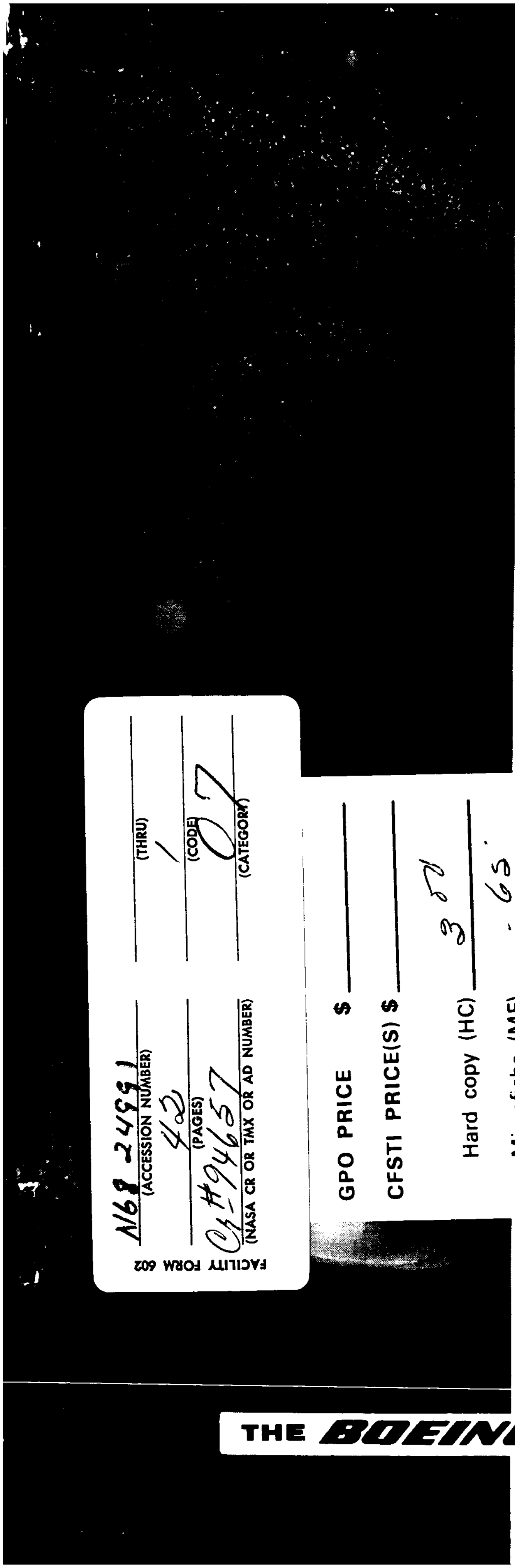
D5-13424



FINAL TECHNICAL REPORT
PROTOTYPE 20 WATT SOLID-STATE TELEMETRY TRANSMITTER

VOLUME III OF III

April 1, 1968

THE BOEING COMPANY - SPACE DIVISION

DOCUMENT NO. D5-13424 VOLUME III OF III

TITLE FINAL TECHNICAL REPORT - PROTOTYPE 20 WATT, SOLID-STATE TELEMETRY TRANSMITTER

MODEL NO. CONTRACT NO. NAS8-20777

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TELEMETRY SYSTEMS

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CONTENTS

ILLUSTRATIONS

SECTION I

1.0 INTRODUCTION

This volume of document D5-13424 contains operating and maintenance instructions for a 20-Watt, solid state, telemetry transmitter developed under Contract NAS8-20777 for George C. Marshall Space Flight Center, NASA. Included in this volume is a theory of operation containing schematics and block diagrams, photographs of the major components, trouble-shooting, alignment, and tuning instructions, and a drawing tree.

SECTION 2
THEORY

2.0 THEORY OF OPERATION

Operation of the transmitter may best be described by breaking the unit down into three major subsystems:

a. Exciter - Modulator
b. Drivers and Power Amplifiers
c. Frequency Multipliers

In addition, several ancillary and interfacing items such as power adders and splitters, filters, isolators, etc., are used and are described in conjunction with the three main subsystems. Figure 2-1 is a photograph of the transmitter and Figure 2-2 is the block diagram. Figure 2-3 is the complete schematic.

2.1 EXCITER-MODULATOR

The exciter-modulator shown in the schematic of Figure 2-4 generates and modulates an output signal which is one-twenty-seventh of the transmitter output frequency, and as such the frequency deviation and stability are also one-twenty-seventh of the transmitter output signal requirements.

The output signal is generated by mixing two frequencies and selecting the sum frequency by means of a filter and tuned amplifier. The frequencies are generated by a crystal oscillator which provides frequency accuracy and stability, and a voltage controlled oscillator (VCO) which allows the signal to be frequency modulated. Isolation of the modulation input signal is maintained by a dc-to-dc converter and by transformer coupling of the output signal.

The exciter-modulator is shown in Figure 2-5.

2.1.1 Crystal Oscillator

The crystal oscillator is a modified Colpitts circuit. Temperature compensation with negative temperature coefficient capacitors is used to maintain a frequency stability of 0.001 percent. This stability is also achieved by operating the crystal in its fundamental mode and at very low power (approximately 500 microwatts). The collector circuit of the oscillator is tuned to the fourth harmonic of the crystal to obtain a mixer injection frequency of 73.2 MHz. Following the oscillator is a buffer amplifier which has a nominal gain of 15 dB. A bandpass filter is used at the output of the amplifier to reject the undesired harmonics of the oscillator.

2.1.2 Voltage Controlled Oscillator (VCO)

The VCO is a Colpitts oscillator using two varactor diodes as the frequency control device. The varactor is essentially a voltage variable capacitor

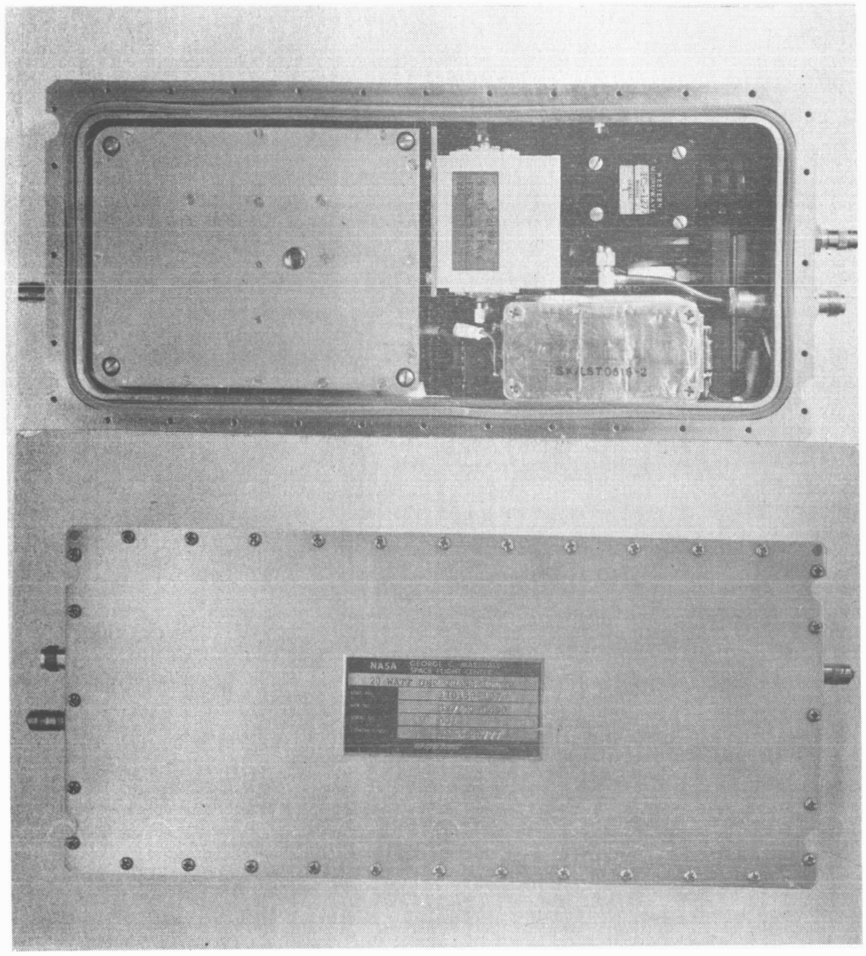
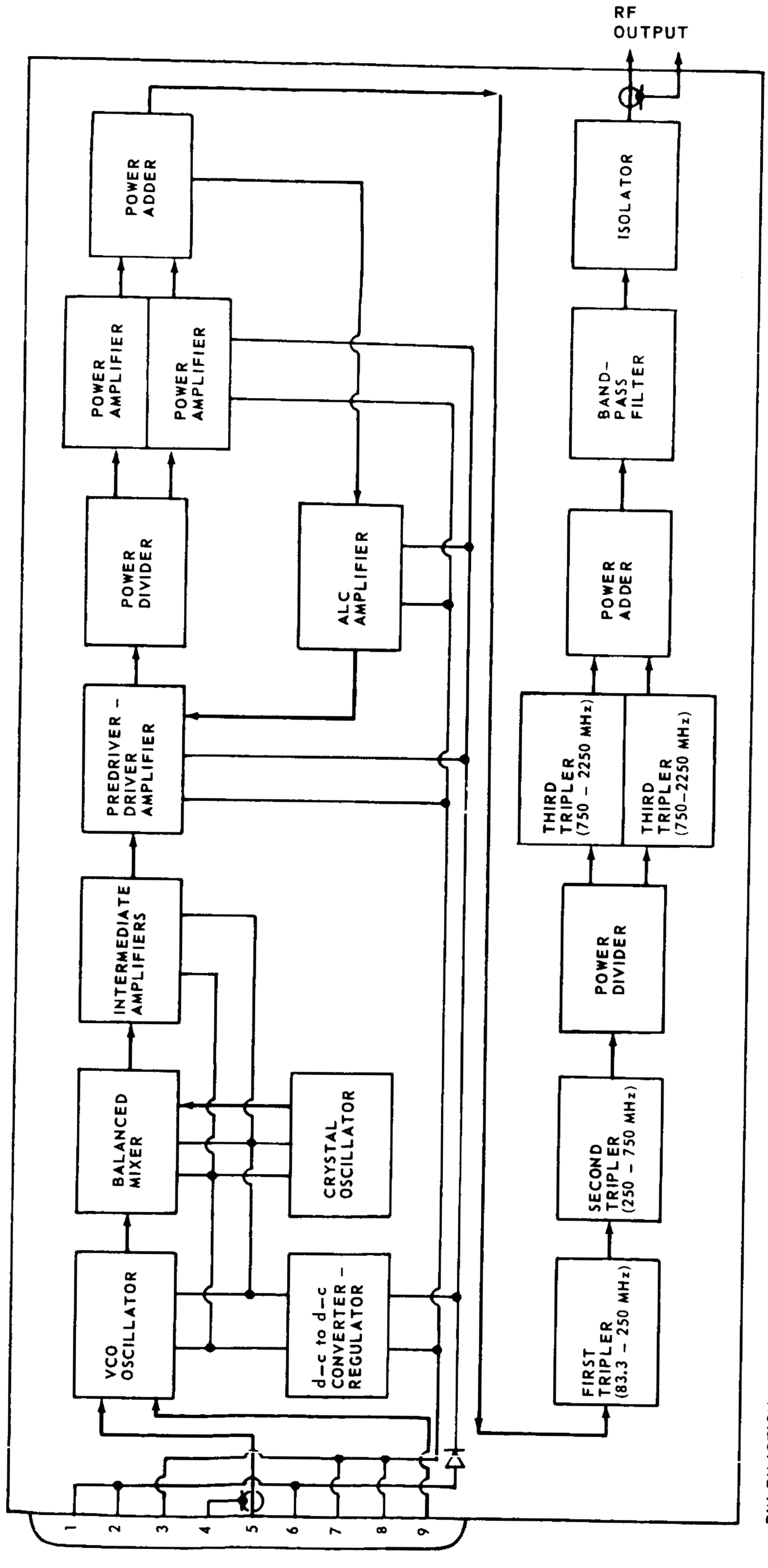


