1. GENERAL

The Model TLE2280A Series Power Amplifier Deck consists of the power amplifier deck casting and associated hardware, which contains the power amplifier substrates and the power control board. Refer to the power amplifier deck model chart, shown in Figure 1, for a cross reference of the power amplifier deck kits. The following paragraphs detail the theory of operation and troubleshooting information for the power amplifier circuitry. Because the setting of power levels is affected by the alignment of the exciter, the power set procedure is part of the overall transmitter alignment procedure provided in the Transmitter section of this manual.

2. THEORY OF OPERATION

2.1 POWER AMPLIFIER CIRCUITRY

2.1.1 The output from the exciter is applied, via J802, to the power amplifier substrates. The 350 mW (nominal) exciter output signal is amplified by Q801 and Q802, on the low level amplifier substrate, to approximately 1.5 watts.

2.1.2 The low level amplifier output signal is applied to predriver Q803 and driver Q804, which together develop up to 45 watts of rf power. The driver output is split into three portions and applied to three parallel final amplifiers, Q805, Q806, and Q807. The three parallel final amplifier output signals are combined to provide a PA deck rf power output (minimum) of 110 watts (at 450-470 MHz), or 95 watts (at 470-512 MHz).

2.1.3 The PA deck rf power output signal is routed through a harmonic filter substrate and, via a directional coupler on the power control board, passed on to the station antenna connector, J803.

2.2 POWER CONTROL CIRCUITRY

2.2.1 General

2.2.1.1 The power control board provides power amplifier protection and power regulation. Output impedance match, final amplifier current and temperature, control voltage level, and power output are monitored by the power control circuit. In turn, the power control circuit controls the low level amplifier output to provide the proper level for optimum power amplifier operation.

2.2.1.2 The resistive voltage divider comprising of R926, R927, and R928 provides dc biasing voltages to improve directivity of the directional coupler, and set the operating point of the directional coupler inputs to the forward power and protection comparators. The reference voltage for forward power detector U901A is developed across power set control R911. The reference voltage for protection comparator U901B is developed at the junction of R913 and R914.

2.2.2 Thermal Protection

As the temperature of the power amplifier board increases, the resistance of RT801 decreases, causing the voltage on the TEMP SENSE HI line to decrease. When this voltage reaches approximately 3.7 volts, CR904 conducts, dropping both the forward power detector and protection comparator reference voltages. This causes the comparators to reduce the voltage on the CONTROL VOLTAGE line, which reduces exciter drive to the power amplifier. The net effect of this is to lower power amplifier output and heat, keeping operating temperature within safe operating limits.

2.2.3 Forward Power Level Control

Forward output power, sampled by the directional coupler, is rectified and filtered by the circuitry associated with CR901. The detected voltage is applied to the inverting input of forward power detector U901A, where it is compared to the set level at the non-
# MODEL CHART
FOR
TLE2280A SERIES
UHF POWER AMPLIFIER DECK
VARIABLE RF POWER OUTPUT
450-470 MHz: 100 TO 50 WATTS
470-494 MHz: 85 TO 45 WATTS
494-512 MHz: 85 TO 45 WATTS

