3.2.3 **Power Amplifier**: References: 30C1000, 30C1002, and 30C1003. (Fig.18)

Each of the four amplifiers consists of two, source grounded, N-channel, insulated gate, enhancement mode Field Effect Transistors (FETs) packaged in a single case, operating in a push-pull configuration, and running in class AB. These FETs require a positive gate-to-source bias voltage on each gate to cause source-drain conduction. The quiescent Class AB idling bias current is set at 0.5 ampere for each half. Gate voltage to produce this current may be between 2 and 5 V due to variations among FETs. Most are 3 to 4 V. Temperature compensation for gate voltage is provided.

Gate bias originates from the +39 V bias rail supplied by the VSWR board of the module. The gate voltage is applied through an adjustable voltage divider, from this +39 V regulated bias rail. Resistors R1, R2, R3, R4 provide gate bias for one half of the amplifier; R5, R6, R7, R8 provide bias for the other half. Thermal compensation is provided by RT1 and RT2.

The RF input is applied to balun T1, L1 to provide two outputs 180° out of phase. These signals are stepped down to match the low input impedance of the FET through π network C1, C2, L2, L3, and C7, and applied to the FET gates. R3 and R6 have no effect at the operating frequency.

R3 and R6 provide a DC bias path, and a low frequency gate load to assist in maintaining amplifier stability. The choice of C4 and C5 values, and their internal equivalent series inductances, also ensures effective bypassing at all frequencies.

The output matching π network, consisting of inductors L4 thru L10, and capacitances C12 thru C15, resonates with the FET drain capacitance and transforms the very low output impedance of the FET, upwards to a standard 50 ohms. The two antiphase output signals are combined in balun T2, L11.

DC is applied to the drains through L4, L5 for the first half, and L6, L7 for the other half. L5 and L6 are sections of microstrip transmission line which transform the apparent RF impedances of L4 and L7 to higher values seen by the FET. RF and lower frequencies are bypassed with C3, C8, C9 and C6, C10, C11. These groups of capacitors are selected in value and for their internal equivalent series inductances so that they will be an effective bypass at all frequencies of interest, to assist in maintaining amplifier stability. Towards this objective of stability, in addition to resonating with the device drain-to-drain capacitance at RF, inductor L9 also places a heavy load on the FET output at low frequencies, where it behaves as a short circuit.

3.2.4 **4-Way Power combiner 40D1243G1**: In 1 kW module. Reference: Figure 19.

The four amplifier outputs are applied to tandem 2-way Wilkinson combiners after two of these outputs are passed through quarter-wave microstrip lines, thus delayed by 90° to correct the quadrature condition imposed by the input splitter board. The total output of these Wilkinson combiners becomes a single 50 ohm, 1 kW output. Terminations for the Wilkinson networks are provided by R1, R2, and R3. There is one directional coupler, and one bi-directional coupler located at the combiner output.

The directional coupler feeds a BNC connector on the module front panel and is used for RF output monitoring. The bi-directional coupler provides detected samples of both the forward and reflected RF power to the VSWR protection board for monitoring module gain, and VSWR protection. Terminations for these coupler line sections are provided by R4, R5, and R6; the RF samples for VSWR monitoring are peak-detected by CR1 and C1 for the forward direction, and by CR2 and C2 for the reflected direction.

3.2.5 **VSWR Control Board 20B1594G1**: References: 20B1594 and 30C1418. (Fig.20)

The VSWR control board performs several functions: it provides regulated bias voltages to the FET power amplifier stages, it provides hot-plug-in capability to protect the amplifier module when plugged into an operating transmitter, it provides protection to the FETs against over-dissipation due to output mismatch, and it monitors the amplifier module RF gain.

In normal operation the power supply enters J1 via pin 2, and is regulated to +39 VDC by series resistor R10 and zener diode VR1. Regulator U1 provides constant B+ voltage for op-amps U2, U3, U4, and the comparator reference voltages. When the module is first turned on (or plugged in) and U1 begins regulating, the charging current of C7 turns on Q1 which pulls the bias line low for a brief period of time. This provides a slow start for the module after DC power is applied.

Reflected power is detected and applied thru pin 11 of J1 to comparator circuit U2B. Control R21 sets the level at which VSWR protection begins. If the level of detected reflected power on pin 5 of U2B exceeds the control voltage set on pin 6, the output on pin 7 will go high. R22, C10, and CR1 provide a fast attack, slow release control voltage to Q2 when a high VSWR condition suddenly occurs. This will turn on Q2 which turns on Q4 which quickly reduces the bias applied to the power amplifiers; this lowers their gain, keeping their dissipation within safe levels.