FIGURE 2-1 S-BAND TELEMETRY TRANSMITTER



NOTE: ARROWED LINES INDICATE SIGNAL FLOW
OTHER LINES ARE d-c DISTRIBUTION

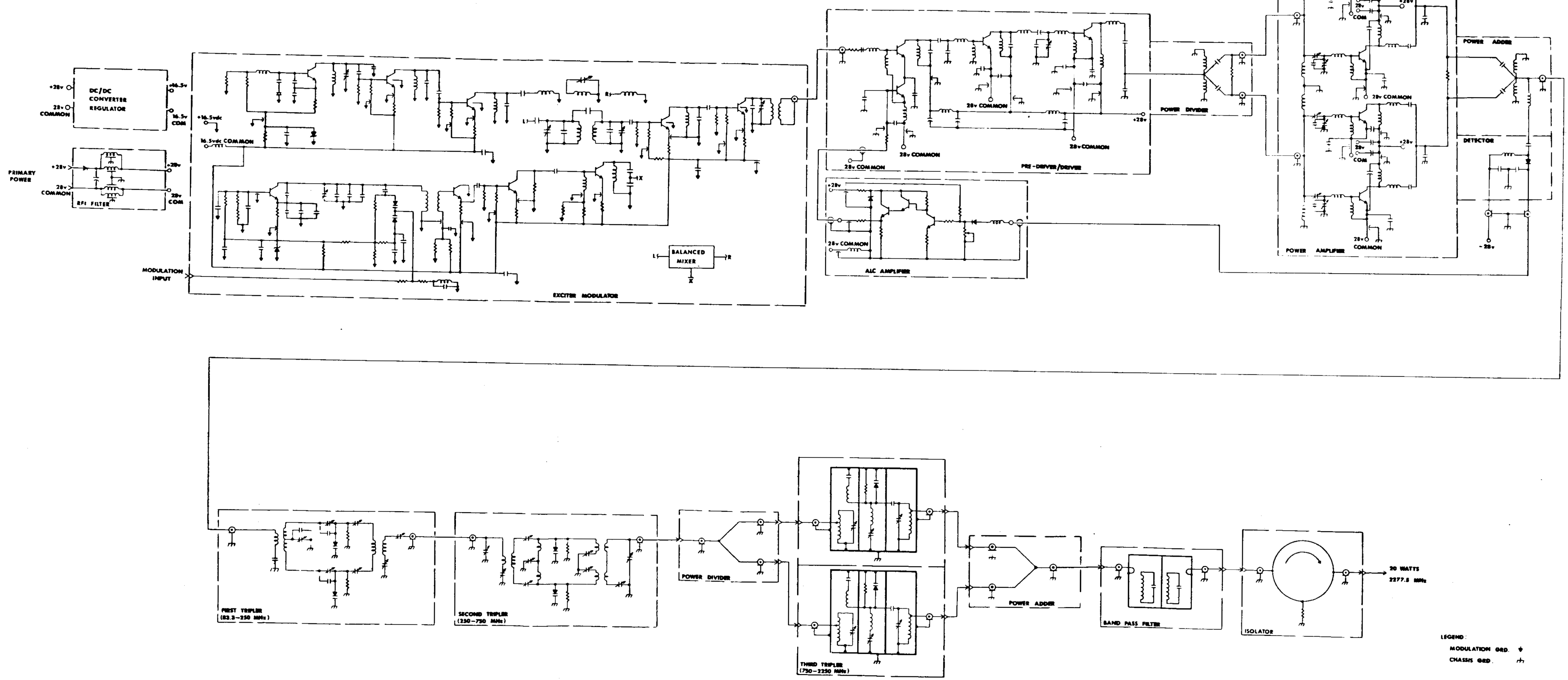
PIN FUNCTION

1. + 28V
2. + 28V
3. - 28V
4. SHLD GND
5. MODULATION INPUT
6. + 28V
7. - 28V
8. - 28V
9. MODULATION INPUT

FIGURE 2-2 TRANSMITTER BLOCK DIAGRAM

FOLDOUT FRAME

FOLDOUT FRAME



FOLDOUT FRAME 1

FIGURE 2-3 TRANSMITTER SCHEMATIC DIAGRAM

FOLDOUT FRAME 2

FOLDOUT FRAME

FOLDOUT FRAME

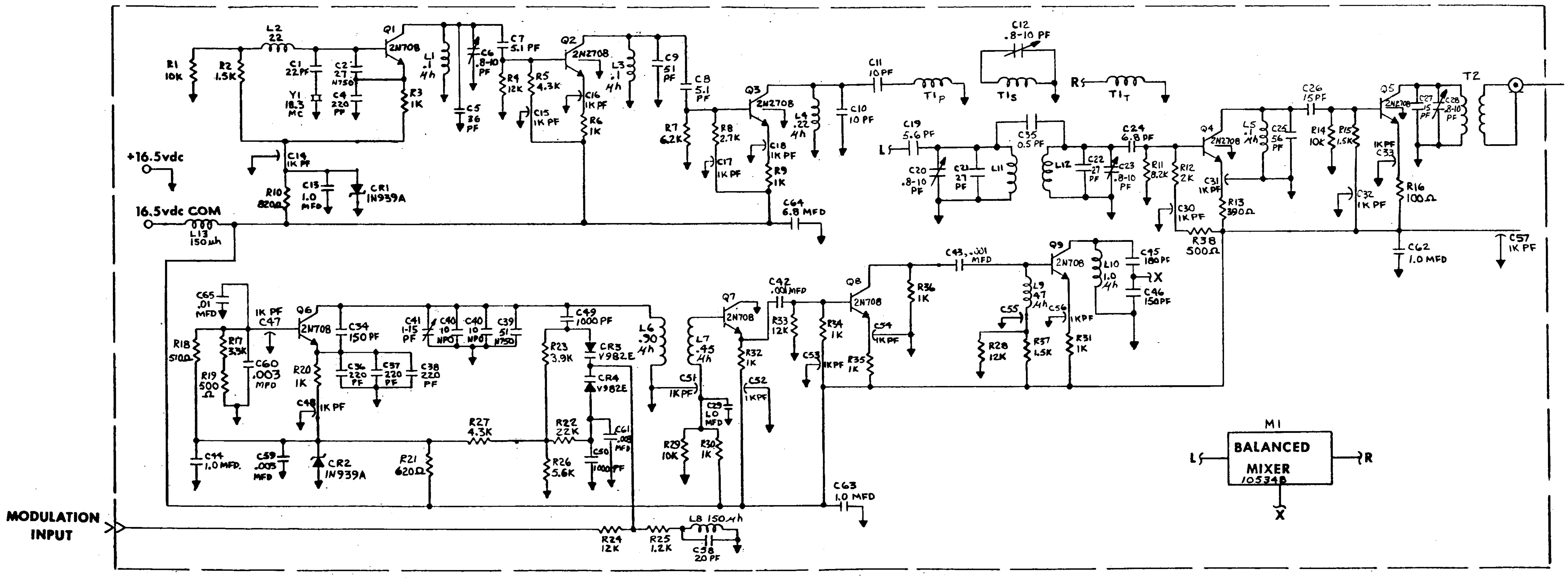


FIGURE 2-4 EXCITER/MODULATOR SCHEMATIC DIAGRAM

FOLDOUT FRAME 1

D5-13424

FOLDOUT FRAME 2

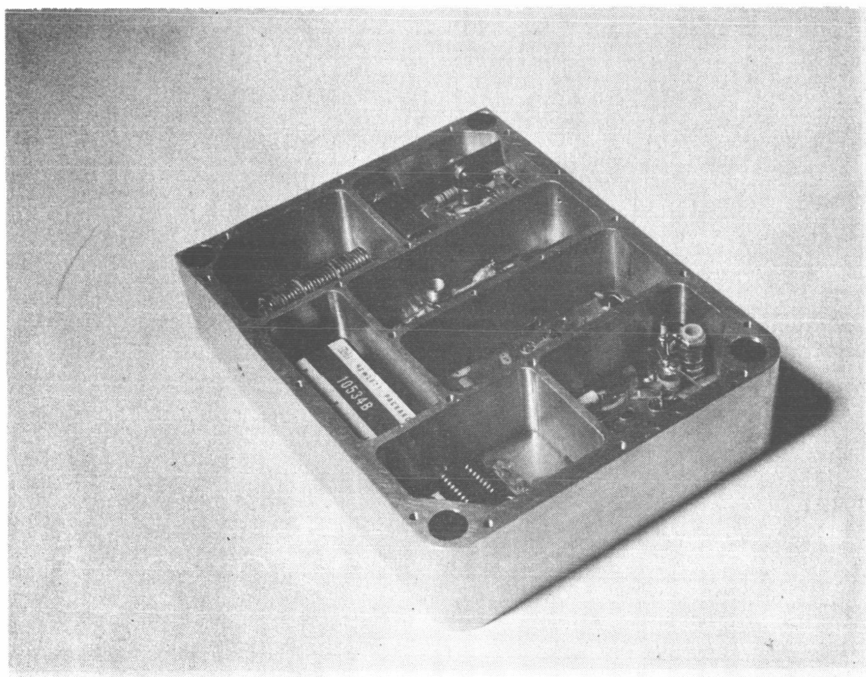


FIGURE 2-5 EXCITER-MODULATOR

2.1.2 (Continued)

and bias applied to the varactor in the tuned circuit controls the frequency of the oscillator. A fixed bias is supplied to set the center frequency at 11.15 MHz and the modulation input applied between the two varactors determines the amount and rate of deviation about the center frequency. The varactors are fixed biased to a point which will provide maximum linearity of the voltage-capacitance characteristics.