CODE:
- = ONE ITEM SUPPLIED
* = NOT PART OF MODEL SERIES, LISTED FOR REFERENCE ONLY

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>HFE4014A</td>
<td>HARMONIC FILTER</td>
</tr>
<tr>
<td>HLE4006A</td>
<td>LOW LEVEL AMPLIFIER</td>
</tr>
<tr>
<td>HLE4005A</td>
<td>COMBINER (450-494 MHz)</td>
</tr>
<tr>
<td>HLE4005A</td>
<td>COMBINER (494-512 MHz)</td>
</tr>
<tr>
<td>HLE4070A</td>
<td>SPLITTER</td>
</tr>
<tr>
<td>HLE4074A</td>
<td>DRIVER INPUT SUBSTRATE</td>
</tr>
<tr>
<td>HLE4073A</td>
<td>PRE-DRIVER SUBSTRATE</td>
</tr>
<tr>
<td>HLE4063A</td>
<td>POWER TRANSISTOR KIT (450-494 MHz)</td>
</tr>
<tr>
<td>HLE4064A</td>
<td>POWER TRANSISTOR KIT (494-512 MHz)</td>
</tr>
<tr>
<td>TKN8971A</td>
<td>INTERNAL PA CABLE</td>
</tr>
<tr>
<td>TLE5623A</td>
<td>PA MISCELLANEOUS PARTS (450-494 MHz)</td>
</tr>
<tr>
<td>TLE5624A</td>
<td>PA MISCELLANEOUS PARTS (494-512 MHz)</td>
</tr>
<tr>
<td>TRN5408A</td>
<td>POWER CONTROL BOARD COVER</td>
</tr>
<tr>
<td>TRN5668A</td>
<td>POWER CONTROL BOARD</td>
</tr>
<tr>
<td>TRN5708A</td>
<td>DISTRIBUTION BOARD</td>
</tr>
<tr>
<td>TRN5708A</td>
<td>PA HARDWARE</td>
</tr>
</tbody>
</table>

*FIGURE 1. Power Amplifier Deck Model Complement*
inverting input. If the two levels are not the same, the output level of U901A changes in a direction that raises or lowers the voltage on the CONTROL VOLTAGE line, until the inputs to U901A are matched. This provides a constant rf power output from the PA.

2.2.4 Reverse Power Protection

Reverse (reflected) power sampled by the directional coupler is rectified and filtered by the circuitry associated with CR902. The output voltage across R908 is applied to the inverting input of U901B, and compared to the reference voltage. Under normal operating conditions with the transmitter feeding a 50-ohm load, the reference voltage is higher than the directional coupler voltage. This keeps the output of U901B at maximum, keeping Q905 turned off. If the reflected power increases to the point that the voltage across R908 exceeds the reference voltage, the output of U901B drops, turning on Q905. Increased collector voltage on Q905 causes an increase in the voltage applied to the inverting input of U901A, to force the control voltage and the power output to drop until the inputs to U901A equalize.

2.2.5 Over-Current Protection

Final amplifier current in the power amplifier is sensed through R801. The voltage drop across R801 is applied to the base at Q907. As the voltage at Q907 decreases, Q907 turns on, increasing the voltage across R908. The power cutback occurs in the same manner as described in the Reverse Power Protection paragraph.

2.2.6 Control Voltage Limit

The circuit of Q905 compares the voltage on the CONTROL VOLTAGE line to the voltage set by the position of the wiper on R931. When the control voltage exceeds the set limit, Q905 conducts, raising the voltage at the inverting input of U901A. U901A, in turn, reduces the control voltage until both inputs are balanced.

3. POWER AMPLIFIER SERVICING

3.1 GENERAL

Troubleshooting information for the MSR 2000 station power amplifier is presented in several levels. It is best to begin by following the power amplifier troubleshooting procedure given in Table 1. If the specific cause of the transmitter failure is not covered in Table 1, the service person is directed to Table 2 (for power control board problems) or to paragraph 3.2 (for power amplifier problems).

3.2 POWER AMPLIFIER SUBSTRATE TROUBLESHOOTING PROCEDURE

3.2.1 Visual Checks

Inspect all transmitter microstrips for obvious physical defects such as broken leads, broken or disconnected components, cracked microstrips, or leached chip capacitors. Microstrip cracks are usually hard to see but can often be found by sliding the tip of a modeling knife or some other sharp object along the surface of the ceramic substrate. Usually, a noticeable "bump" will be felt as the sharp object passes over the crack in the microstrip. Slide the knife in both directions. An ohmmeter can also be used to locate cracks.