When a module is plugged into an operating transmitter, the slow start circuitry consisting of C7 and Q1 will initially keep the module turned off. RF power from the other modules via the combiner will enter the module in the direction that would be detected by the reflected power detector. This would prevent the module from ever operating properly unless the VSWR circuitry is momentarily over-ridden.

The circuit of U4 produces a pulse approximately 2 seconds after power is applied to the module. At power—up, pin 2 of U4 will be pulled high by C11. R26 charges this capacitor, and when the pin 2 voltage goes below the voltage on pin 3, the output of U4 will go high. A pulse whose duration is controlled by C9 and R18 will then be applied to pin 3 of U2A. U3B detects that the module is not producing forward power and that the reverse power is high. Under these conditions the output of U2A goes high, turning on Q3, momentarily disabling VSWR protection, and allowing the module to come on.

DC samples corresponding to forward power into and out of the module are applied to U3A pins 2 and 3 respectively. When pin 3 voltage is higher than that of pin 2, corresponding to "enough RF output from the module," the comparator output U3A pin 1 is high, causing the green LED on the front panel of the module to light. The comparison threshold (ie. module gain is ok) is set by adjustment of R4. Any RF that the LED might pick up due to its proximity to the module input, is filtered out by L1 and C5.

3.2.6 1 kW PA and Visual Driver Modules - Test and Alignment Procedures:

Important: 50 ohm input and output terminations are necessary to achieve consistent results when testing modules. Termination is relatively simple for the PA modules, but for the Visual Driver module, its amplifier output Anaren coupler must be terminated. This can be done in either of two ways.

The first method, as done in the factory: simply terminate all three outputs of the splitter, each with a non-inductive 50 Ω dummy load fitted with the appropriate connector. Any of these outputs can be used for measurements, but each will read about 4.8 dB low due to the fact that only 1/3 of the total is being measured. If full power RF testing is to be done, use 25 W loads; for sweep testing, 2 W or 5 W loads will do.

The second method, if proper connectors or terminations are unavailable in the field, is connection to the output of the Anaren hybrid. To do this, carefully unsolder and lift the center conductor of the semi-rigid coax cable from the output terminal of the Anaren unit.

In its place, solder the center conductor of a 50 Ω Teflon coax cable whose electrical length is a multiple half wavelength at the operating frequency. The outside conductor can be soldered to the outside conductor of the semi-rigid cable. The far end of this temporary cable connects to a coaxial 20 dB attenuator rated for 25 W or more, if sweep measurements are to be carried out. The output of this attenuator can be terminated in the sweep comparator input, or in a coaxial dummy load resistor. For full power testing, the attenuator should be at least 75 watts.

After testing is complete, carefully unsolder the temporary cable, and resolder the center conductor of the semi-rigid cable. Be certain that everything is restored to its original condition.

A. Adjustment of bias voltage to establish proper quiescent FET bias current on 1 kW and Visual Driver High Band amplifiers:

1. Remove all fuses from the amplifier boards.

2. Adjust all bias pots to maximum resistance, for minimum bias voltage.

3. Terminate the RF input and output into a 50 ohm load.

4. Apply +50 VDC from a lab power supply, or the module test voltage available on the transmitter front panel, to the B+ copper bus, and its negative to chassis. **Caution: Observe polarity!** The lab power supply should have variable current limit protection such that the current can be limited to about 1 amp for the bias adjustment, and to about 5 amps for the low power sweep procedure.

5. Check the voltage on the bias terminals, it should be 39 V ±2 V. (The bias terminals are connected together via insulated bus wire).

6. Disconnect one side of inductor L9, located at output of each FET.

7. Install a fuse in one half of amplifier #1; adjust the corresponding bias pot for an idling drain current of 0.5 A. Move the fuse to the remaining fuse holders, one at a time, and adjust each bias pot for a corresponding drain current of 0.5 A.

8. Install remaining fuses after all bias adjustments have been made.

9. Setting of bias on the visual driver module is accomplished in the same way as on the PA modules. The amplifier output Anaren coupler must be terminated in 50 ohms during the above procedure.

3.2.6 **1 kW PA and Visual Driver Modules - Test and Alignment**: continued.

B. **Low power sweep of 1 kW and Visual Driver High Band amplifiers:**

1. Reconnect the inductors L9 that were disconnected in step A6 above. Be sure that each one is properly soldered to the output of its corresponding FET.

