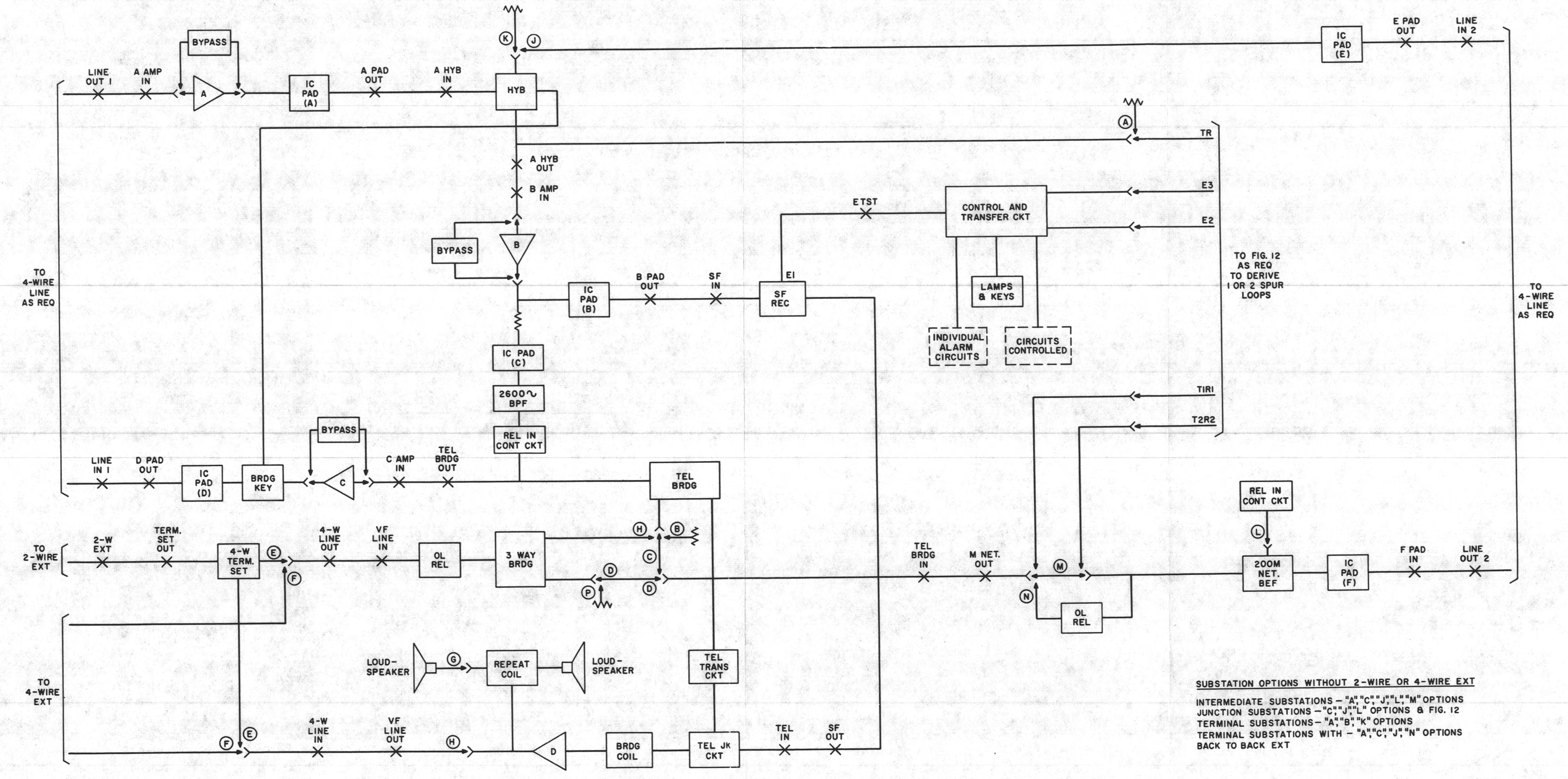


Fig. 10 — Principal Elements of Substation Unit