Checks and tests in the following paragraphs and Table 1 may be used to locate defects isolated to the power amplifier substrates. The following checks assume 13.8 volts dc is applied to the PA and that the amplifier is driven with a 250-400 mW rf source. Set all power control potentiometers (R911, R931, R939) fully clockwise.

WARNING

Key station intermittently until problem is repaired.

3.2.2 DC Voltage Checks

Step 1. Check the voltage between the C870 A + feed-thru capacitor (red lead) and the C871 A - feed-thru capacitor (black lead). If the voltage is not the same as the power supply voltage, check the cabling.

Step 2. Measure the dc voltage at the collectors of the final amplifier (Q805-Q807) with respect to A - on the power amplifier. The readings should be greater than +12 volts with the transmitter keyed or unkeyed. If not, check R801 (located on the power distribution board), the A + collector feed coils, the feed pins, and the combiner substrate for continuity.

Step 3. Similarly, check the dc voltages at the collectors of Q803 and Q804. The readings should be greater than +12 volts. If not, check the A + collector feed coils, the feed pins, the substrates, and the power distribution board for continuity.

Step 4. The low level amplifier operates from a controlled voltage supplied by the power control circuitry. This voltage normally varies between approximately +3 volts and +10 volts. Key the transmitter and check the control voltage at the collectors of Q801 and Q802. If the readings are less than +10 volts, check the collector feed coils, the feed pins, the low level amplifier substrate, and the power distribution board for continuity or shorts. If these checks fail to isolate the problem, proceed to Table 2.
### Table 1. Power Amplifier Troubleshooting Procedure

<table>
<thead>
<tr>
<th>Step</th>
<th>Symptom</th>
<th>Procedure</th>
<th>Normal Indication</th>
<th>If Normal</th>
<th>If Abnormal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Suspected Transmitter Failure</td>
<td>Measure rf output power at antenna connector.</td>
<td>Rated power</td>
<td>Transmitter OK.</td>
<td>High Power — perform Power Amplifier Control and Protection Troubleshooting Procedure. Low Power — go to 3. No Power — go to 2.</td>
</tr>
<tr>
<td>2</td>
<td>No Output Power</td>
<td>a. Set all controls fully clockwise and observe meters 1 and 5.</td>
<td>Both greater than 15 μA</td>
<td>Go to 2b.</td>
<td>No Indication — Perform Transmitter Control and Protection Troubleshooting Procedure. Meter 1 indication, no Meter 5 indication — go to 2e.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. Measure dc voltage across antenna relay coil during transmit.</td>
<td>5 V</td>
<td>Go to 2c.</td>
<td>Check coil continuity (dc resistance approximately 160 ohms).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. Check reed switch continuity.</td>
<td>Continuous during transmit</td>
<td>Go to 2d.</td>
<td>Replace.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>d. Check harmonic filter and output cable for shorts and discontinuities.</td>
<td>See schematic diagram</td>
<td>Perform Power Amplifier Substrate Troubleshooting Procedure.</td>
<td>Repair Defect.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>e. Measure rf power at the exciter output.</td>
<td>300 mW minimum</td>
<td>Perform Power Amplifier Substrate Troubleshooting Procedure.</td>
<td>Refer to Exciter section of manual.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. Measure rf power at exciter output.</td>
<td>300 mW minimum</td>
<td>Perform Power Amplifier Substrate Troubleshooting Procedure.</td>
<td>Refer to Exciter section of manual.</td>
</tr>
</tbody>
</table>