Two back-to-back varactors are used to reduce the incidental frequency modulation of the VCO due to the voltage swing on the collector of the oscillator transistor. Using two varactors in this manner also increases the modulation frequency response of the oscillator.

The oscillator is extensively temperature compensated to maintain a stability of approximately 0.02 percent. The temperature sensitive collector capacitance of the transistor generally has a significant effect on the frequency stability of the circuit. To minimize this effect, a relatively large capacitance is placed in parallel with the transistor. The physical layout of the oscillator circuit is optimized to obtain additional frequency stability. A trimmer capacitor is placed in the emitter circuit of the oscillator transistor to provide the capability for fine tuning the transmitter center frequency. This control provides a resolution of 0.001 percent of the transmitter output frequency.

The VCO is loosely coupled to a buffer amplifier having a gain of approximately 15 dB. Following the amplifier is a low pass filter which rejects the higher order harmonics of the VCO.

2.1.3 Balanced Mixer

The balanced mixer is a double balanced mixer and consists basically of transformers and hot-carrier diodes in a bridge arrangement. Signals from the VCO and the crystal oscillator are injected into the mixer. The tuned circuit output of the mixer passes the sum of these two signals, 84.35 MHz. This signal is amplified to a level of approximately 30 milliwatts (mw) by two sharply tuned amplifiers. The output of the final amplifier is transformer-coupled to provide d-c isolation from the following circuits.

2.2 PRE-DRIVER/DRIVER AND POWER AMPLIFIER

The output of the exciter-modulator is a low-level signal which must be greatly amplified for application to the multiplier chain. This is accomplished by the predriver-driver and power amplifier circuits.

2.2.1 Pre-Driver-Driver Amplifiers

The predriver-driver circuit, shown schematically in Figure 2-6, contains three amplifying stages. The last two stages are extensively decoupled for maximum operational stability. The first transistor operates as part of the Automatic Level Control (ALC) circuit. The transistor in the