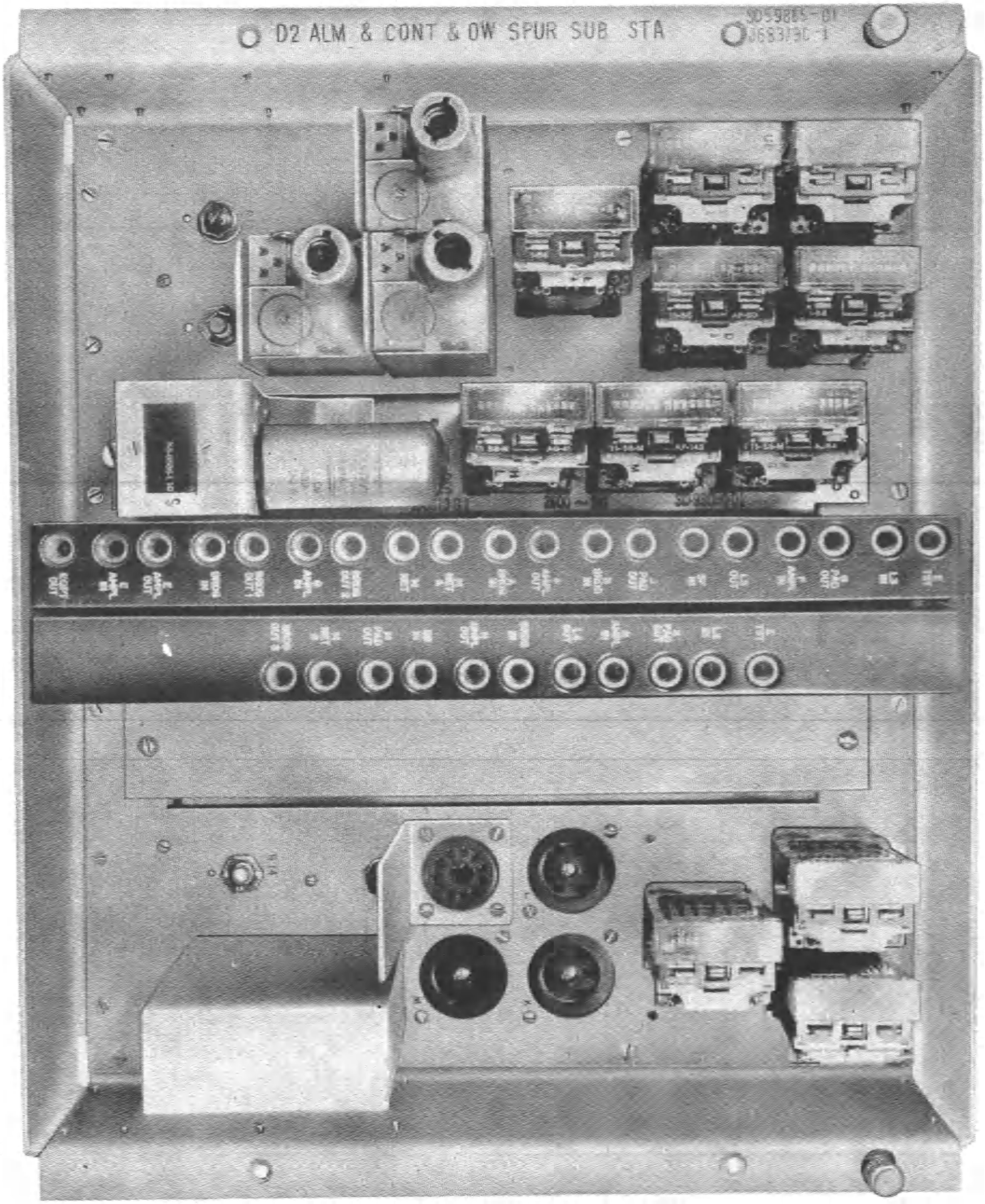


Fig. 11 — Spur Unit — Front View