### Table 2. Power Amplifier Control and Protection Troubleshooting Procedure

<table>
<thead>
<tr>
<th>Step</th>
<th>Symptom</th>
<th>Procedure</th>
<th>Normal Indication</th>
<th>If Normal</th>
<th>If Abnormal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No meter 1 or 5 with all controls clockwise</td>
<td>a. Disconnect PA from exciter J802. Check for keyed 9.3 V at U901-8.</td>
<td>9.3 V</td>
<td>Go to 1b.</td>
<td>Check Q554 (in exciter) keyed 9.3 V switch.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. Measure output voltage of U901A, pin 1.</td>
<td>Greater than 3.3 V</td>
<td>Repair fault in control voltage amplifiers Q903 &amp; Q904.</td>
<td>Go to 1c.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. Measure voltages to input of U901A, pins 2 &amp; 3.</td>
<td>Pin 3 greater than Pin 2</td>
<td>U901 defective.</td>
<td>Check for shorts or opens in resistive feed circuits to pins 2 &amp; 3.</td>
</tr>
<tr>
<td>2</td>
<td>Meter 1 reads max of about 10 μA with all</td>
<td>a. Disconnect PA from exciter at J802. Measure voltage of protection</td>
<td>Greater than 7 V</td>
<td>Troubleshoot Q905 circuit.</td>
<td>Go to 2b.</td>
</tr>
<tr>
<td></td>
<td>controls fully clockwise, little or no output</td>
<td>comparator output, at U901B-7.</td>
<td></td>
<td></td>
<td>Analyze and repair current limiter circuitry Q906, Q907 &amp; Q908.</td>
</tr>
<tr>
<td></td>
<td>power</td>
<td>b. Measure voltages to input of U901B, pins 5 &amp; 6.</td>
<td>Pin 5 greater than Pin 6</td>
<td>U901 defective.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>All controls inoperative and meter 1 approx.</td>
<td>a. Disconnect PA from exciter at J802. Observe meter 1 in RX mode.</td>
<td>0 μA</td>
<td>Go to b.</td>
<td>Repair fault in control voltage amplifiers Q903 &amp; Q904.</td>
</tr>
<tr>
<td>4</td>
<td>Control voltage limit (R931), current limit</td>
<td>a. Q905 and associated resistors probably defective. Analyze and repair.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(R939) and reflected power (VSWR) protection inoperative</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2. Power Amplifier Control and Protection Troubleshooting Procedure (Cont’d.)

<table>
<thead>
<tr>
<th>Step</th>
<th>Symptom</th>
<th>Procedure</th>
<th>Normal Indication</th>
<th>If Normal</th>
<th>If Abnormal</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Current limit (R939) inoperative</td>
<td>Disconnect PA from exciter at J802. Pull current sense line (green) from C897. Observe meter 1.</td>
<td>15 mA</td>
<td>Check for short to A+ of current sense line.</td>
<td>Analyze fault in current limit circuit Q906, Q907 &amp; Q908 and repair.</td>
</tr>
<tr>
<td>6</td>
<td>Reflected power (VSWR) protection inoperative</td>
<td>Check and repair defect in reflected power detector components R902, CR902, etc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Thermal protection inoperative</td>
<td>Check and repair defect in thermal protection components RT801, R915, R930 and CR904.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Power set (R911) inoperative</td>
<td>Check and repair defect in forward power detector components R901, CR901, etc.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.2.3 Low Power Output

Step 1. Remove the exciter output cable at J802. Connect the exciter to a UHF-rated wattmeter with a 50-ohm (resistive) dummy load. Key the transmitter. If the power is less than 300 milliwatts, refer to the exciter troubleshooting procedure. If it is greater than 300 milliwatts, replace the exciter cable and continue.

Step 2. Remove the strap connecting the driver output stripline to the splitter substrate. Solder the center conductor of an 8-inch (or shorter) 50-ohm coaxial test cable to the driver output stripline and the shield of the coaxial cable to the adjacent ground pad. With the coaxial cable terminated with a 50 ohm, 50-ohm (resistive) dummy load and a UHF-rated wattmeter, key the transmitter. If the driver output is less than 40 watts, the low level amplifier control stage must be checked (Step 3). Remove the coaxial cable and replace the strap.