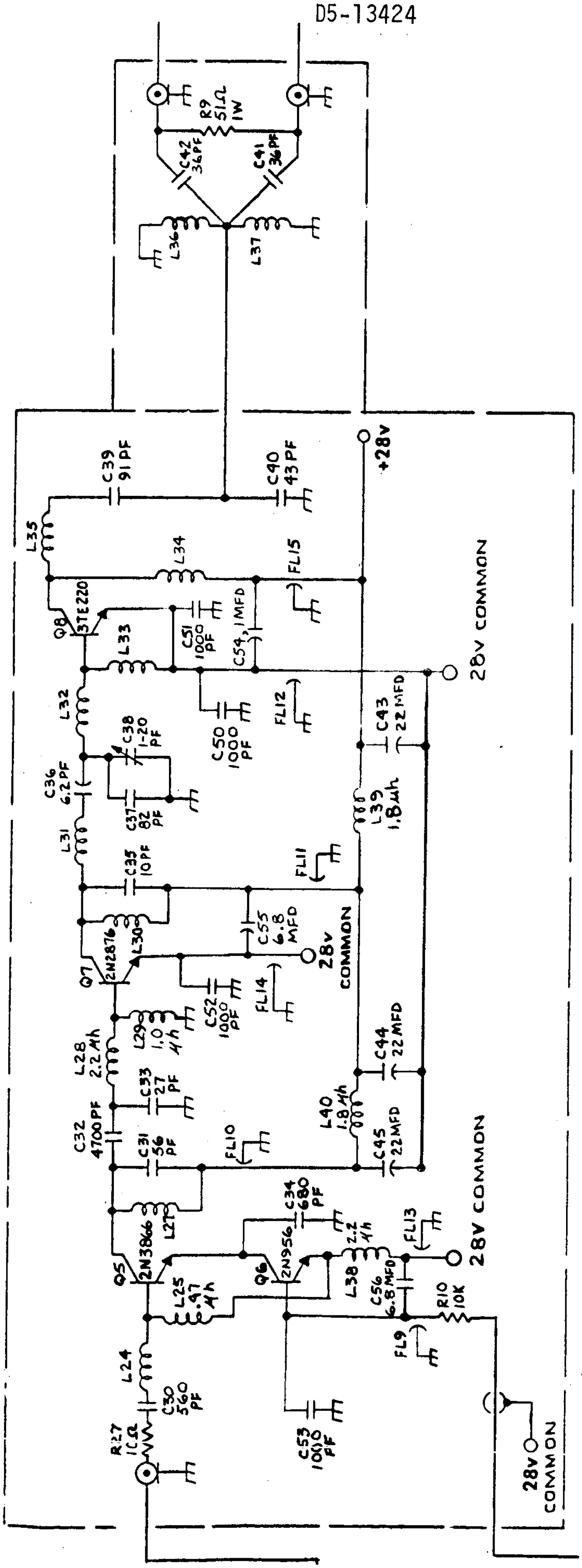


FIGURE 2-6 PREDRIVER-DRIVER SCHEMATIC DIAGRAM

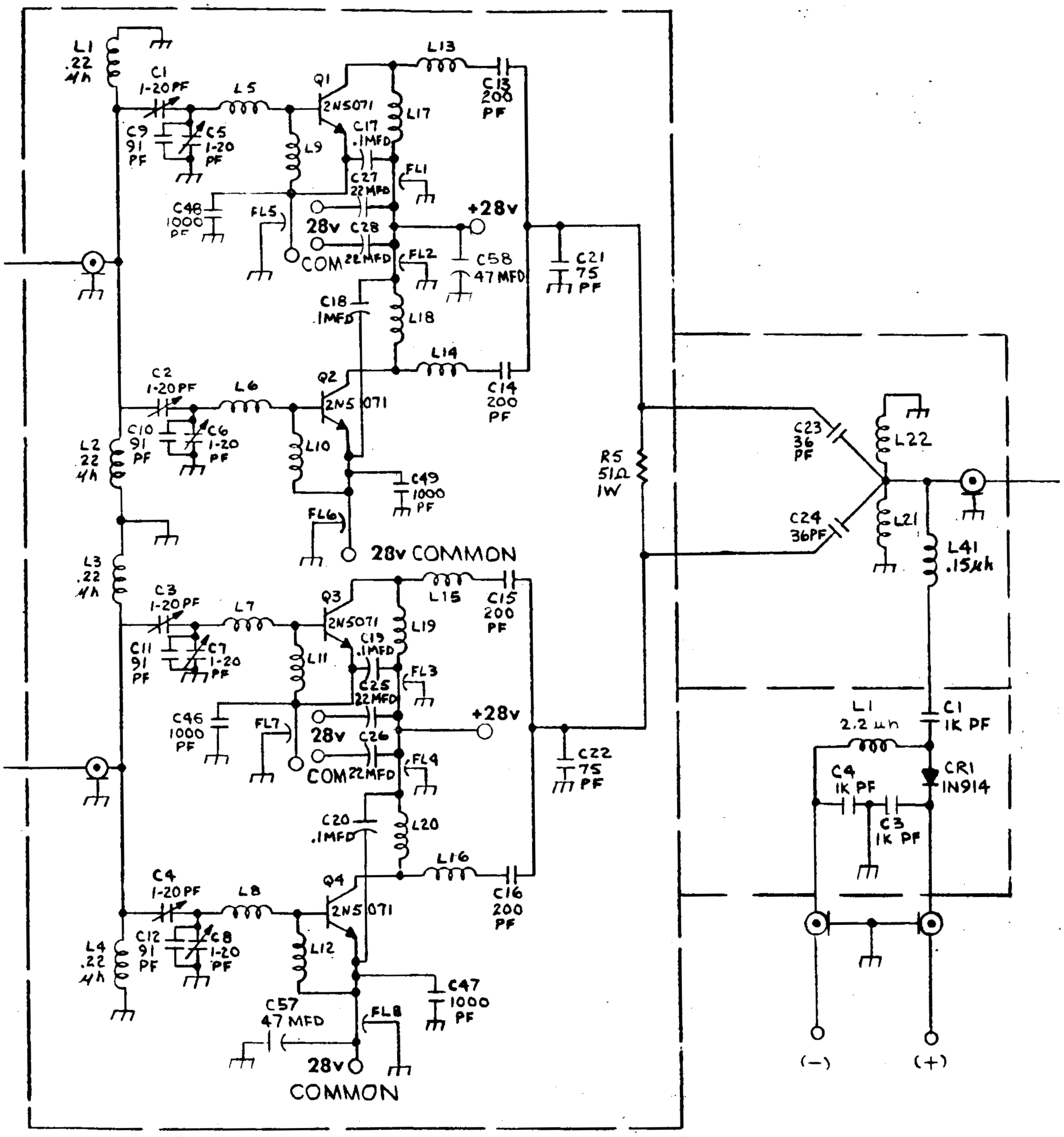


FIGURE 2-7 POWER AMPLIFIER SCHEMATIC DIAGRAM

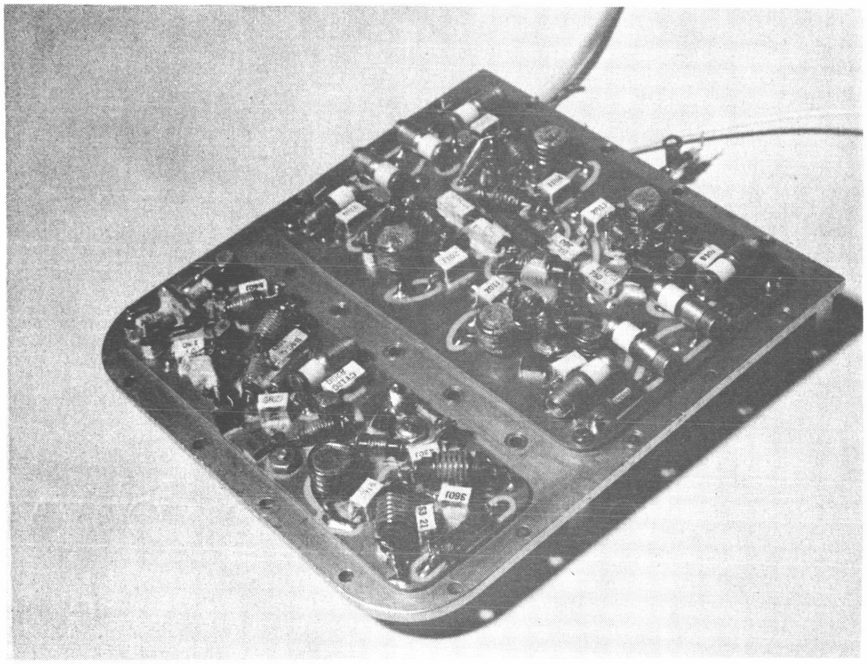


FIGURE 2-8 PREDRIVER-DRIVER AND POWER AMPLIFIER

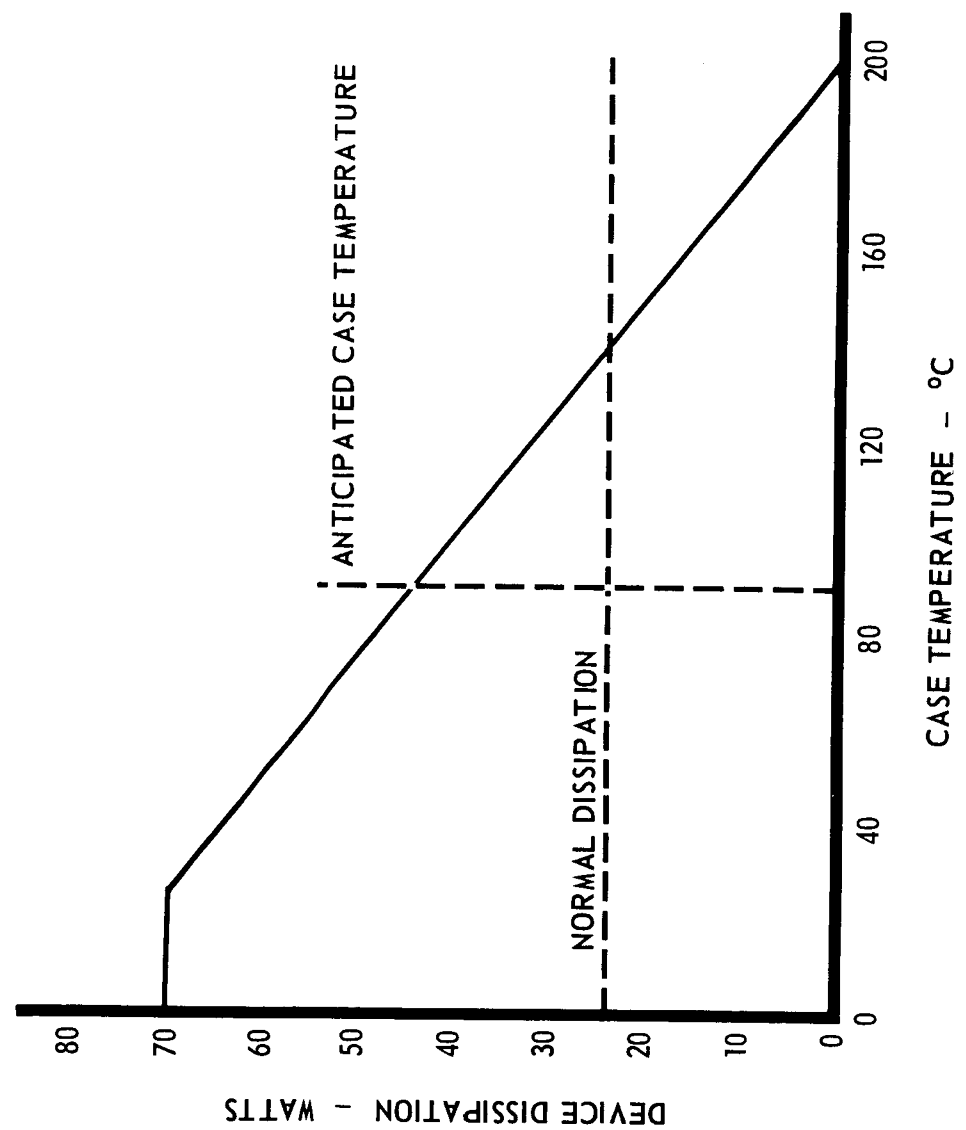


FIGURE 2-10 TRANSISTOR THERMAL CHARACTERISTICS RCA, 2N5071

2.2.1 (Continued)

emitter circuit acts as a variable emitter-resistor for controlling the gain of the stage. The d-c control voltage at the base circuit of the emitter transistor will vary the output power of the predriver-driver between zero and 30 watts. The nominal output is 14 watts with a nominal overall gain of 26 db. The predriver-driver amplifiers operate from the prime dc power supplied to the transmitter. Figure 2-8 is a photograph of the predriver-driver and power amplifier module.

2.2.2 Power Amplifier

The output of the predriver-driver amplifier is coupled to a lumped constant, two-way power divider. This circuit is a passive LC network, the outputs of which are coupled to two separate amplifier circuits. Each amplifier shown in Figure 2-7 consists of two transistors in parallel. As with the predriver-driver circuit, these transistors are also operated common-emitter and are extensively decoupled from the prime 28 volt supply for optimum stability. The power amplifier is shown in Figure 2-8.

The outputs of the two amplifiers are combined in a lumped constant power adder. This adder is similar to the power divider at the input, except that it is used in the reverse direction. A maximum of 140 watts of power can be obtained at the combined output. The nominal operating level is 110 watts, with an overall circuit gain of 9 db.

The transistor type used in the power amplifier is the RCA - 2N5071. This is an epitaxial, silicon, n-p-n, planar transistor employing an overlay emitter-electrode design. A plot of the thermal characteristics for this device is shown in Figure 2-10.

2.2.3 Automatic Level Control (ALC)

The ALC circuit shown in Figure 2-11 is used to maintain a constant drive power to the frequency multiplier chain. This is required to provide a constant transmitter power output regardless of prime power fluctuations or temperature environment. The RF output of the power amplifier is sampled by a diode detector in the power adder. This signal is coupled to a three-stage, d-c amplifier using a zener regulated supply voltage. The amplified d-c output is used as a bias control on the emitter transistor located in the predriver-driver. When the power amplifier output decreases, the ALC amplifier increases the bias on the emitter control transistor in the predriver-driver circuit. This increases the drive to the power amplifiers, thereby restoring the power amplifier output to the desired level. Figure 2-12 is a photograph of the ALC circuit.

2.3 FREQUENCY MULTIPLIERS, FILTER, ISOLATOR

The high-level RF output of the power amplifier stage is used to drive a times 27 multiplier which uses three varactor tripler stages.

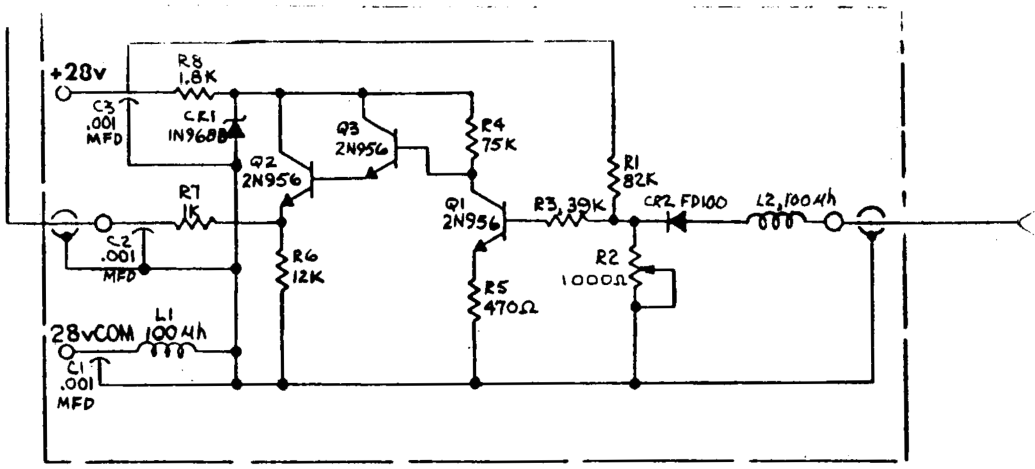


FIGURE 2-11 AUTOMATIC LEVELING CIRCUIT (ALC) SCHEMATIC DIAGRAM

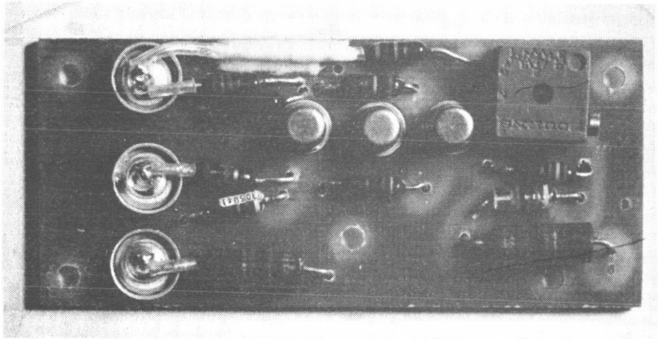


FIGURE 2-12 AUTOMATIC LEVEL CONTROL

2.3.1 83.3 - 250 MHz First Tripler

The first tripler, Figure 2-13, uses two Varian Associates VAB800H varactor diodes in a push-pull configuration. These diodes are referred to as "Bimode" diodes because they have two modes for generating harmonics of the drive signal. One mode is the normal operating, non-linear reactance mode. The second mode is referred to as the charge storage mode. When the diode is biased in the reverse direction by the drive signal, a large charge is built up and stored at the junction. As the drive signal approaches an amplitude where the junction is forward biased, this charge is suddenly released resulting in a sharp increase in current flow which is rich in harmonics.

The input of the tripler is transformer-coupled with the primary tuned to the fundamental frequency. The overall efficiency is approximately 75 percent with a nominal drive of 110 watts. Figure 2-14 is a photograph of the first tripler, and Figure 2-15 is a plot of the thermal characteristics of the VAB800H varactor.

2.3.2 250 - 750 MHz Second Tripler

The second tripler, Figure 2-16, uses two Motorola MV1805C varactors in a push-pull configuration similar to the first tripler. The MV1805C diodes are graded junction devices, and operate in the charge storage mode mentioned in the discussion of the first tripler. The efficiency of the circuit is in excess of 70 percent with an input of 80 watts. Figure 2-17 shows the second tripler module, and Figure 2-15 shows the thermal characteristics of the varactors.