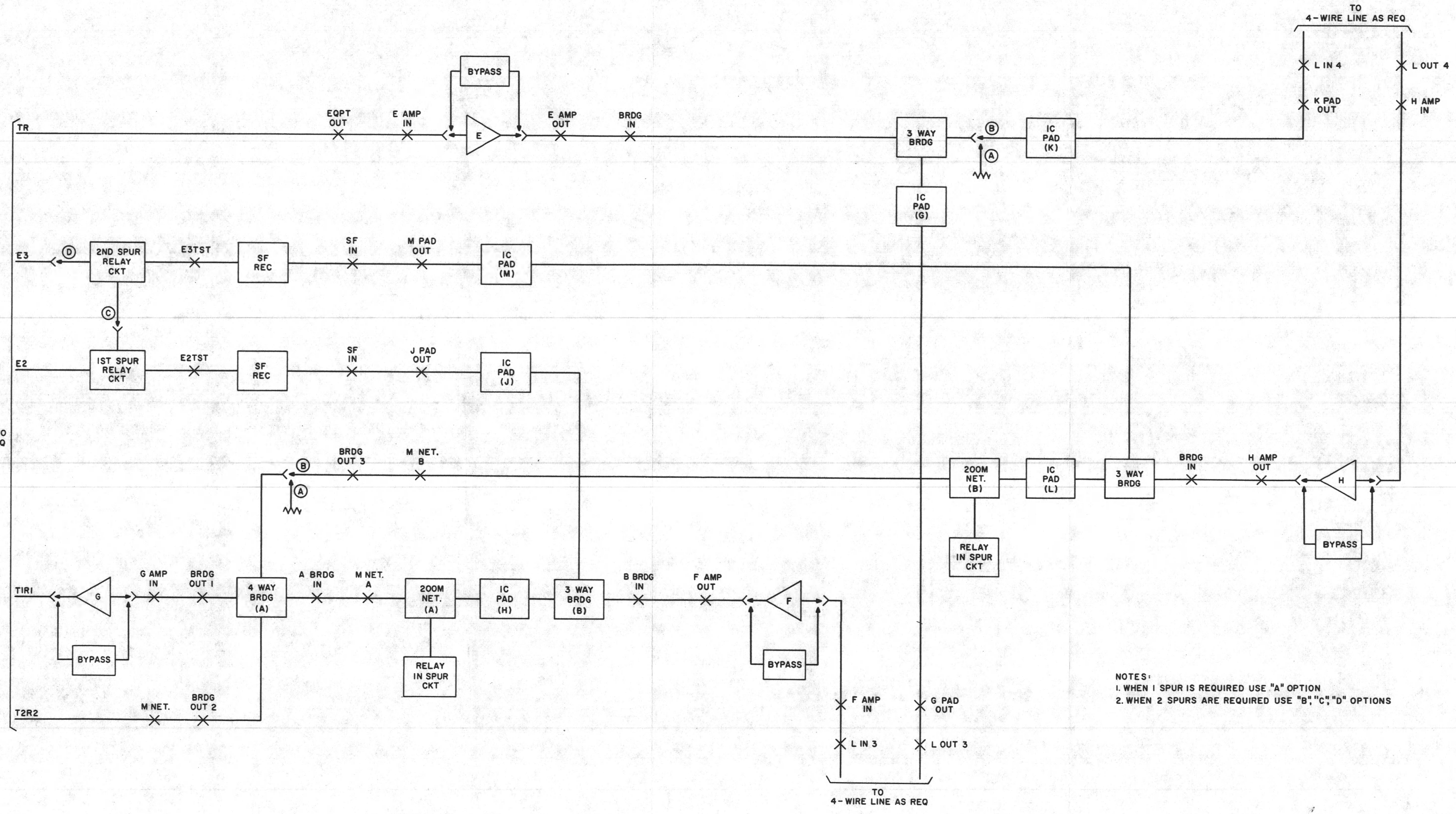


Fig. 12 — Principal Elements of Spur Unit

