# L3 CARRIER SYSTEM

# PEARL LINE ARRANGEMENTS

# DESCRIPTION

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## 1. GENERAL

1.01 This section describes the line equipment and arrangements of a system for the Performance Evaluation of Amplifiers at Remote Locations (PEARL). A general description of the principle of operation, an equipment description, and a functional description of the circuit operation are provided.

1.02 PEARL is designed for use with L3 carrier systems to provide remote identification of the location of a failed or faulty amplifier in a switching section of the repeatered coaxial line. The basic principle of PEARL is to add a distinctive, continuous tone in each of the amplifiers between switching and/or terminal main repeaters. Tone from the PEARL oscillator is fed to the input and output of the L3 amplifier through high-impedance bridging pads. The amplitude and phase of the tone to the amplifier input are adjusted to make the tone through the amplifier balance out the tone added at the amplifier output. In this manner a distinctive signaling tone is added to an amplifier but is transmitted over the cable to the receiving terminal at a very low level. If a particular repeater fails, or if its gain changes appreciably, the balance at the repeater output will be degraded and the PEARL tone from that repeater will be transmitted to the receiving main station at a higher level. Measurement of this high-level tone on an in-service basis, at the receiving main station, will locate the defective repeater. Modulation measurements are made by removing the line from service and sending a high-level tone from the transmitting end. Products will be formed by the high-level tone and the PEARL tone in each amplifier and transmitted to the receiving main station. Since the PEARL tone, and therefore the modulation product frequency, are distinctive to a particular repeater, an amplifier with excessive modulation is uniquely identified. The line equipment required for PEARL operation is mounted on each auxiliary, equalizing auxiliary, and equalizing main repeater bay. This added equipment consists basically of oscillators and bridging and balancing circuits and is powered from existing repeater power supplies.

1.03 PEARL requires the continuous insertion of a distinctive identification tone into each of the line and flat-gain amplifiers located between switching main repeaters, as illustrated in Fig. 1. It should be noted that each of the three amplifiers in the equalizing auxiliary and equalizing main repeaters has a different assigned frequency. The identification tones are located just below the L3 switching tone and message transmission frequency bands and are spaced at 1-kc intervals. These identification tones are inserted at each amplifier as illustrated in Fig. 2. The output tone of the oscillator is inserted at the output of the amplifier through a high-impedance bridging pad. The oscillator tone is also applied to the input of the amplifier through an adjustable attenuator, an adjustable phase shifter, and a high-impedance bridging pad. The attenuator and the phase shifter are adjusted so that the oscillator tone passing through the amplifier is equal to, but 180 degrees out of phase with, the oscillator tone applied directly to the amplifier output. The two tone signals then balance each other at the amplifier output. In this manner a distinctive tone is inserted into each amplifier but is transmitted over the cable to the receiving terminal at a very low level. This is advantageous because for normal, nontrouble con-