2.3.3 750 - 2250 MHz Third Tripler

The third tripler, Figure 2-18, consists of two coaxial cavity triplers connected in parallel by means of a power splitter and a power adder. Figure 2-19 is a photograph of the two triplers, and the power divider and adder. The overall circuit, exclusive of the filter, operates at an efficiency in excess of 50 percent with a drive of 55 watts. Each tripler uses a single 1N5150 varactor operating in the same mode as the MV1805C units of the second tripler. The thermal characteristics of the 1N5150 are shown in Figure 2-15.

Each third tripler consists of three coaxial cavity filters. The first is a quarter wavelength cavity tuned to the input frequency by a variable capacitor mounted at the end of the center conductor. Input coupling is made by a direct tap, and output coupling to the varactor is obtained with a tuned loop. The varactor is mounted in the center, or idler, cavity. This cavity is tuned to resonance at the second harmonic of the input frequency using the average diode capacitance and the variable capacitor mounted to the center conductor. In effect, these components constitute a half-wavelength, series resonant circuit. Coupling to the third cavity is capacitive. This cavity is tuned to the third harmonic of the input, which is the required output frequency. Output coupling is made with a direct tap to the center conductor.

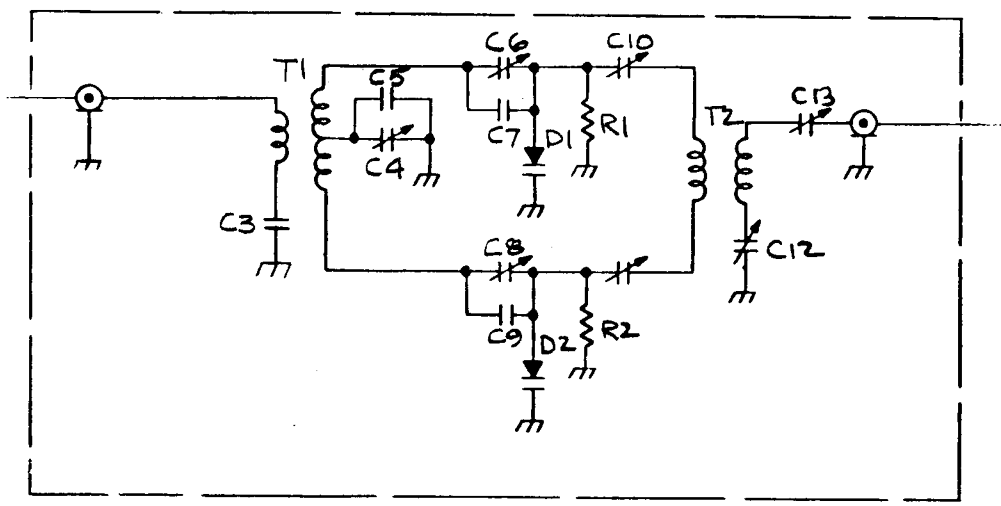


FIGURE 2-13 FIRST TRIPLER SCHEMATIC DIAGRAM

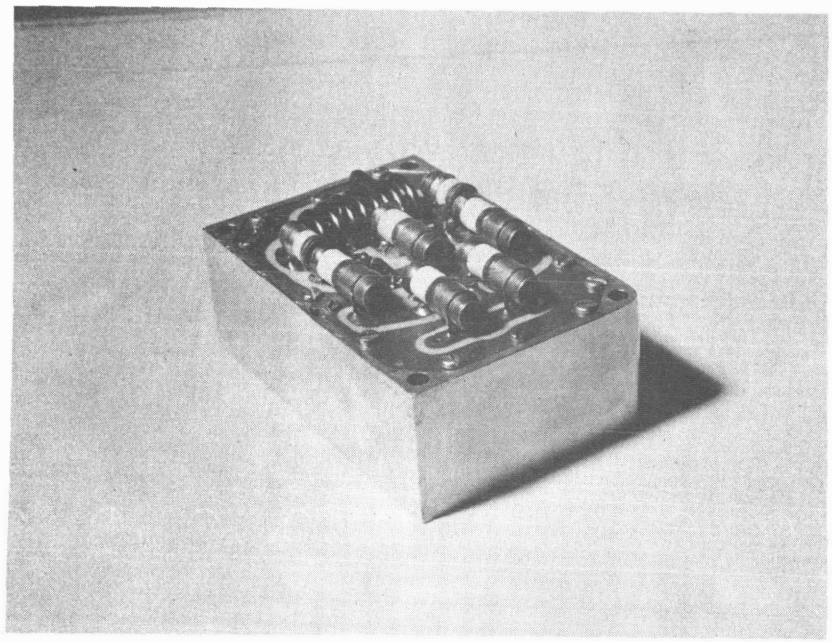


FIGURE 2-14 FIRST TRIPLER (83.3 - 250 MHz)

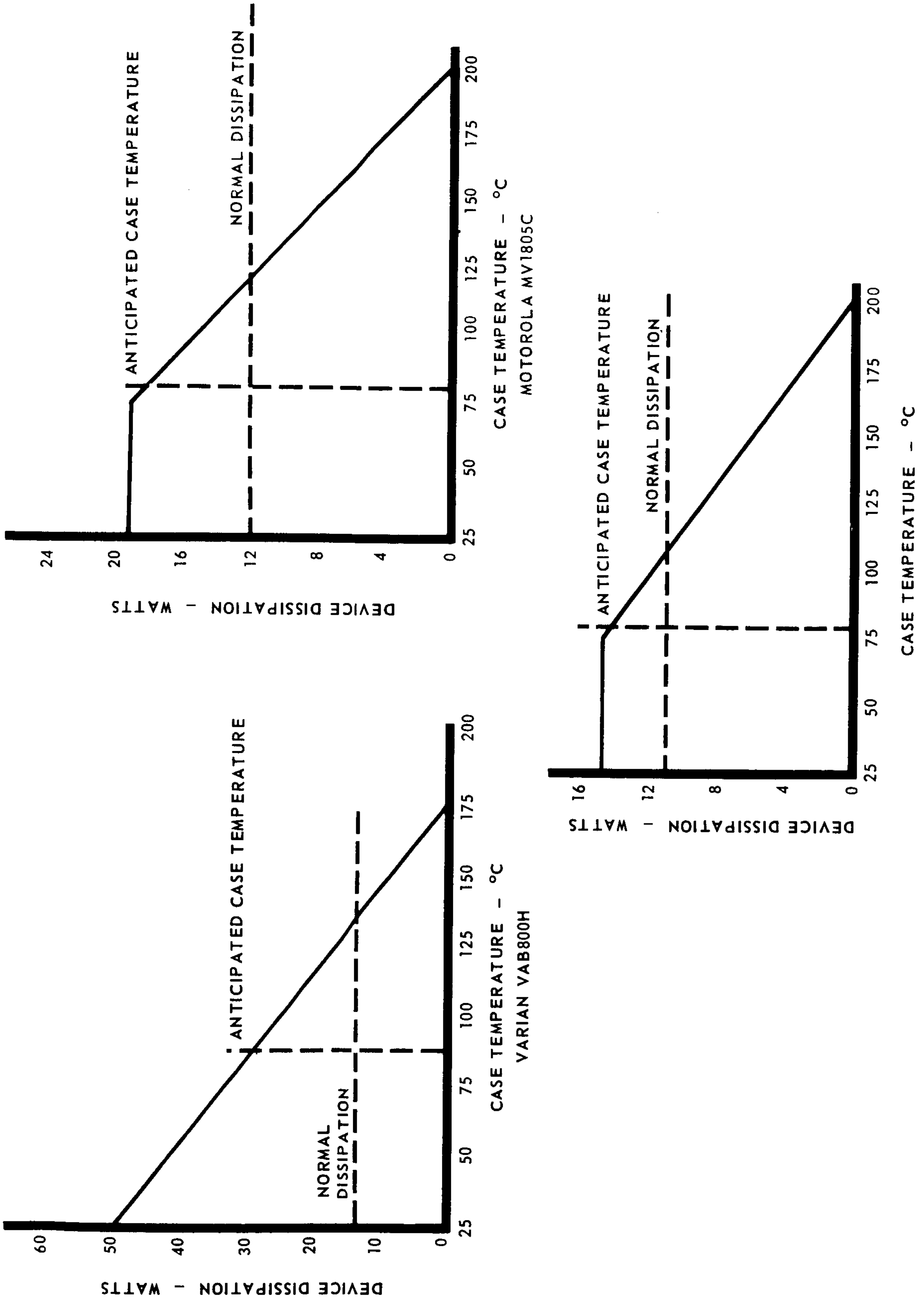


FIGURE 2-15 VARACTOR THERMAL CHARACTERISTICS

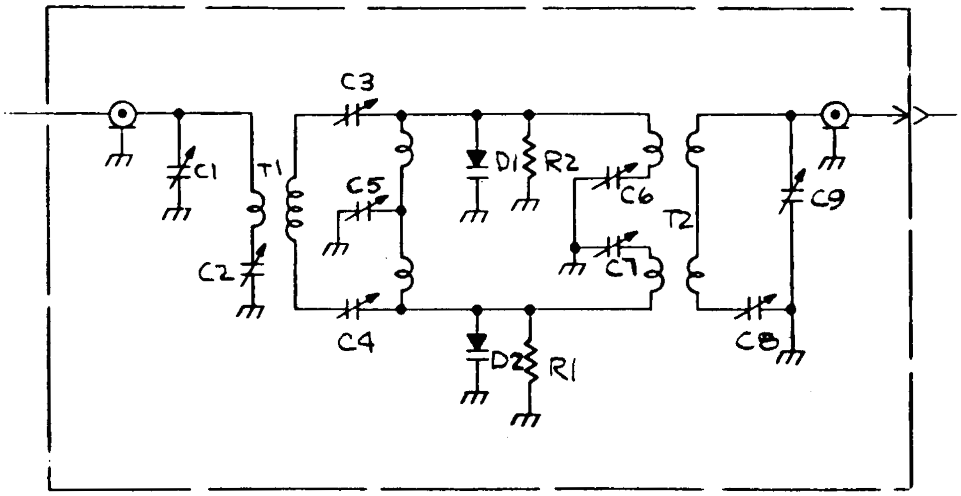
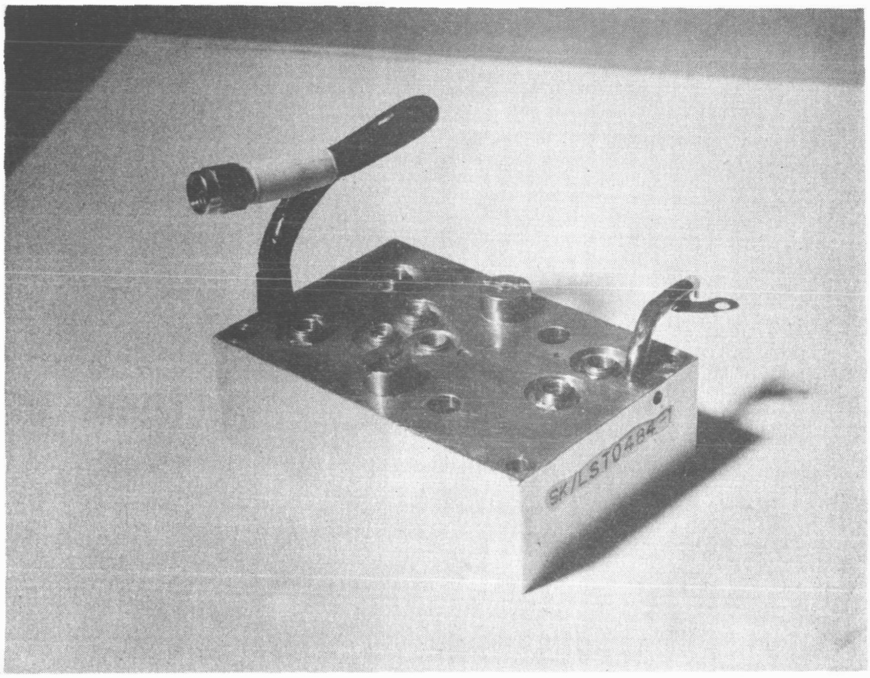