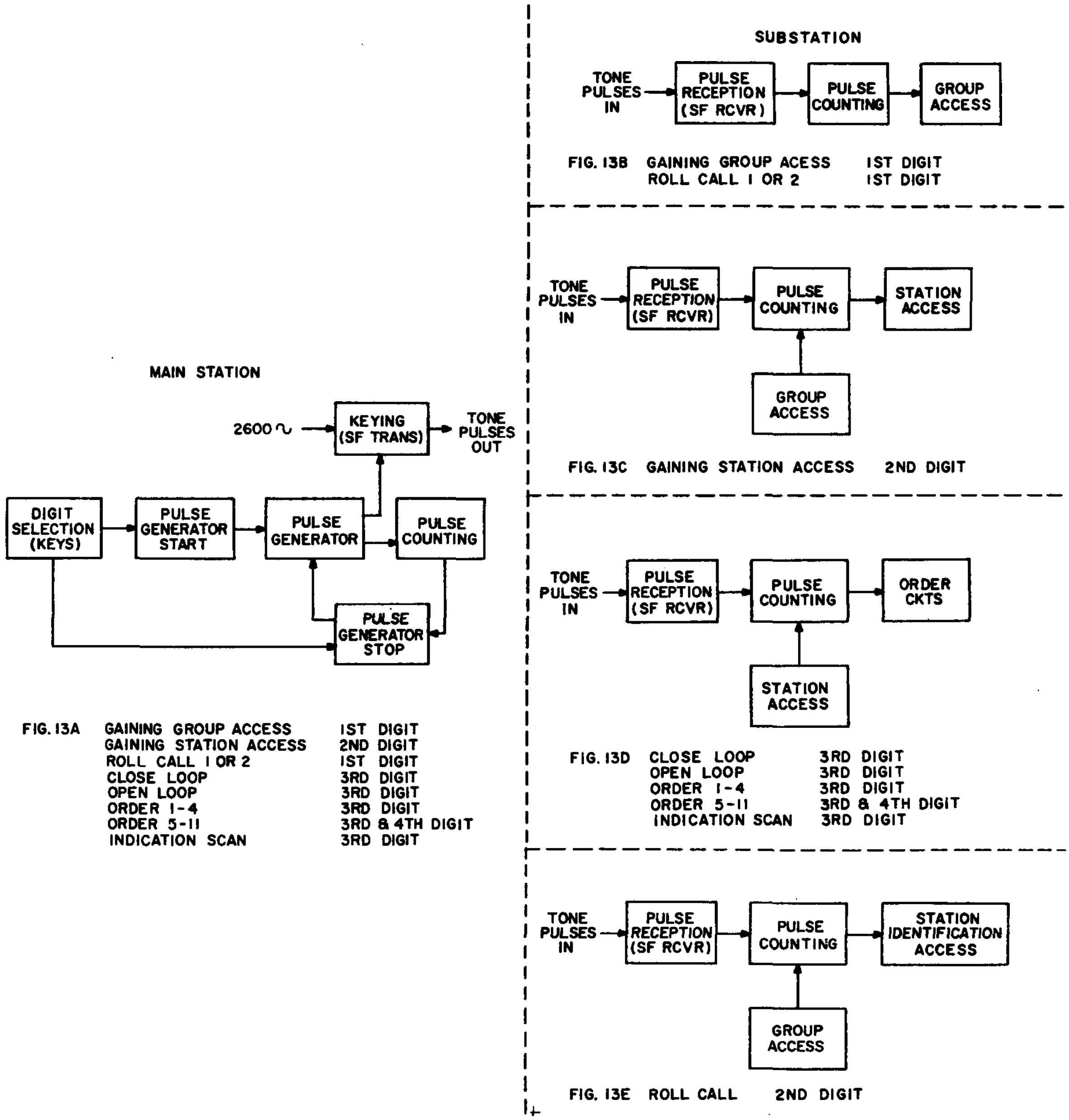


Fig. 13 — Functional Block Diagram — Orders