2. Connect the lab power supply or transmitter front panel test voltage source +50 V to the copper B+ rail, and the negative to the chassis of the amplifier. The current should be limited to 5 A for this test. **Caution: observe polarity!**

3. Connect the module to a sweep system, typically as shown in Figure 3-1. The sweep generator should be adjusted to give a linear sweep from 160 to 230 MHz so that the whole band is swept, with a small amount of out-of-band signal on both ends. Ensure that a coaxial 20 dB attenuator pad is connected to the RF output of the amplifier, in order to prevent possible damage to the sweep comparator.

   For sweeping of the driver module, the "temporary output cable" discussed above, connects to the coaxial 20 dB attenuator.

4. With the power supply switched on, the current drawn should be no more than approximately 4 amperes (8 x 0.5 A) for the 1 kW module, and approximately 2 amperes for the visual driver module.

   The swept in-band frequency response, for the high band 174-216 MHz 1 kW PA modules, should be essentially flat within ±1 dB as shown in Figure 3-1, with gain of approximately 16 ±1 dB.

   For the high band visual driver module, from the "temporary output cable" the swept response likewise should be essentially flat within ± 1 dB as shown in Figure 3-1; gain should be approximately 14 ±1 dB overall, and at any one output should be about 9 to 9.5 dB.

Ignore those parts of the response that are out-of-band; many modules will show harmless peaks and valleys that appear to be of significantly greater observed amplitude than the in-band swept response. These are mostly due to the effects of the various reactances present in the circuit, including the "hidden" ones found in the FETs themselves, and should not affect the overall performance of the transmitter.

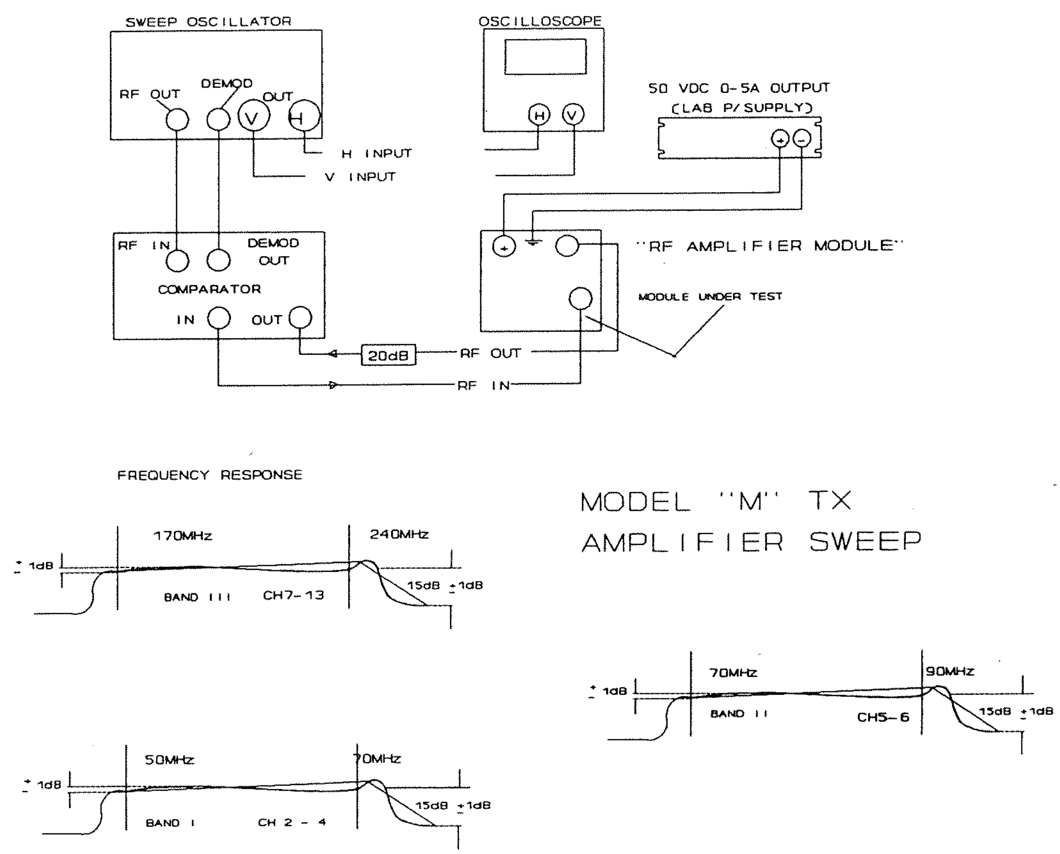
CAUTION: It is only natural that most of us will want to try and improve anything and everything we are able in the transmitter, and module swept frequency response may be judged to be no exception. However, before you succumb to temptation, we must caution you that getting a wideband amplifier sweep response to look "right" is a job not to be undertaken lightly. Unless you see an obviously damaged component that simply requires replacement, adjusting sweep response is not - repeat NOT - a job that can be easily done in the field, nor in the usual maintenance shop.