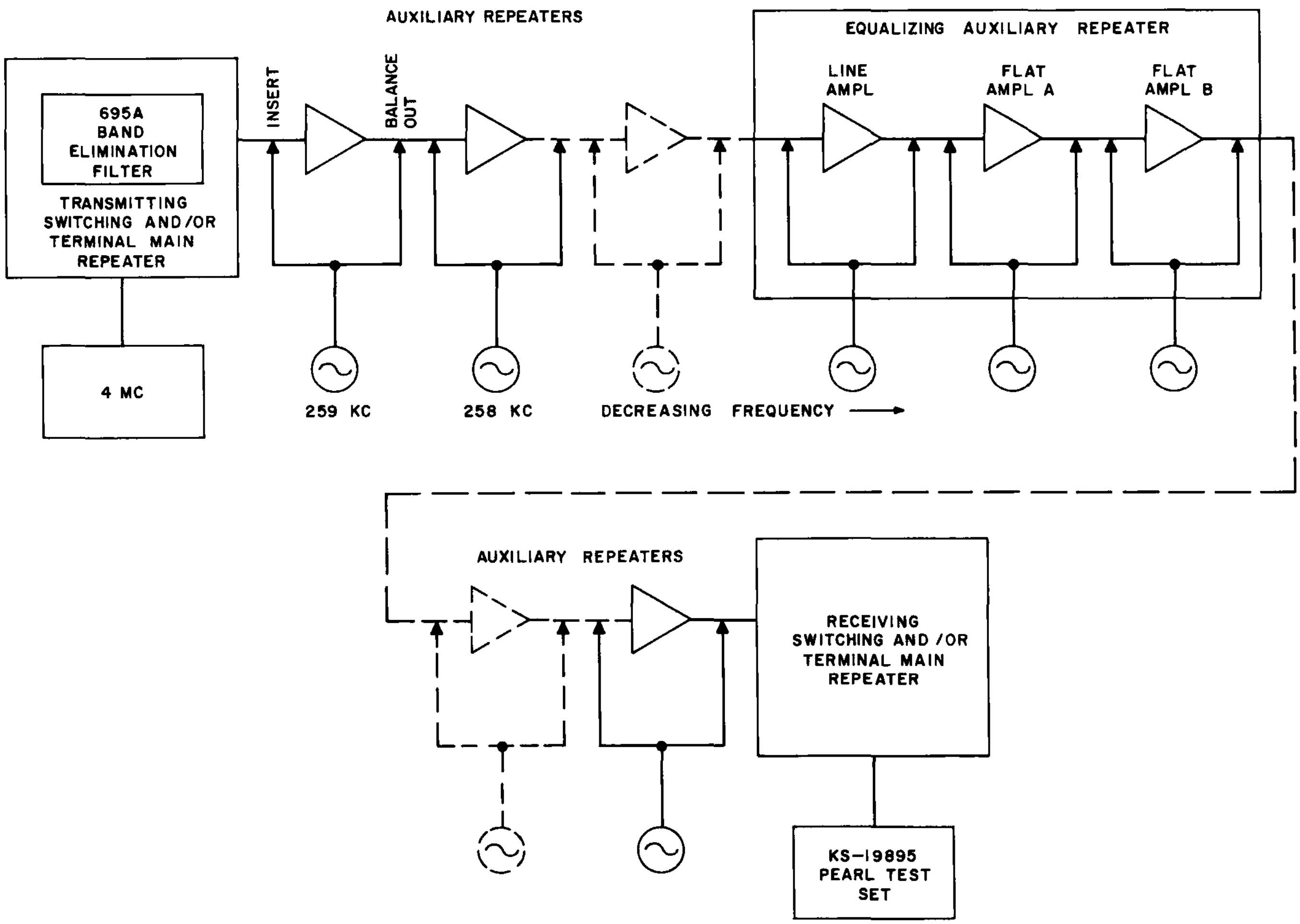


**Fig. 1 — Application of PEARL to L3 Repeatered Line Switching Section**

ditions the presence of the low-level tones confirms the proper operation of the line facilities and the PEARL circuits.

**1.04** If the gain of an amplifier changes appreciably, the balance of the identifying tone at the amplifier output will be upset, and the tone from that amplifier will be transmitted over the line to the receiving main station at a higher level. At the main station, the frequency of the received tone identifies the amplifier experiencing the gain change. Should an amplifier fail completely, the full oscillator signal power applied at the amplifier output would be transmitted to the main station.

**1.05** A perfect balance of oscillator tones cannot be maintained over long periods of time, but good amplifiers do maintain balances exceeding 20 db. The tones are transmitted over the line at least 34 db below OTLP. A full strength tone is —20 dbm at the amplifier output and was set thus so as to be compatible with L3 modulation requirements for TV, data, and message circuits.

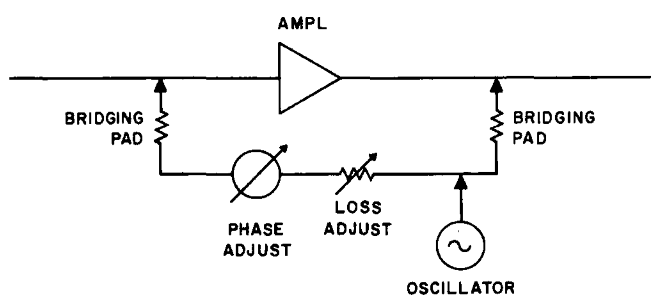


**Fig. 2 — Method of Inserting PEARL Identification Tone at Individual Amplifier**

**1.06** As previously described, the identification tones are located just below the L3 switching signal and message transmission bands. The gain of L3 line amplifiers is a square root of frequency characteristic that matches the coaxial cable loss. The gain-frequency characteristic of the amplifier is controlled by an external regulator to compensate for changes, due to temperature, of the coaxial cable loss. The normal amplifier gain change at frequencies below the L3 band is a fraction of the change at frequencies above the band. Therefore, the lower band is the more desirable for PEARL use.

**1.07** For normal applications the identification tones will be spaced at 1-kc intervals in a band extending from 210 to 259 kc. This provides a total of 50 tones and will accommodate the majority of switching sections in the Bell System. Because the system gain decreases with decreasing frequency within the frequency range assigned to the PEARL tones, the highest frequency of 259 kc is always assigned to the first amplifier from the transmitting end, and each succeeding amplifier toward the receiving terminal is assigned a tone decreased in frequency by 1 kc (see Fig. 1). In case of a failure, the tone from the failed amplifier must pass through all succeeding amplifiers to reach the receiving end. Since the tones from the amplifiers near the transmitting end must pass through the greatest number of amplifiers to reach the receiving station, the most distant amplifiers are assigned frequencies which suffer the least loss per amplifier.