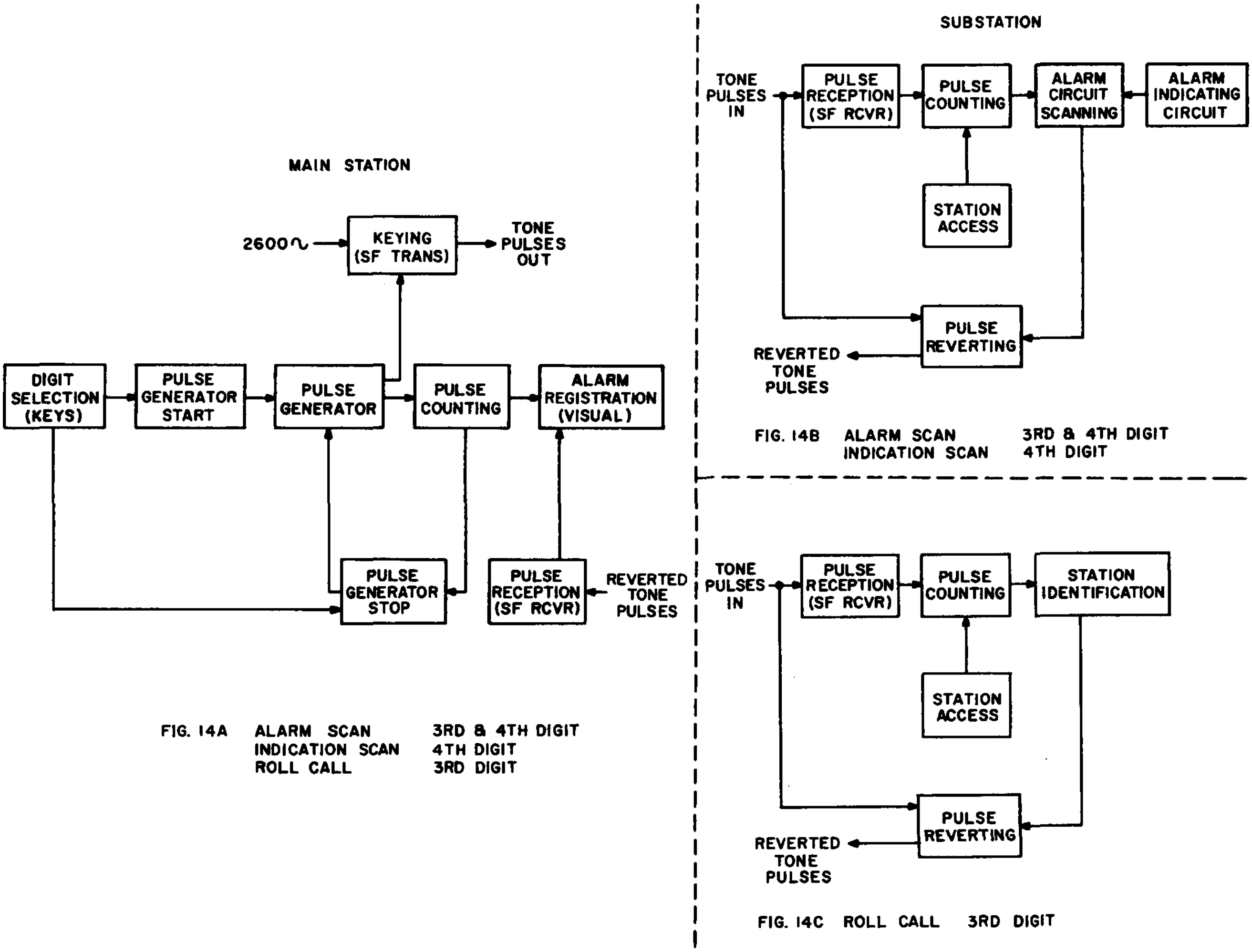


Fig. 14 — Functional Block Diagram — Orders (Cont.)