FIGURE 2-16 SECOND TRIPLER SCHEMATIC DIAGRAM



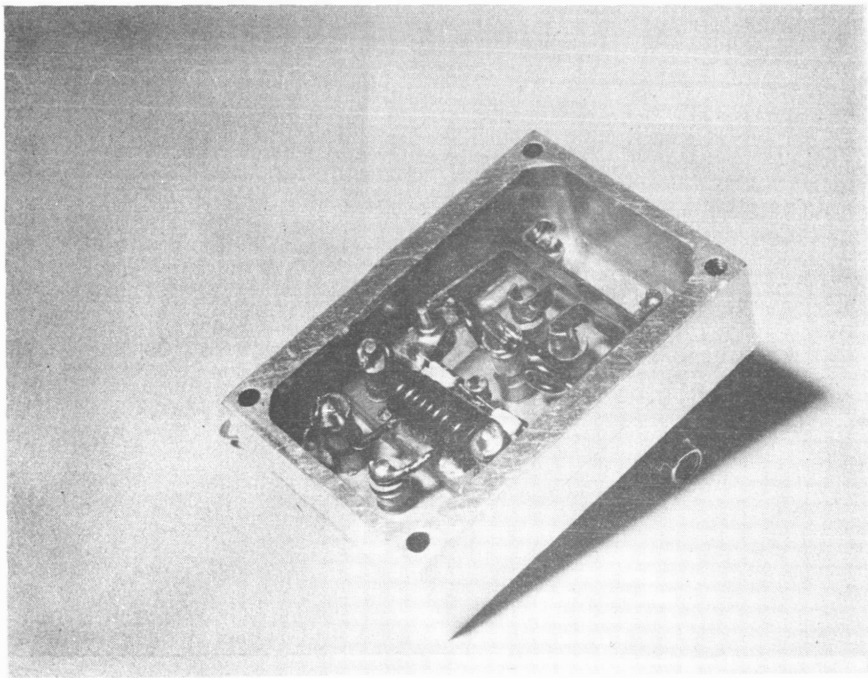


FIGURE 2-17 SECOND TRIPLER (250-750 MHz)

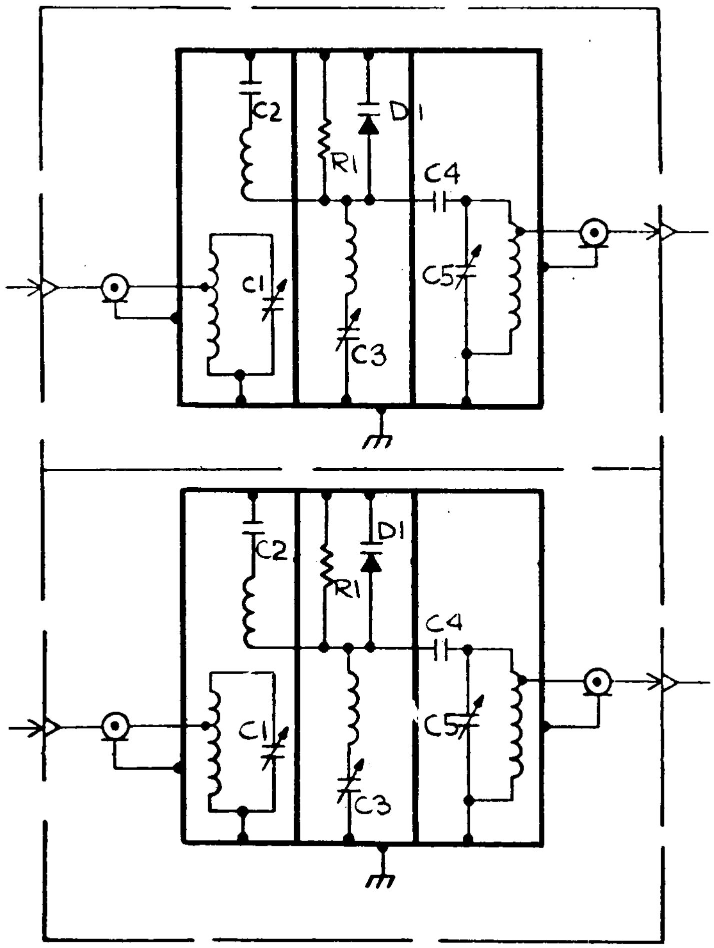


FIGURE 2-18 THIRD TRIPLER SCHEMATIC DIAGRAM

2.3.3 (Continued)

The power splitter at the input to the tripler is constructed with quarter wavelength lines using microwave stripline techniques. The output adder uses the same stripline techniques. The splitter and adder have a combined insertion loss of 0.4 db, which increases the overall loss of the tripler by about eight percent.

Not clearly shown in Figure 2-19 are the low-loss Rexolite center conductor supports. These supports are bonded to the center conductor of each cavity at the point where the tuning capacitor fastens to the conductor and cause no discernable loss in the efficiency of the tripler. The supports are necessary to prevent generation of any incidental FM or AM due to center conductor vibration under extreme environmental conditions.

2.3.4 Bandpass Filter and Isolator

The bandpass filter is a two-section coaxial cavity filter, and suppresses all harmonics of the output to the required levels. The isolator at the output protects the transmitter from high standing wave ratios (SWR) occurring during open and short circuited load conditions.

The combined insertion loss of the filter and isolator is 0.8 db, which decreases output power by approximately 17 percent.

Figure 2-20 shows a schematic representation of the bandpass filter and siolator, and Figure 2-21 is a photograph of both devices.

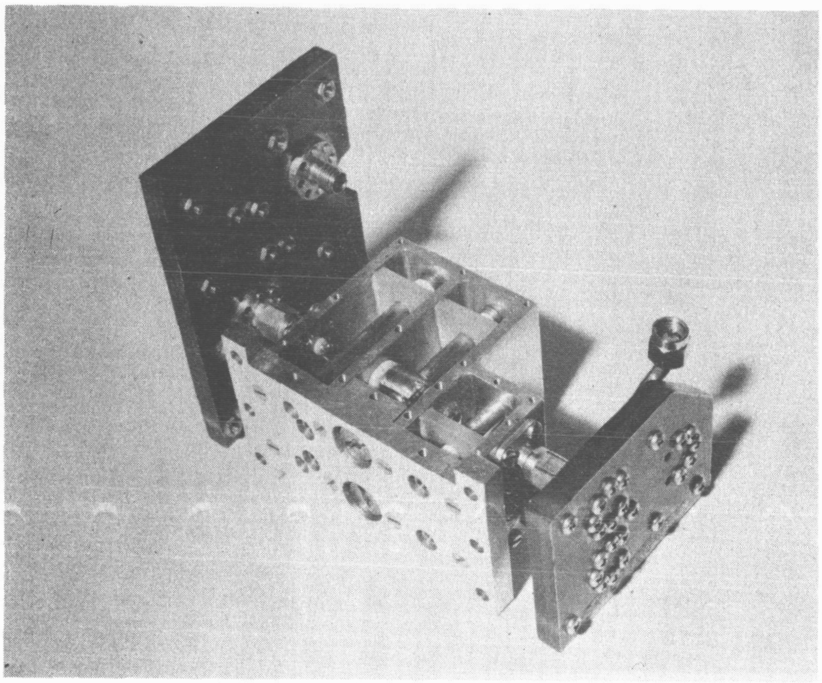
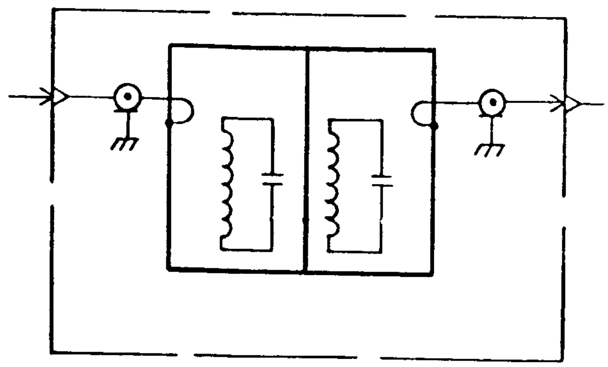