Step 3. Remove the strap connecting the output stripline (at the output of C809) of the low level amplifier to the input of the pre-driver stage. Remove the coaxial cable from the driver output and solder it in similar fashion to the low level amplifier output. With the transmitter keyed, the power measured at the output of C809 should be at least 2 watts. If not, replace the low level amplifier as instructed in paragraph 3.3.1. Replace the removed straps and realign the transmitter.

Step 4. If the measured power is greater than 2 watts, note the current drawn by the radio set when keyed. Replace the strap between low level amplifier and pre-driver stages and return the coaxial cable to the driver output. With the transmitter keyed, if the increase in the current drawn (over that previously noted) is less than 1.5 amperes, replace the pre-driver (Q803) module. If greater than 1.5 amperes, replace the driver (Q804) module. The power output should now be greater than 40 watts.

Step 5. If amplifier output is still low, the fault can now be attributed to either the final amplifier, or harmonic filter, or directional coupler (on power control board), or associated cables. Carefully unsolder the coaxial cable from the combiner substrate. In its place, carefully solder an 8 inch (or shorter) 50-ohm coaxial test cable connected to a UHF-rated wattmeter with a 200 watt, 50-ohm (resistive) dummy load.

Step 6. Key the transmitter. If the power output is greater than 130 watts (450-470 MHz range) or 100 watts (470-512 MHz range), the harmonic filter, or directional coupler (on power control board), or associated cables are defective. Replace the faulty component and recheck the power output.

Step 7. If the power output of the final amplifier is low, one (or more) of the final amplifier modules is defective. Alternately unsolder the base tab of each final amplifier (Q805-Q807) module from the splitter substrate. Note the power output each time. Replace the module that degrades the output power the least when the base tab is lifted. Repeat this process if the power output (as specified in Step 6) is not obtained.

3.3 TRANSISTOR MODULE REPLACEMENT

**NOTE**

Transistors are replaced as part of a module assembly. There are six module assemblies in each power amplifier; low level amplifier (controlled stage), pre-driver, driver, and three finals.

3.3.1 Whenever the low level amplifier, or Q804, or Q805, or Q807 is replaced, the additional parts contained in the PA miscellaneous parts kit (TLE5623A for 450-494 MHz or TLE5624A for 494-512 MHz) should also be replaced. When the low level amplifier is replaced, the following parts should be added: C965, C969, R960 and R961. When replacing Q804, C957 and C958 should be added. Add C960 when replacing Q805, and add C961 when changing Q807. Refer to Figure 2.
3.3.2 To remove the low level amplifier (control stage), unsolder the input coax, output strap, and the bias pin. Using C805 as a handle, carefully pull up on the module until Q802 is released from its heat sink clip. Before installing a new module, apply a light coating of heat sink thermal compound to Q802. Care must be exercised in installing the new module to avoid breaking the substrate. When Q802 is aligned with the heat sink clip, apply pressure to Q802 only until the module is firmly seated.

3.3.3 To remove any of the other modules, unsolder the tabs from the ceramic substrates (8 tabs on driver module and 6 on the predriver module and on each of the final stage modules). Remove transistor mounting screws and extract module. Before installing the new module apply a thin coating of heat sink thermal compound to the mounting surface. Be sure that the module output (as indicated by the beveled corner) is facing the proper direction.

CAUTION

The transistor mounting screws must be tightened before the transistor tabs are soldered to the circuit board. Do not tighten more than 6-7 inch pounds, or damage to the transistor may result.

Solder the module tabs to the substrate so that the connection covers the entire surface of the tab.

3.4 RF POWER AMPLIFIER ASSEMBLY AND A+ DISTRIBUTION BOARD REMOVAL

3.4.1 Unless access to the A+ distribution board is required, there should be no need to remove the power amplifier assembly. If access is required, the following procedure should be followed.

Step 1. Unsolder bias pin connections from substrates (total of 7).

Step 2. Unsolder input and output coaxial cables.