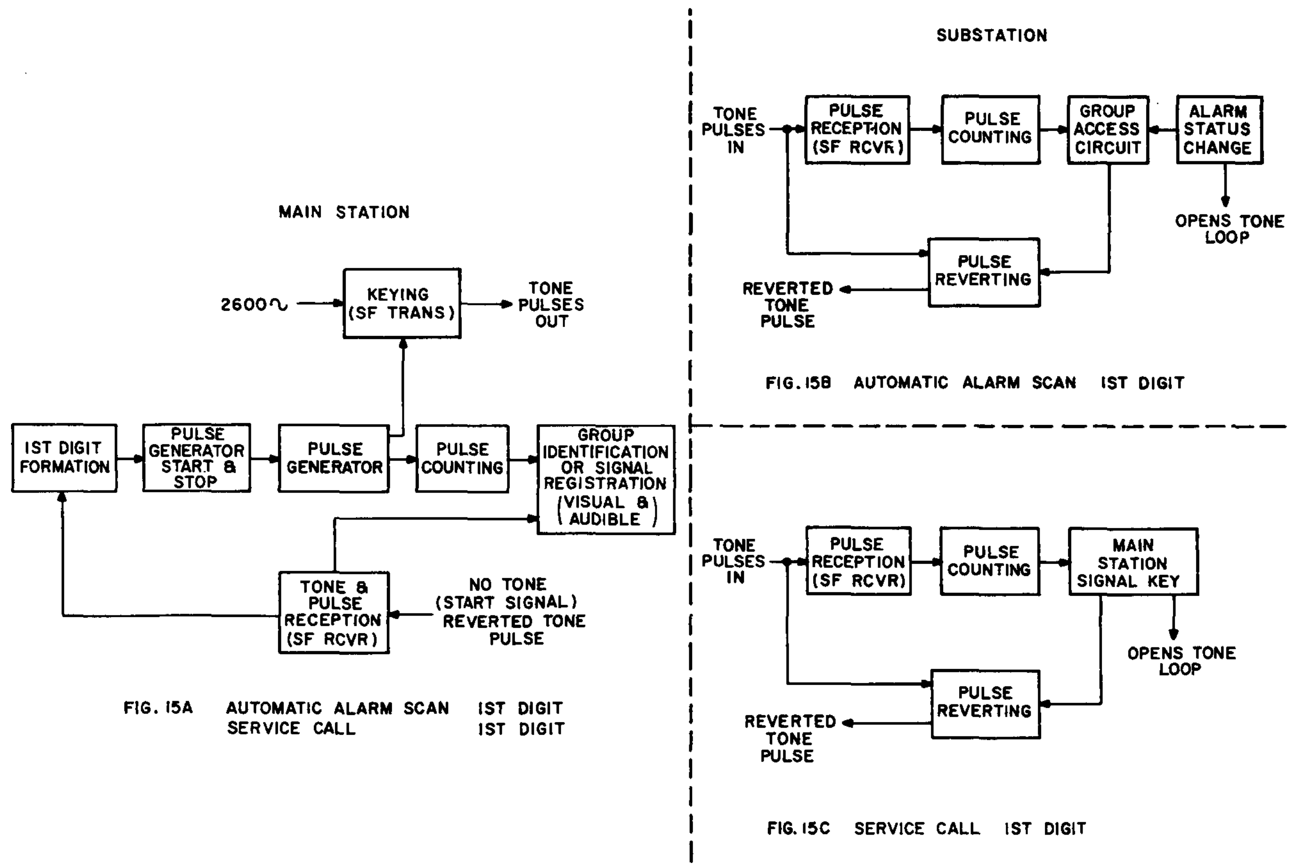


Fig. 15 — Functional Block Diagram — Automatic Identification and Scanning

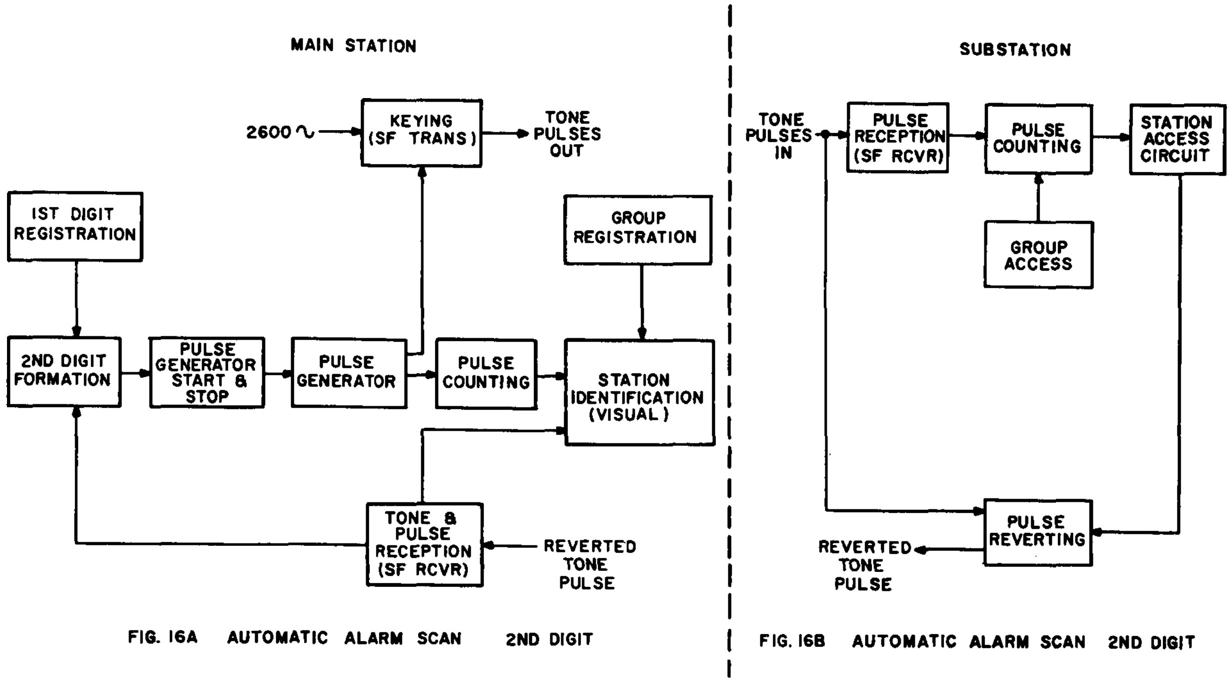


Fig. 16 — Functional Block Diagram — Automatic Identification and Scanning (Cont.)