FIGURE 2-19 THIRD TRIPLERS (750 - 2250 MHz) WITH ADDER AND SPLITTER



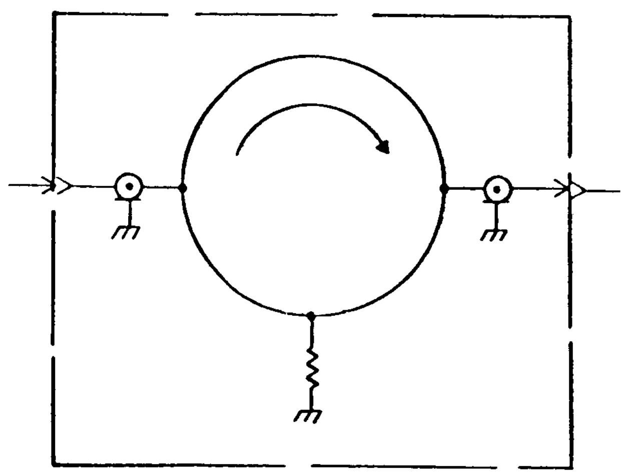


FIGURE 2-20 BANDPASS FILTER AND ISOLATOR SCHEMATIC DIAGRAM

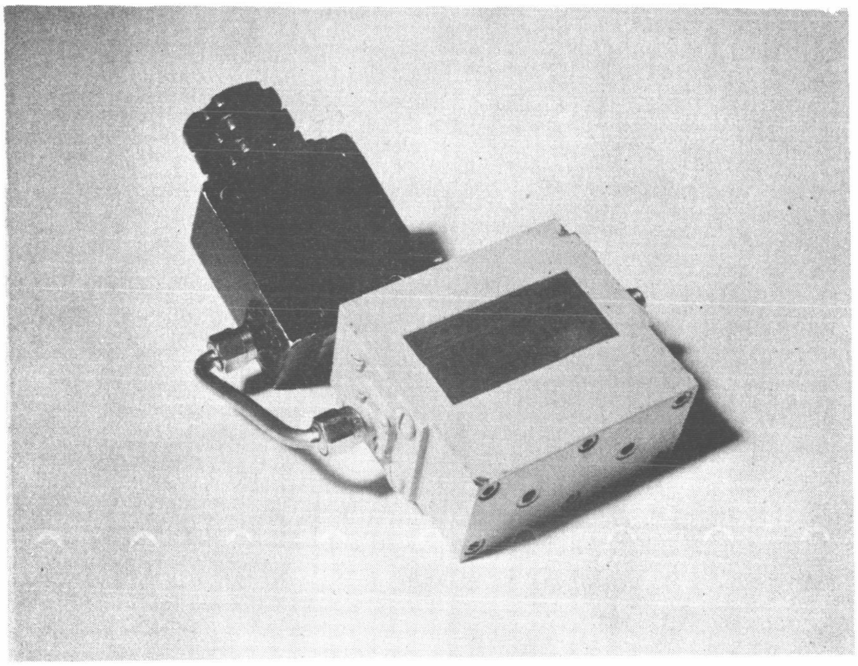


FIGURE 2-21 FILTER AND ISOLATOR

SECTION 3

SPECIAL TROUBLESHOOTING AND ALIGNMENT INSTRUCTIONS

3.0 INTRODUCTION

This section provides alignment and troubleshooting instructions for the transmitter. The individual modules of the transmitter are each tuned separately and then are integrated into the system one at a time. This procedure starts with the exciter/modulator then proceeds with the predriver-driver, power amplifier, automatic level control, first tripler, second tripler, and third tripler.

3.1 MODULE TEST AND ALIGNMENT

3.1.1 Exciter/Modulator (Figure 2-4)

The exciter modulator is composed of the following circuits: power supply, voltage-controlled oscillator, crystal oscillator, and output filter, and amplifier. The exciter modulator operation, maintenance, and performance are described in the following paragraphs utilizing the circuit schematic of Figure 2-4.

3.1.1.1 Voltage-Controlled Oscillator (VCO)

This oscillator operating at 11.15 MHz allows the transmitter frequency to be deviated up to 500 KHz at rates from 0 to 500 KHz. Modulation is accomplished in the colpitts type circuit with voltage-variable capacitors in the tuned circuitry. The oscillator is frequency stabilized for temperature by selecting a combination of positive and negative coefficient capacitors during initial circuit test.

In the oscillator, transistor Q6 is forward biased by R17, R18 and R19. C47 and C60 ground the base for ac signals. Capacitors C34, C36, C37 and C38 form the oscillator feedback network. C39 and C40 are used for coarse setting of the oscillator frequency and temperature compensation. C41 is a double-ended variable air capacitor connected in parallel and so mounted that one section is accessible for frequency adjustment of the transmitter when the exciter/modulator is installed and the main chassis. The other section of C41 is accessible from the bottom of the exciter/modulator. L6 is the tank circuit inductive component. C49 couples the voltage-variable capacitor network to the oscillator tank circuit and prevents grounding of D3 bias voltage through L6. C50 and C61 provide an ac signal ground path for the voltage-variable capacitor network, D3 and D4. R22, R23, R26 and R27 bias the voltage-variable capacitors D3 and D4. R24, R25, L8 and C58 constitute an input signal divider network which determines the deviation sensitivity and input impedance. Temperature compensated zener diode D2 provides a regulated 9.1 volts for the VCO stage only. Inductor L7 injects (or couples) the VCO signal

3.1.1.1 (Continued)

into emitter follower Q7 which drives Q8, an untuned amplifier, and Q9 a tuned amplifier. The output of 1 mw is fed to the mixer.

3.1.1.2 Crystal Oscillator Circuits

The crystal oscillator is a Colpitts type circuit utilizing a fundamental mode crystal. The oscillator transistor collector circuit is tuned to the fourth harmonic of the oscillation frequency. Two tuned amplifier stages and a bandpass filter follow the oscillator. The filter output of 0.5 mw, at 73.2 MHz, is fed to the mixer. Transistor Q1 is forward biased through RFC L2 by R1 and R2 to obtain a power level of 0.2 to 0.7 mw across CR1. C1 dc isolates CR1. C2, C3 and C4 form the oscillator feedback network. C2 is used for temperature compensation of the circuit. No provision is made for correction of the oscillator frequency, since this is readily compensated for in the tuning of the VCO. C6 is tuned for maximum output of the bandpass filter (T1). D1 provides a temperature compensated regulated 9.1 V for the oscillator stage. Transistor amplifier stages Q2 and Q3 are fixed tuned, C9 and C10 being selected to match inductors L3 and L4, respectively. T1 is a triple tuned filter tuned by C12. C12 is tuned for maximum output to the mixer (approximately 0.5 mw) or for maximum output of the exciter/modulator (at T2).

3.1.1.3 Mixer

A HP 10534B Double balanced mixer is used. This is a sealed unit requiring no adjustment or maintenance. Conversion loss will be 6-8 DB.

3.1.1.4 Output Filter and Amplifier

The 84.35 MHz signal (upper sideband) from the mixer is selected by the filter and amplifier tuned circuits. The double tuned filter, consisting of C20, C21, C35, L11, L12, C22 and C23, and the tuned circuit of Q5 are tuned for a passband of 3 MHz. The capacitor tuning L5 in the collector circuit of Q4 is fixed tuned. Variable capacitors C20, C23 and C28 are tuned for maximum output of 28 mw at T2.

3.1.1.5 Power Supply

The power supply provides an isolated and regulated nominal 15 VDC from which the exciter/modulator operates. Input current should be approximately 60 ma with a 28.0 VDC input and the output current 50 ma when loaded by the exciter/modulator. Regulation of the output is $\pm$0.25%. An output voltage level control is provided. The output voltage level control may be set within the range of 13.5 V to 16.5 V to optimize the exciter/modulator output power level.

3.1.1.6 Performance

The exciter/modulator performance shall conform to the following paragraphs of Volume 1 Section 1.

2.1.1	2.1.10*
2.1.2	2.1.11*
2.1.4*	2.1.12*
2.1.5*	2.1.13
2.1.7	2.1.14*
2.1.8	2.1.15
2.1.9	

*Output frequency and frequency deviation of the exciter/modulator will be one twenty seventh (1/27) of the overall transmitter requirement.

3.1.2 Predriver/Driver (Figure 2-6)

The predriver/driver has only one alignment or tuning control, C38. This adjustment is used to match the output of transistor Q7 to the input of transistor Q8 and provide maximum output power of the module. The exciter/modulator is used to supply RF power to the module at the open end of R27. The ALC voltage is obtained from an additional dc power supply with a zero to 20 volt range and is connected between the open end of R10 and dc common. Initial tests of the predriver/driver are conducted with the power splitting network, L36, L37, C41 and C42, disconnected. A 50 ohm coaxial test cable is connected from the junction of C39 and C40 to the 50 ohm coaxial load and power meter capable handling 30 watts of power. The predriver/driver shall perform as follows under the specified conditions:

Module Temperature = no greater than 30°C

Supply Voltage = 24 to 32 volts, dc

Supply Current = less than 2.0 Amperes

Power output = no less than 20 watts

Power Gain = no less than 28 DB

CAUTION: Do not allow the supply current to exceed 2.5 amperes

The ALC voltage is used to control the output power and supply current.

For the complete supply voltage range of 24 to 32 volts, all spurious signals within ± 20 MHz of the carrier shall be 70 DB below the carrier peak amplitude. Some re-adjustment of the bandpass filters and output coupling of the exciter/modulator module may be required to obtain

3.1.2 (Continued)

adequate suppression of the spurious signals (see paragraph 3.1.1). If the filters are re-adjusted it will be necessary to measure the frequency response of the exciter/modulator to ensure that it is still within tolerance.

3.1.3 Power Amplifier (Figure 2-7)

The power amplifier has eight variable capacitors, two each of which are used to match and balance the drive to each transistor. The transistors are tuned in pairs. The power adding circuit consisting of R5, C23, C24, L21 and L22 is disconnected during this procedure. RF power is supplied to the power amplifier from the exciter/modulator and the predriver/driver circuits. An external bias supply is used in place of the ALC to control the output of the predriver/driver as described in paragraph 3.1.1. A 50 ohm coaxial test cable is used to connect the output of the predriver/driver (junction of C39 and C40 figure 2-6) to the input of one pair of ampliers of the power amplifier (junction of either L1 and L2 or L3 and L4). This test cable shall be no longer than six inches. Another 50 ohm coaxial test cable is used to connect the output of the transistor pair to a 50 ohm coaxial load and power meter capable of monitoring 300 watts (at the hot end of either C21 or C22 depending upon which pair of amplifiers are being tested). The dc supply current of each transistor must be monitored separately and continuously. A common dc supply is used for the exciter/modulator (including the dc-dc converter), predriver/driver and the power amplifier. The dc current of the predriver/driver must also be monitored separately.

Initially adjust the series capacitors C1, C2, C3 and C4 to minimum capacitance (the tuning slug all the way out). Adjust the shunt capacitors C5, C6, C7 and C8 to maximum capacitance (tuning slug all the way in). Adjust the supply voltage for 24 volts. Gradually increase the output power of the predriver/driver to approximately 5 watts by means of the ALC bias control. Alternately adjust the series capacitors, approximately one quarter turn at a time, of the transistor pair being tested to obtain maximum power output. In the same manner, alternately adjust the shunt capacitors to maintain a dc current balance between the two transistors.