Step 3. Remove 10 transistor mounting screws.

Step 4. Remove 5 hex head screws holding the plastic carrier.

Step 5. Remove amplifier (note special precautions in paragraph 3.3.1).

If it is necessary to remove the A+ distribution board, unsolder the 7 feed-thru capacitor connections and remove the 3 mounting screws.

3.4.2 To replace the assembly, reverse the removal procedure. When replacing the power amplifier assembly, note the special handling of the low level amplifier (paragraph 3.3.1). Apply a thin coating of heat sink thermal compound to the transistor mounting surfaces. Start transistor mounting screws to insure pro-
per alignment then insert and tighten the hex head screws in the plastic carrier. Tighten the transistor mounting screws.

3.5 POWER AMPLIFIER FUNCTIONAL TESTS

3.5.1 General

The tests in this section should be performed AFTER servicing but BEFORE alignment, to verify that the power amplifier and control circuitry are operating correctly.

3.5.2 Set-up

Step 1. Connect radio to proper dummy load through a wattmeter.

Step 2. Plug metering connector of DC Metering Chassis, TEK 5 Metering Panel (set to position E) or S1056-59 Portable Test Set, into J1 on power control board.

---

**CAUTION**

Key transmitter only while making test or adjustment.

3.5.3 Control and Protection Tests

3.5.3.1 Control Voltage Limiting

Step 1. Set Current Limit (R939) and Power Set (R911) fully clockwise.

Step 2. Set Control Voltage Limit (R931) fully counterclockwise. Key transmitter and observe meter 1. Meter 1 should read approximately 8 uA.

Step 3. Rotate Control Voltage Limit Set (R931) clockwise. Near mid-rotation the reading of M1 should begin increasing to a maximum of approximately 25 uA at maximum clockwise rotation.

3.5.3.2 Current Limiting

Step 1. Set Power Set (R911) and Control Voltage Limit (R931) fully clockwise.

Step 2. Set Current Limit (R939) fully counterclockwise. Key transmitter and observe M5. Meter 5 should indicate less than 8 uA. Rotate Current Limit clockwise. Meter 5 should increase to a maximum indication of no more than 28 uA before maximum clockwise rotation is reached.

3.5.3.3 Power Set

Step 1. Set Control Voltage Limit (R931) and Current Limit (R939) fully clockwise.

Step 2. Set Power Set (R911) fully counterclockwise.

Step 3. Key transmitter and observe wattmeter. Power output should be zero. Power output should increase as Power Set is rotated clockwise.

3.5.3.4 Thermal Protection

Step 1. Set Control Voltage Limit (R931) and Current Limit (R934) fully clockwise.

Step 2. Adjust Power Set (R911) for 110 watt output (450-470 MHz), or 95 watt output (470-512 MHz). Using a short length, (6 inches) of 22 AWG solid wire, short Temp Sense Hi, P901-6, to Temp Sense Lo, P901-7, with P901 connected to J901 on the power control board. Power output should drop to less than 50% of set power.

3.5.3.5 Reflected Power Protection

Step 1. Set Control Voltage Limit (R931) and Current Limit (R939) fully clockwise.

Step 2. Adjust Power Set (R911) for 110 watt output (450-470 MHz), or 95 watt output (470-512 MHz). Remove cable from the station antenna connector, J803.

---

**CAUTION**

As the following step requires transmitting without a dummy load, key transmitter long enough to verify operation only.

Step 3. Key transmitter and observe meter 5. Meter 5 should indicate less than 23 uA.

3.5.4 Power Amplifier Deck Test

Step 1. Disconnect PA from station antenna connector, J803.

Step 2. Connect the PA directly to a wattmeter and dummy load via J803.

Step 3. Set Power Set (R911), Control Voltage Limit (R931), and Current Limit (R939) fully clockwise.

Step 4. Key transmitter and observe the wattmeter. Power output should exceed 125 watts.