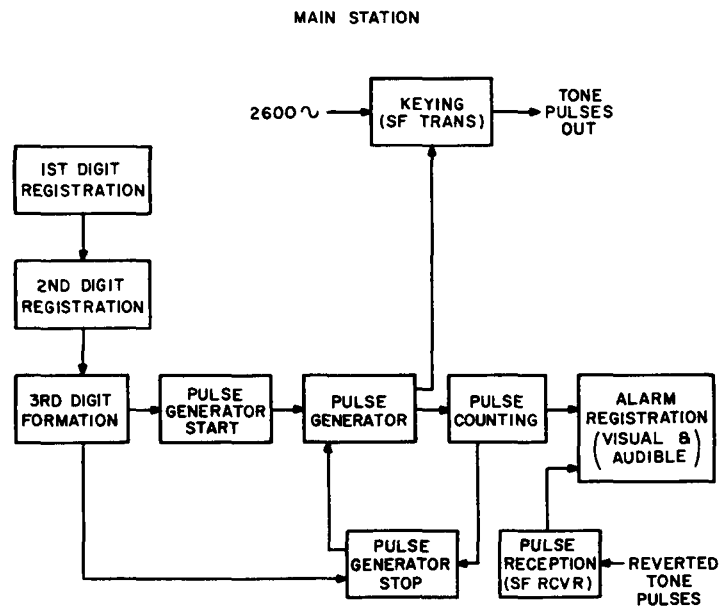


FIG. 17A AUTOMATIC ALARM SCAN 3RD DIGIT

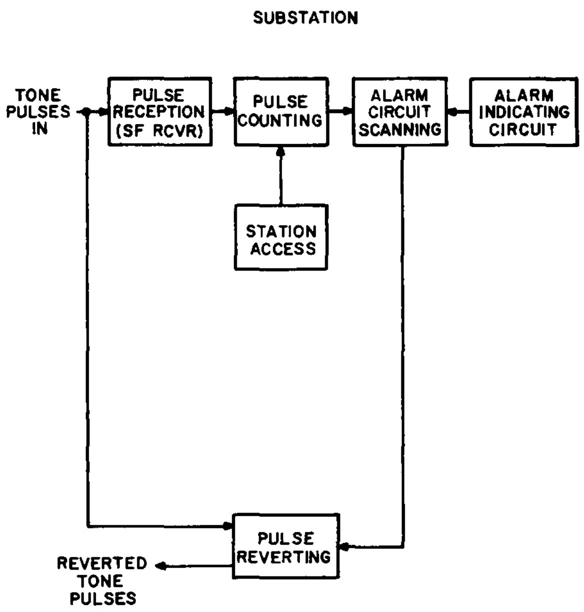


FIG. 17B AUTOMATIC ALARM SCAN 3RD DIGIT

Fig. 17 — Functional Block Diagram — Automatic Identification and Scanning (Cont.)