**1.08** For switching sections which exceed the 50-amplifier limit set for normal application, the basic PEARL capacity is extended to provide an additional 10 tones to allow a total of 60 tones per switching section. These additional tones occupy the 260- to 269-kc frequency range. Although these additional tones are higher in frequency than the basic tones, the additional tones are placed at the ***receiving*** end of the switching section. The 269-kc tone is inserted adjacent to the 210-kc tone, and decreasing frequencies at 1-kc intervals are inserted at each amplifier toward the receiving main station. This is done in order to allow the 259-kc tone to ***always*** be inserted at the first amplifier from the transmitting end.

**1.09** Modulation measurements are made by removing the line from service and applying a high-level 4-mc tone at the transmitting end of the section. In each amplifier, a distinctive set of modulation products is formed by the high-level tone and the identifying tone. Each amplifier will produce its own set of modulation products by mixing the test tone with the PEARL tone. Since each amplifier contains a PEARL identification tone which is restricted to the amplifier by the balance at the amplifier output, these modulation products will be unique for each amplifier and will identify the amplifier.

**1.10** The second-order sum product is used to measure the modulation performance of the amplifiers. These products are in the frequency band from 4210 to 4259 kc (or 4269 kc for long sections).

**1.11** The use of PEARL with switching main repeaters requires a 695A blocking filter in the line-connecting equipment between switching sections. This high-pass filter blocks both the line switching tones (280 to 296 kc) and the PEARL tones (210 to 269 kc) and passes the L3 transmission band to the next switching section. This filter is a replacement for the 546A filter which blocks only the switching tones.

**1.12** The KS-19895 L3 PEARL test set is used for balancing the PEARL equipment. The test set is a transistorized, portable, and battery-powered unit.

## 2. EQUIPMENT DESCRIPTION

**2.01** The equipment required to provide PEARL capability for auxiliary, equalizing auxiliary, and equalizing main repeaters consists of either a J68818C or J68818D identification tone and balancing unit equipped with 62-type oscillators and ED-50494 input and output probe assemblies.

**2.02** The J68818C identification tone and balancing unit (see Fig. 3) contains the equipment required to provide PEARL capability for both the odd and even amplifiers of an auxiliary repeater, thus providing the equipment needed for both directions of transmission. The unit consists of two identical identification tone and balancing circuits and a power supply which is common to both. Each identification tone and balancing circuit contains a plug-in 62-type oscillator, a phase

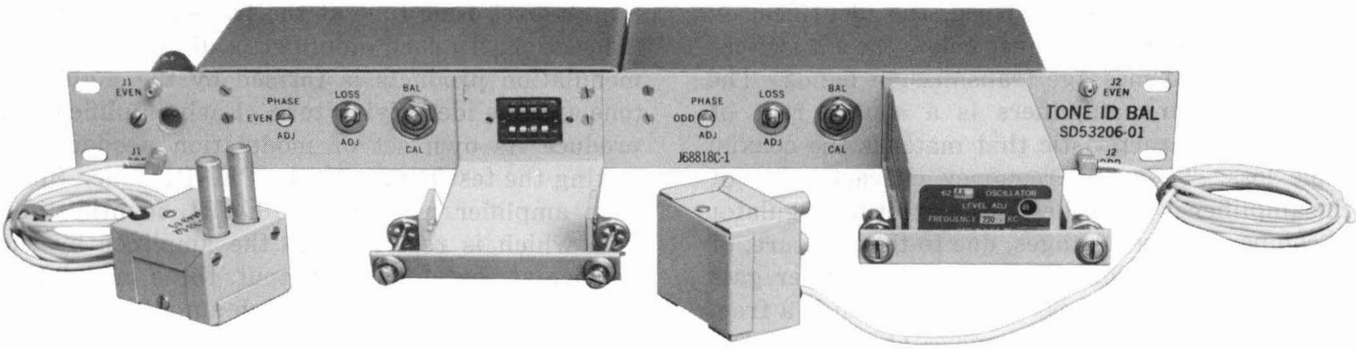


**Fig. 3 — J68818C Identification Tone and Balancing Unit**

shift network and a loss-adjust network to adjust the phase and loss of the oscillator signal, a balancing and calibrating switch, and input and output jacks for the ED-50494 probes. Power for the panel is obtained from the repeater 190-volt power supply. The components comprising the identification tone and balancing unit are located on a 1-3/4 inch mounting plate. This panel operates over the 210- to 269-kc band.