A fully equipped RF laboratory is the only environment in which such an undertaking would have a reasonable chance for success.

If you believe the sweep response is bad enough that you think you should fix it, the chances are good that one or more defective components are present in the module. At this point, you have choices: 1.) it may be found feasible to rent or purchase a full complement of RF test equipment, or 2.) return the module to LARCAN for repair and realignment.

A third choice can be the purchase of one or more additional modules as spares to be used where needed, which will allow implementation of choice #2 with no compromise in the transmitter performance.

Figure 3-1: Module Sweep Setup



After the sweep tests are completed, the amplifier can be placed in the transmitter and powered up.

In the factory, the VSWR cutback and Green LED adjustments are carefully done with the module placed in a fixture equipped with: a 300 cfm @ 1" SP cooling blower, a lab DC power supply with adjustable output 0-60 V and current limit 0-75 A, two digital voltmeters, an ammeter shunt (50 mV at 50 amps) or clamp-on DC current probe for digital voltmeter, two in-line wattmeters and their sampling elements, a 500 W dummy load, an adjustable gain (0-25W) RF driver amplifier, an exciter aural section or a signal generator (testing is done with CW), and suitable interconnecting cables.

Because the VSWR cutback and Green LED circuits have been adjusted at the factory, and are considered to be stable, they should not normally require any field adjustment. In fact, field adjustment is discouraged because all the adjustment potentiometers are located on the BACK of the 1 kW module; any adjustment is then impossible when the module is powered-up inside the transmitter. The Green LED adjustment, however, can be done incrementally with the module out of the transmitter, as explained on the next page.

3.2.7 Green LED Set Up Procedure: (Incremental on-site field method):

One of the functions of the VSWR board is to monitor the gain of the 1 kW module. This VSWR board is located on the rear of the module, adjacent to the output RF connector. For the locations of the components on the board, please refer to Figure 20. (Assembly drawing 20B1594).

Assuming that all the 1 kW modules are in good working order, proceed as follows:

1. With all modules running at normal operating power, place AGC/MANUAL switch into the MANUAL position and adjust the exciter output power until the transmitter output power reads 110%.

2. Remove the module to be set up, and remove the two front fuses from it, in order to simulate a single FET package failure. Replace this "crippled" module in the transmitter, and apply a 50% APL staircase video signal to the transmitter.

   The LED should now be extinguished; if it is not, remove the module and adjust the blue potentiometer (R4) on the VSWR board counter-clockwise, replace the module and try again, repeating until the LED just extinguishes when the module is re-powered.

3. Replace the fuses and check that the green LED now is fully lit when the module is re-powered.

   NOTE: It is recommended that R4 be adjusted one full turn at a time in order to establish a known reference point.

4. Place the AGC/MANUAL switch in the AGC position, and with the RAISE/LOWER switch, readjust the transmitter output power to 100%.

5. Similarly, the aural amplifier may be adjusted in the same manner, but obviously there is no requirement for a video input signal.

   (In the factory test fixture, with an uncrippled good module, the power supply voltage is simply lowered until the module output is reduced to 3/4 of its rated power, and R4 is adjusted to barely extinguish the LED. This factory procedure depends on the fact that these FETs are constant current devices so their gain is a linear function of their supply voltage).

3.2.8 VSWR Cutback Adjustment in optional test fixture:

CAUTION: Adjustment of the VSWR cutback potentiometer R21 should only be attempted with the module in a properly configured test fixture, because it must be adjusted with RF drive, and at nearly full power.

The VSWR board is located on the BACK of the module, and because the 3-way output combiner is located behind the modules and is essential to the transmitter operation, it is impossible to reach R21 when the module is in the transmitter.

If a test fixture is not available, a better course of action is simply to return the module to LARCAN for adjustment.

Procedure:

When a test fixture is available, use the exciter aural section as a CW generator, make connections per Figure 3-2 (page 3-11), and do this:

3.2.8 **<u>VSWR Cutback Adjustment</u> in optional test fixture:** continued.

10. (Continued) Now gradually decrease the power supply voltage until the module output power is 375 W, corresponding to a failure of one of the four push-pull amplifiers, and adjust R4 to barely extinguish the green LED front panel indicator. Restore the supply to 50 V and observe that the LED operates at full brightness.

11. Shut off the RF drive and the power supply. Disconnect the module, and reinstall it in the transmitter. Restore transmitter connections to the exciter if it was used to generate the CW signal for the RF driver amplifier in the fixture.