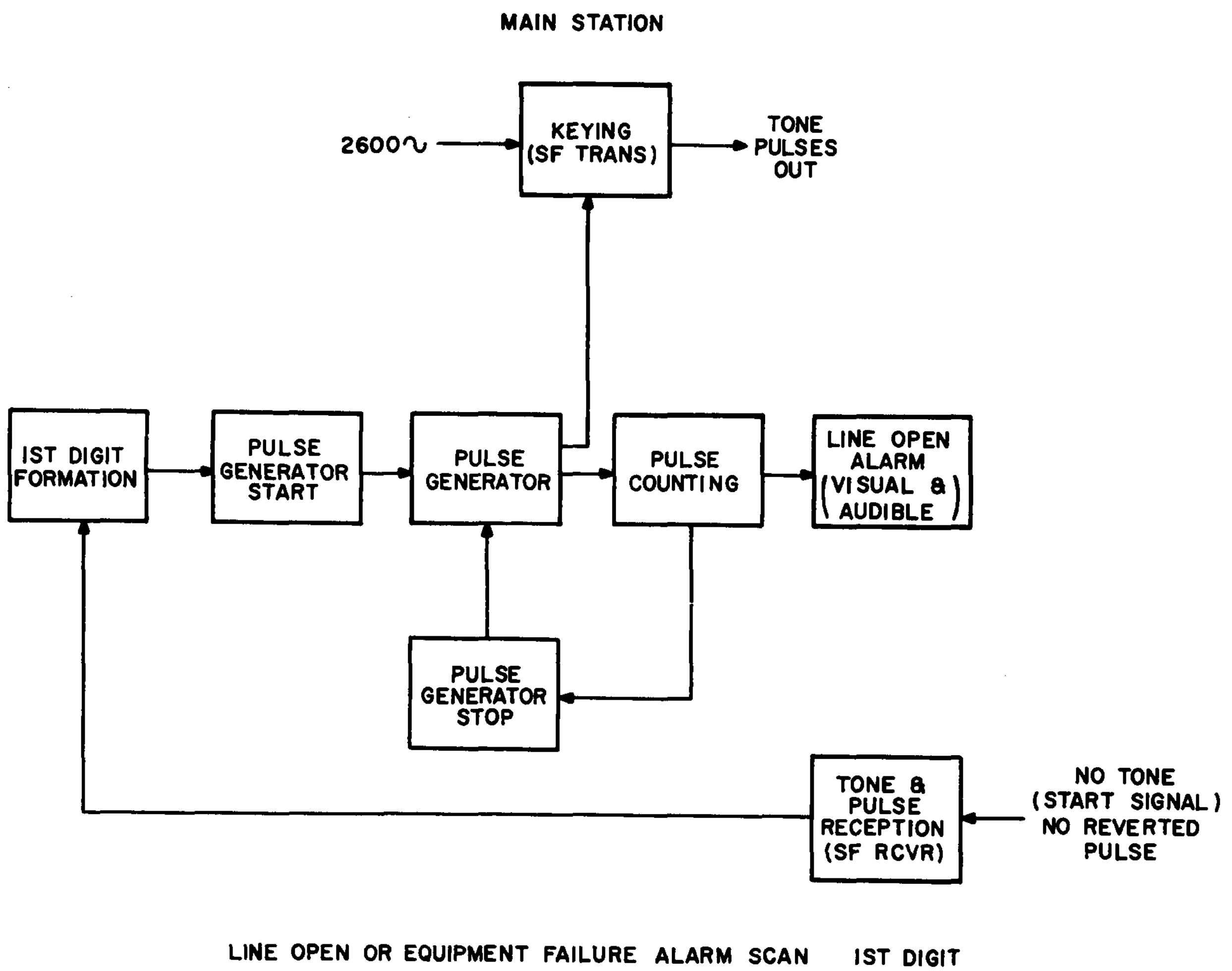


Fig. 18 — Functional Block Diagram — Automatic Identification and Scanning (Cont.)