**2.03** The J68818D identification tone and balancing unit (see Fig. 4) contains the equipment required to provide PEARL capability for the line amplifier and flat A and flat B amplifiers of an equalizing auxiliary repeater or equalizing main repeater. A separate panel is required for each direction of transmission. The unit consists of three identification tone and balancing circuits, three associated plug-in 62-type oscillators, and a power supply which is common to all three circuits of the J68818D unit. Power for the panel is obtained from the repeater 190-volt power supply. The components comprising the identification tone and balancing unit are located on a 3-1/2 inch mounting plate.

**2.04** The J68818D identification tone and balancing unit is available in three versions to provide different PEARL frequency ranges as follows: 210 to 231 kc, 231 to 259 kc, and 230, 231, and 232 kc. The differences between the three units are in their electrical component values and wiring options.

**2.05** The ED-50494 amplifier input and output probe assemblies (Fig. 3 and 4) are mounted on the transmission panels at the amplifier input and output jacks. The input and output probes are the same except for a 180° phase difference in their outputs. Each probe assembly con-

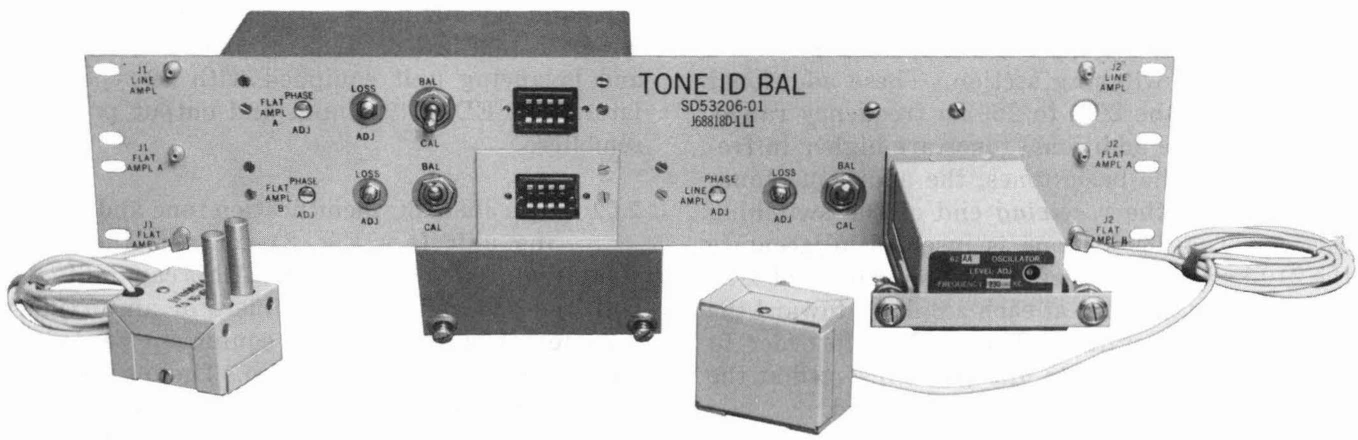


**Fig. 4 — J68818D Identification Tone and Balancing Unit**

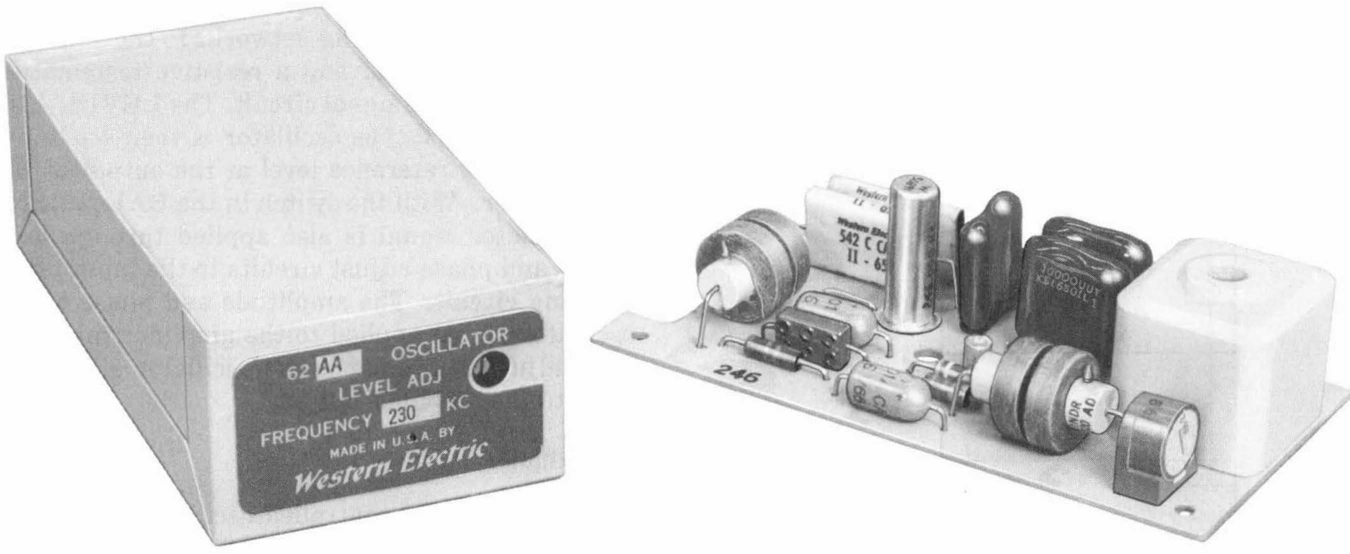


Fig. 5 — 62-Type Oscillator

tains an impedance-matching transformer, two bridging resistors, a frequency-compensating capacitor, and two coaxial jacks. A coaxial cable is used to connect each probe assembly to the PEARL identification tone and balancing unit.

**2.06** The 62-type oscillators are transistorized plug-in units (Fig. 5). Each oscillator contains a transistor, a crystal, a LEVEL ADJ control, and associated components. The oscillators are coded as indicated in Table A. Each oscillator is stamped with its code and its frequency designation. Each oscillator requires 27 volts at approximately 10 milliamperes for operation. The power to operate the oscillators is obtained from the power supply located in the PEARL identification tone and balancing unit.