This completes the adjustments that are possible to be made on the module. Of course, if the test fixture is available, the sweep response can be measured, and bias settings can be done as well; the same basic technique applies, as described in Sections 3.2.6.A and 3.2.6.B above. Because the module test fixture provides air cooling, the advantage is gained that the module can be powered up for full power testing.

Figure 3-2, the hookup of the optional test fixture, is to be found on the facing page. It is indeed possible for station technicians to build a test fixture of this kind, but in all fairness we must warn you that it will not be an inexpensive nor easy venture, because of the requirement for a relatively high powered adjustable DC supply, and for an adjustable gain RF amplifier (adjustable from zero output to at least 25 watts with only 1 to 2 mW input. This last item can be much more time-consuming than many of us engineering people would care to admit. That is the main reason why LARCAN uses commercial test equipment most of the time.

Cable lengths are not considered to be critical; for your information, the LARCAN factory test fixture uses a straight reducing adapter (from module output to type N), followed by a right angle type N adapter between the module output reducer and the RF wattmeter input. (There is no cable used; the total distance through the connector combination is about 10 cm from the module output to the wattmeter input).

Approximately 60 cm of Teflon dielectric coax cable is connected between the output connector of the wattmeter and the 500 W dummy load.

Our test signal used for high band comes from a lab signal generator at about 195 MHz. The total bandwidth of high band is around ±11% of its center frequency, and in our factory tests we try for as few adjustments as possible so we can cover the entire high band. We do this because the module has not yet been installed in a transmitter whose frequency is known, and we need to make sure the module is okay first.

Theoretically, any frequency in the band should work, but obviously if your exciter aural output is used for a driving signal, the test fixture will operate on your assigned carrier frequency. Which is all you need.

1. Start with everything (except the exciter) turned OFF, and with the driver RF gain and the power supply controls turned down to minimum.

2. Place the module in the fixture, start its blower, and ensure that air flows through the heatsink. Connect the input, output, and DC cables to the module. BE SURE THERE IS NO RF INPUT TO THE MODULE.

3. Switch the power supply ON, advance the power supply current limit control to about 10 A, and watch the output in-line RF wattmeter with its most sensitive sampling element in place, while increasing the power supply voltage gradually to 50 V.

   If RF is observed, STOP right there! RF indicates instability in the amplifier which must be investigated and corrected. A spectrum analyzer, if available, is a much more sensitive instrument for the detection of stray RF, but care must be taken that the input of the analyzer is protected from being damaged by too-high RF levels.

4. Change the output in-line RF wattmeter sampling element to 500 W full scale. If RF was not observed during step 3, increase the power supply current limit to maximum, increase the voltage to 50 V, turn on the aural section of the exciter, and gradually advance the RF gain control of the driver amplifier until the module output RF reads 500 W. This CW power level is a convenient amount that is chosen because RF wattmeters are most accurate at full scale. It is only about 3/4 dB lower than the 595 W average power contained in a 1 kW sync peak visual signal at black level.

5. Observe the DC input voltage and current. Their product is the DC input power. The RF output power divided by the DC input power and multiplied by 100 is the efficiency of the module. Observe the RF input power. It should be somewhere between 12 and 16 watts. The gain in dB is 10 times the logarithm of the ratio (Po/Pi) and for high band modules typically should be 15 to 16 dB.

6. Reduce the RF drive, to read 250 W at the module output. Adjust the power supply current control to begin limiting at this 250 W RF level. This avoids the possibility of damage to the FETs when subsequent adjustments are made.

7. Reduce the RF drive to zero and disconnect the dummy load cable from the output RF wattmeter. This places an extreme output mismatch on the module. (The output RF wattmeter must remain connected to the module). Gradually increase the RF gain until the output wattmeter reads maximum. Avoid increasing input power to more than 25 W.

8. Adjust R21 until the output RF power reading decreases to 200 W. For the module, this represents a safe level. Accuracy is not an issue; the objective here is simply to get an R21 cutback setting that will save the FETs from over-dissipation when bad mismatch is seen by the module. (Output metering circuits in the transmitter respond accurately to pre-set VSWR seen in the external RF system).

9. Adjust the RF input to the module, until the original input RF power of about 12 to 16 W is reached. Gradually increase the power supply current limit. The unterminated RF output from the module should not exceed 200 W under any circumstances.

10. Shut off the RF drive, and re-terminate the module. Apply RF drive again, and increase the power supply current limit to maximum. The module operating conditions should be the same as in step 5; i.e. output should be 500 W, and the input drive between 12 and 16 W.