**2.07** The PEARL equipment required for a J68819A auxiliary repeater or a J68819G auxiliary repeater consists of one J68818C identification tone and balancing unit, two ED-50494 amplifier input probe assemblies, two output probe assemblies, and two 62-type oscillators. Fig. 6 illustrates the location of the J68818C unit in an auxiliary repeater bay.

**2.08** The PEARL equipment required to fully equip a J68819B equalizing auxiliary repeater or a J68830E equalizing main repeater consists of one J68818D identification tone and

**TABLE A**

**62-TYPE OSCILLATORS**

| 62-TYPE | FREQ (KC) | 62-TYPE | FREQ (KC) | 62-TYPE | FREQ (KC) |
|---|---|---|---|---|---|
| A | 210 | AA | 230 | BA | 250 |
| B | 211 | AB | 231 | BB | 251 |
| C | 212 | AC | 232 | BC | 252 |
| D | 213 | AD | 233 | BD | 253 |
| E | 214 | AE | 234 | BE | 254 |
| F | 215 | AF | 235 | BF | 255 |
| G | 216 | AG | 236 | BG | 256 |
| H | 217 | AH | 237 | BH | 257 |
| J | 218 | AJ | 238 | BJ | 258 |
| K | 219 | AK | 239 | BK | 259 |
| L | 220 | AL | 240 | BL | 260 |
| M | 221 | AM | 241 | BM | 261 |
| N | 222 | AN | 242 | BN | 262 |
| P | 223 | AP | 243 | BP | 263 |
| R | 224 | AR | 244 | BR | 264 |
| S | 225 | AS | 245 | BS | 265 |
| T | 226 | AT | 246 | BT | 266 |
| U | 227 | AU | 247 | BU | 267 |
| W | 228 | AW | 248 | BW | 268 |
| Y | 229 | AY | 249 | BY | 269 |

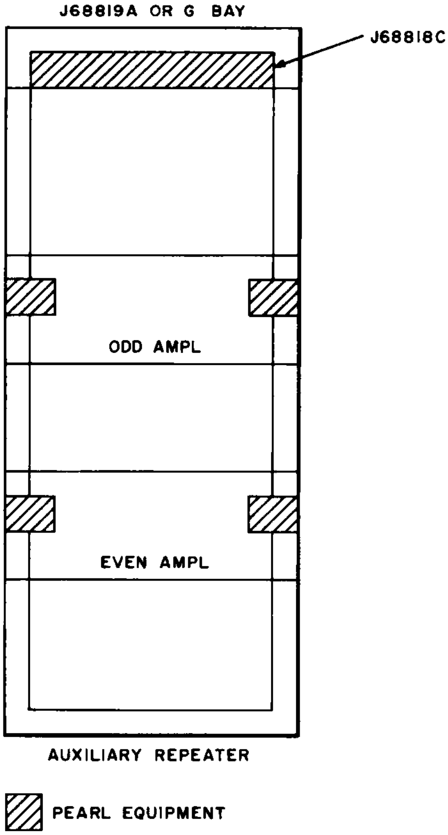


**Fig. 6 — Auxiliary Repeater Bay Equipped with J68818C Identification Tone and Balancing Unit**

balancing unit, three ED-50494 amplifier input probe assemblies, three output probe assemblies, and three 62-type oscillators. Fig. 7 illustrates the location of the J68818D unit in each of the repeater bays.

## 3. FUNCTIONAL DESCRIPTION

### A. General

**3.01** As illustrated in Fig. 8, the identification tone and balancing circuit consists of an oscillator, a pad, a bandpass filter, a balance-calibrate (BAL CAL) switch, a loss-adjust and a phase-adjust network, input and output probe bridging circuits, and a power supply circuit.

**3.02** The signal output of the 62-type oscillator is applied through a 2-db pad and a 210- to 269-kc bandpass filter. The filtered oscillator signal is applied to the output probe bridging circuit and to contacts of the BAL CAL switch. With the switch in the CAL position, the circuit through the loss- and phase-adjusting networks to the amplifier input is disconnected and a resistive termination is connected to the signal circuit. The LEVEL ADJ control on the 62-type oscillator is then set to obtain a specific reference level at the output of the L3 amplifier. With the switch in the BAL position, the oscillator signal is also applied through loss-adjust and phase-adjust circuits to the input probe bridging circuit. The amplitude and phase of the oscillator signal applied to the amplifier input are then adjusted to balance the oscillator signal applied to the amplifier output.

### B. Oscillator

**3.03** The crystal-controlled oscillator contains a single NPN transistor. The output of the oscillator is controlled by a LEVEL ADJ potentiometer in the power supply lead. The output power of the oscillator at the 75-ohm input of the 2-db pad is variable between +13 dbm and +17 dbm to compensate for circuit losses between the oscillator output and the amplifier output. Since these circuit losses vary with frequency, the oscillator LEVEL ADJ control is set as required to obtain a signal of —20 dbm at the L3 amplifier output.

### C. 2-DB Pad

**3.04** The 2-db pad located at the output of the oscillator furnishes a resistive load for the oscillator and allows the LEVEL ADJ control setting on the oscillator to be set to approximately midpoint.

### D. Bandpass Filter

**3.05** A 210- to 269-kc bandpass filter is provided at the output of the 2-db pad to reduce the level of the oscillator harmonics which fall in the L3 band. The maximum allowable harmonic tone in the L3 band is —82 dbm. The second harmonic of a PEARL oscillator has the highest level and will fall in the L3 band. The purpose of the bandpass filter is to reduce the harmonic content of the oscillator signal to at least —82 dbm at the amplifier output.

### E. Calibrate-Balance Switch

**3.06** The CAL BAL switch is used in the CAL position to switch the PEARL oscillator signal from the amplifier input to a 150-ohm terminating resistor. This presents the same impedance

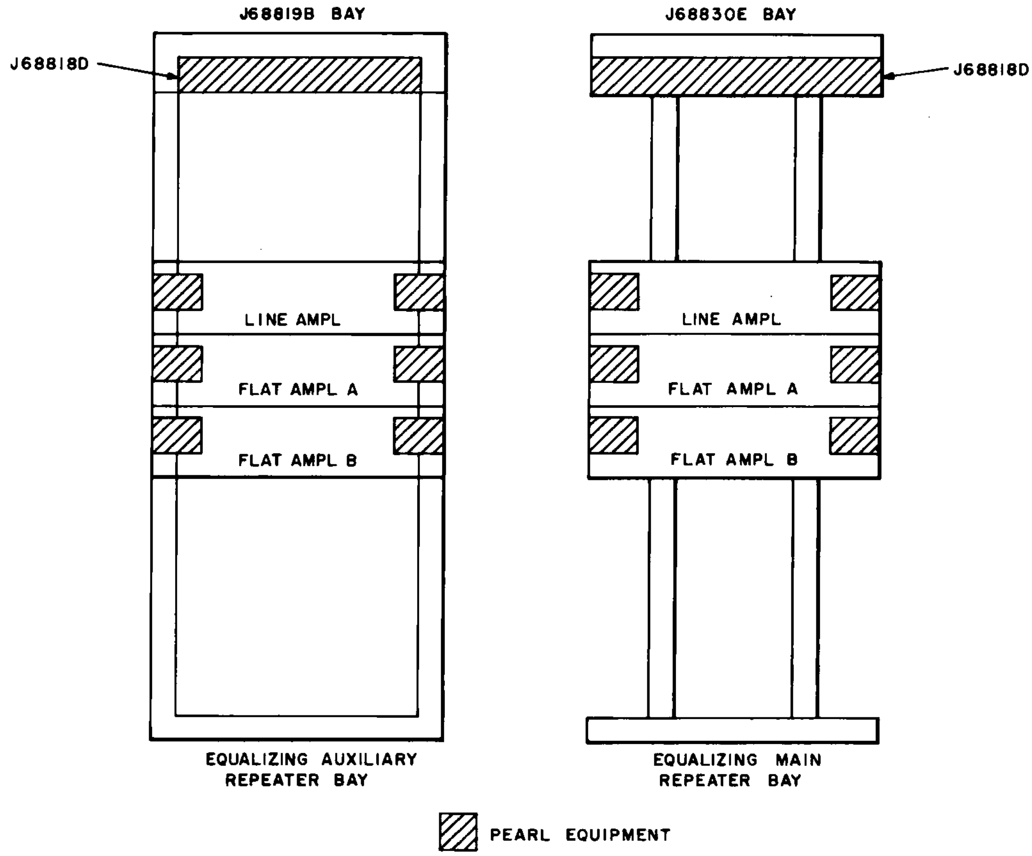


**Fig. 7 — Equalizing Auxiliary and Equalizing Main Repeater Bays Equipped with J68818D Identification Tone and Balancing Unit**

load to the oscillator as when the switch is in the BAL position. With the switch in the CAL position, the LEVEL ADJ control is used to adjust the oscillator signal at the amplifier output.

**3.07** With the CAL BAL switch in the BAL position, the oscillator output is applied to the amplifier input through controls, while the signal is also being applied to the amplifier output.

### F. Loss-Control Circuit

**3.08** The loss-control circuit consists of a bridged-T attenuator in series with a fixed pad. The attenuator in conjunction with the fixed pad is used to adjust the level of the oscillator signal and presents a constant 150-ohm load to the oscillator through the bandpass filter. The loss introduced by the pad and the attenuator is adjusted to be equal to the gain of the amplifier.

**3.09** Since the gain of a line amplifier and that of a flat-gain amplifier differ by approximately 20 db in the 210- to 269-kc band, the value of the fixed pad is different for the two applications. When the identification tone and balancing circuit is used with line amplifiers, the fixed pad provides 5 db attenuation; combined with the variable attenuator, it provides loss control over the range of 5 to 10 db. When the identification tone and balancing circuit is used with flat-gain amplifiers, the fixed pad provides 26 db attenuation; in combination with the variable attenuator, it provides control over the range of 26 to 31 db.

### G. Variable Phase Shift Circuit

**3.10** The variable phase shift circuit is a modified half-section, low-pass filter and contains a variable capacitor which is used for adjusting the phase shift of the tone applied to the input of the amplifier. Since the phase shift of a line amplifier and a flat-gain amplifier differ considerably, the amount of variable phase shift will be different for the two applications.

3.11 When the identification tone and balancing circuit is used with line amplifiers, the variable phase shift circuit is factory equipped to provide a range of phase shift from approximately 30 to 70 degrees over the frequency range of 210 to 269 kc; the nominal phase shift is 54 degrees at 230 kc at an impedance of 150 ohms.

3.12 When the identification tone and balancing circuit is used with flat-gain amplifiers, the variable phase shift circuit is factory equipped to provide a range of phase shift from approximately 10 to 20 degrees over the operating frequency range. Since the phase shift of the flat-gain amplifiers varies with frequency, the phase shift circuit is factory equipped to operate over a particular portion of the 210- to 269-kc frequency band.

### H. Input and Output Probe Bridging Circuits

3.13 The bridging circuit furnishes a means of injecting the identification tone into the amplifier input and output jacks. To avoid excessive insertion loss and thus excessive oscillator power output requirements, an impedance of only 10,000 ohms is used to bridge the amplifier. The use of just a bridging resistor alone would result in a flat insertion loss across the L3 band. The line amplifier has a square root of frequency gain shape. To approximate this shape and thereby reduce misalignment error, a shunting capacitor

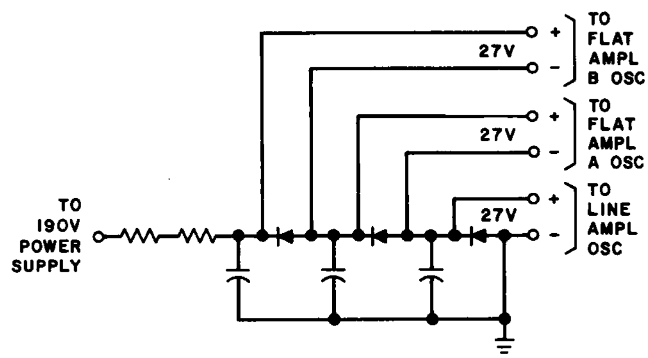


**Fig. 10 — Identification Tone and Balancing Unit Power Supply for Equalizing Auxiliary or Equalizing Main Repeater**

is placed across the high-impedance bridging resistor at the midpoint.

3.14 An impedance-matching transformer is used to match the 10,000-ohm bridging circuit to the 150-ohm identification tone and balancing circuit. To avoid the possibility of noise pickup by high-impedance leads, the impedance-matching transformers and bridging circuits are located at the input and output jack fields of the amplifier. A coaxial cable is used between each input and output probe assembly and the identification tone and balancing circuit. The two coaxial jacks on the probe assembly are multipled so as to assure transmission continuity when installed in the amplifier jack field.

### I. Power Arrangements

3.15 Power used to operate the PEARL oscillators is obtained from the associated repeater +190 volt power supply. It is converted in the identification tone and balancing unit by individual power supplies to provide the 27 volts necessary for operation. The power supply in the J68818C unit consists of a dropping resistor in series with two zener diode oscillator supplies as illustrated in Fig. 9. The power supply in the J68818D unit consists of two dropping resistors in series with three zener diode oscillator supplies as illustrated in Fig. 10. The capacitors act as filters to keep the oscillator signal out of the power supply.

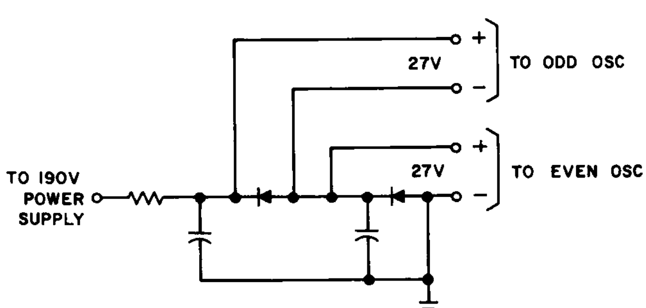


**Fig. 9 — Identification Tone and Balancing Unit Power Supply for Auxiliary Repeater**

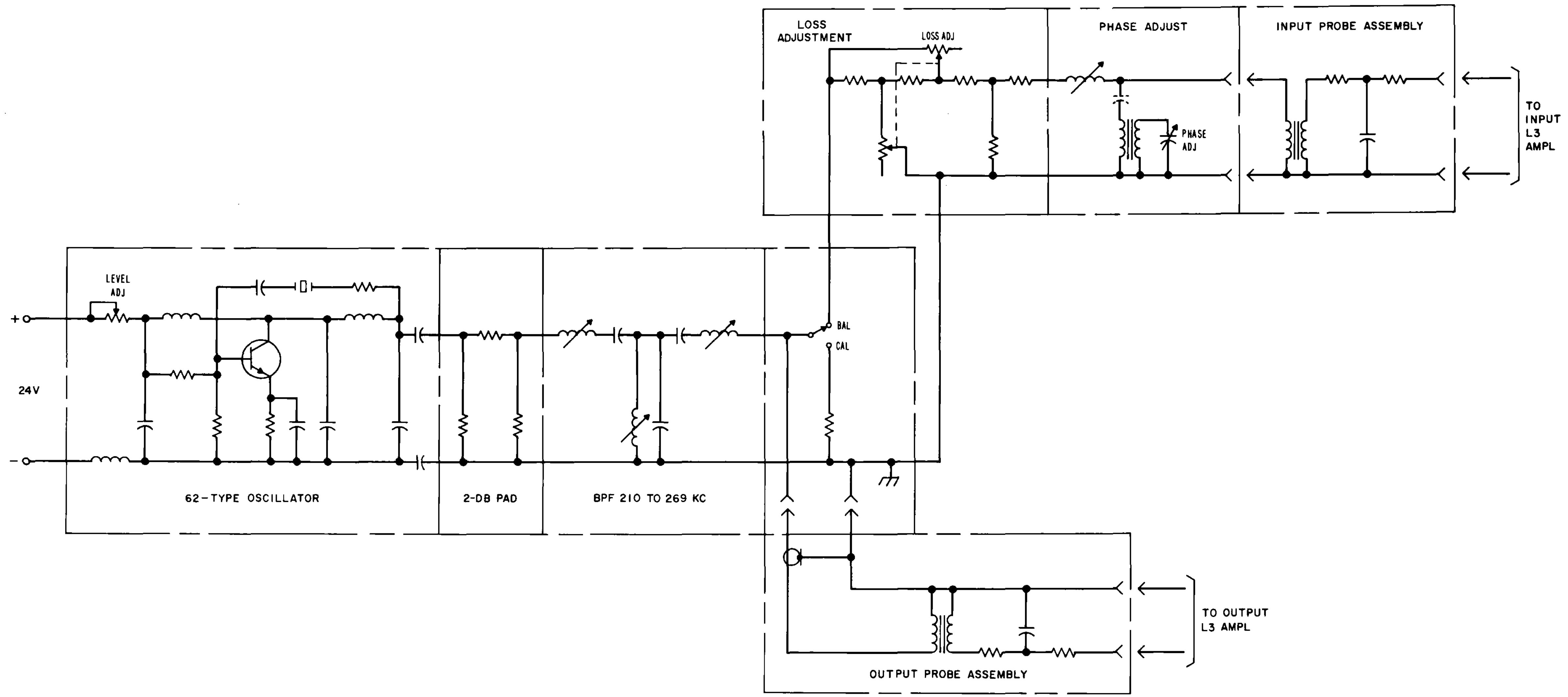


**Fig. 8 — Identification Tone and Balancing Circuit — Simplified Schematic**