CAUTION: Never allow the individual transistor current to exceed 2.5 amperes nor the unbalance between the transistor pair to exceed 0.75 amperes. Do not allow the module base plate temperature to exceed 30°C for these tests.

Gradually increase the predriver/driver output to approximately seven watts. The performance of the transistor pair shall be as follows for a supply voltage range of 24 to 32 volts:

3.1.3 (Continued)

Supply Current = less than 2.0 amperes per transistor

Power Output = no less than 60 watts

Power Gain = no less than 9 DB

For the complete supply voltage range of 24 to 32 volts, all spurious signals within ±20 MHz of the carrier shall be 70 DB below the carrier amplitude.

After alignment of the individual pairs of transistors has been accomplished, the power splitting network is added to the output of the predriver/driver (L36, L37, C41 and C42 of figure 2-6). Monitor the individual power outputs of the predriver/driver module with 50 ohm coaxial test cables to insure that they are balanced and that the combined power outputs are as specified in paragraph 3.1.1.

Connect the RF outputs of the predriver/driver to the inputs of the power amplifier per the assembly drawing (SK/LST0481). Connect individual loads to the transistor pairs and monitor the dc current of each power amplifier transistor individually and the complete predriver/driver module. The power amplifier shall perform as previously stated. The outputs of each pair of transistors shall be balanced to within two watts. Alternately adjust the series input capacitors of each pair to obtain the required balance of dc current and power output. Only a very small adjustment should be required if any.

Install the power adder network for the power amplifier (R5, C23, C23, L21 and L22). Continue to monitor the individual currents of the power amplifier transistors and the complete predriver/driver module. The power amplifier combined output shall be no less than 120 watts under the same conditions of supply voltage, dc current and power gain stated previously.

3.1.4 Automatic Level Control (Figure 2-11)

The automatic level control (ALC) circuit has only one variable component. This resistor, R2, is used to adjust the output voltage of the circuit. To connect the ALC circuit into the system or "close the ALC loop", set the dc supply to 26 volts. Using an external ALC bias supply, as in the previous paragraphs, adjust the power amplifier output to nominal 115 watts. Adjust R2 of the ALC circuit to obtain the same voltage at the ALC output (C2) as that of the external bias supply. Remove the external bias supply and substitute for it the ALC output. Some additional adjustment of R2 may be required to obtain the 115 watt output. Vary the dc supply voltage from 24 to 32 volts. The power output shall not vary more than ± 3.0%. It is not required that the individual current of the power amplifier transistors nor the individual current of the predriver/driver module be monitored separately. However, the total current of the dc

3.1.4 (Continued)

supply should never exceed 10.0 amperes at 24 volts and 9.0 amperes at 32 volts under any circumstances. For a nominal 115 watt output, the dc current at 24 volts should be less than 8.5 amperes and less than 8.0 amperes at 32 volts.

3.1.5 First Tripler (Figure 2-13)

The first tripler has seven variable capacitors which require adjustment. C6 and C8 are adjusted to provide a series resonant circuit at the input frequency. They also provide some impedance matching capability for the input circuit. These capacitors are generally adjusted to obtain maximum output power of the tripler as well as maintaining a good impedance match at the input. C4 is the idler capacitor and is used to provide a resonant impedance path to ground at the second harmonic of the input frequency. This capacitor is also tuned to provide maximum power output and optimum impedance matching at the input. C10 and C11 are tuned for series resonance and maximum power out of the output circuit. C12 and C13 provide the output impedance matching capability. In general, all the capacitors are adjusted to obtain maximum power out. C6 and C8 in the input, are balanced adjustments and should be set at approximately the same value. This is also true of C10 and C11 in the output.

When initially driving the first tripler with the power amplifier, the ALC loop should be open and an external bias used in its place. Performance of the exciter/modulator, predriver/driver, power amplifier and first tripler should be as follows:

Supply Voltage	24 V	28 V	32 V
Supply Current	<8.2 A	<7.8 A	<7.8 A
Power Output (250 MHz)	>85 Watts	>85 Watts	>85 Watts

After adjustment of the first tripler, the ALC loop should be closed and tested. This is accomplished in the same manner as was done in paragraph 3.1.4. However, because the first tripler causes some distortion of the power amplifier output signal and the detected signal, it is necessary to monitor the ALC output signal to ensure that it does not saturate or reverse direction as the power amplifier output power is increased. If the ALC output signal should saturate or reverse direction, this condition can be corrected by slight re-adjustment of C4 and C13 of the first tripler. With the ALC loop closed, the output power should not vary more than $\pm 5\%$ when the supply voltage is varied from 24 to 32 volts.

3.1.6 Second Tripler (Figure 2-16)

There are nine variable capacitors of the second tripler which require adjustment. This circuit is quite similar to the first tripler and is adjusted in the same manner. C1 and C2 are input impedance matching

3.1.6 (Continued)

capacitors. C3 and C4 are used to tune the input of the varactor diodes to the input frequency. C5 is the idler capacitor and is adjusted to provide a series resonant path to ground at the second harmonic of the input frequency. C6 and C7 tune the varactor output circuit to resonance at the third harmonic of the input frequency. C8 and C9 provide output impedance matching. C3 and C4 are balance capacitors and should set at approximately the same value. This is also true of C6 and C7. Generally, all the capacitors are adjusted for maximum power output.

The ALC loop should be open and an external biased used to control the output power of the power amplifier when the second tripler is initially connected and tuned with the rest of the system. Performance of the complete system including the second tripler should be as follows:

Supply Voltage	24 V	28 V	32 V
Supply Current	<8.2 A	<7.8 A	<7.8 A
Power Output (750 MHz)	>52 Watts	>52 Watts	>52 Watts

The ALC loop should be tested in the same manner as was described in paragraph 3.1.5 after final adjustment of the second tripler to ensure that the ALC output voltage does not reverse or saturate. If the ALC voltage does reverse or saturate, re-adjust C1 and C2 of the second tripler to correct this condition. With the ALC loop closed, the output power should not vary more than $\pm 5\%$ with a supply voltage variation from 24 to 32 volts.

3.1.7 Third Tripler (Figure 2-18)

The system contains two separate third tripler assemblies. Each assembly is individually tuned and then connected together with the power splitter and power adder (See Figure 2-19). Each assembly has five variable capacitors used for tuning. C1 adjusts the input cavity to resonance at the input frequency. C2 adjusts the varactor input coupling loop for resonance also at the input frequency. C3 adjusts the idler cavity for resonance at the second harmonic of the input frequency. C4 is adjusted for optimum coupling of varactor output at the third harmonic of the input frequency. C5 adjust the output cavity for resonance at the third harmonic of the input frequency.

A Sierra model 470A-1000 power oscillator or equivalent is used as a signal source for initial alignment of each of the third triplers. Also, the bandpass filter and isolator (Figure 2-21) are connected to the output during the alignment of the units. Each tripler is driven with 25 watts of RF power at 759 MHz which is obtained from the Sierra power oscillator. The adjustments of the tripler are all tuned to obtain maximum power out. Several modes of operation can be obtained in the tripler. Usually, one mode of operation can be obtained which is more stable and yields a higher efficiency than any of the others. Each

3.1.7 (Continued)

tripler should yield at least 45% efficiency including the losses of the bandpass filter and isolator. The tripler efficiency, exclusive of the filter and isolator losses, should be greater than 52 percent. Both triplers must be aligned to operate in the same mode. This can be checked by comparing the positions of the capacitor tuning slugs of the two units.

After individual alignment of the triplers has been accomplished, the two units are assembled together with the power splitter, power adder, bandpass filter and isolator. This assembly is then driven with 50 watts of power at 759 MHz which is supplied by the power oscillator. Only a slight amount of tuning of the triplers should be required to obtain the required output power. The corresponding capacitors of each unit should be tuned alternately and only a very small amount each time. If the units are inadverently too far misaligned, it will be necessary to disassemble the units from the power splitter and power adder and realign them on an individual basis. The overall efficiency of the complete assembly should be greater than 43% with a minimum output greater than 21 watts.

After alignment of the third tripler including the power splitter, power adder, filter and isolator has been completed using the power oscillator, the units are then integrated with the complete transmitter assembly. Slight re-adjustment of the second tripler output (C6 and C7) and the third tripler input (C1) may be required. As was the case with the first and second triplers, the ALC loop should be open and an external supply used in its place to control the power output. The performance of the complete transmitter shall be as follows:

Supply Voltage	24 V	28 V	32 V
Supply Current	<8.2 A	<7.8 A	<7.8 A
Power Output (2277.5 MHz)	>20.0 Watts	>20.0 Watts	>20.0 Watts

A final test of the ALC output voltage should be made to ensure that it does not reverse or saturate. With the ALC loop closed, the output power should not vary more than ± 5 % with a supply voltage variation between 24 and 32 volts. All spurious signals at the output should be a minimum of 70 DB below the amplitude of the carrier. Some re-adjustment of the exciter/modulator bandpass filters and output coupling may be necessary to accomplish this (Paragraph 3.1.1). After any re-adjustment of the exciter/modulator filters, a recheck of the modulation frequency response should be made.

3.2 DISASSEMBLY AND ASSEMBLY OF MAIN CHASSIS (SK/LST0490)

In order to disassemble the transmitter for purposes of troubleshooting or adjustment of one of the modules, a certain order must be followed for removal of the modules from the main chassis. This order is as follows:

3.2 (Continued)

a. Remove exciter/modulator assembly (SK/LST0480) and disconnect all wires.

b. Remove automatic level control (ALC) assembly (SK/LST0485) from the exciter/modulator assembly. Disconnect all wires to the ALC board.

c. Remove the screws holding the predriver/driver power amplifier assembly (SK/LST0481) in place. Do not remove the assembly at this time.

d. Remove the bandpass filter and isolator as follows:

   1. Remove the screws holding the bandpass filter and isolator in place.

   2. Loosen the output coaxial feed through connector.

   3. Remove the output connection of the isolator.

   4. Remove the input connection of the bandpass filter.

   5. Remove the bandpass filter and isolator as a single unit.

e. Disconnect all the wires to the power supply (SK/LST0516) and remove it from the assembly.

f. Loosen all the screws which hold the weldment assembly (SK/LST0509).

g. Loosen all of the screws holding the second tripler (SK/LST0484).

h. Tilt the end of the weldment assembly which is over the first tripler (SK/LST0483) out of the chassis until the two screws, in the first tripler next to the chassis wall, can be removed. After removing the screws, allow the assemblies to fall back in place.

i. Remove the remaining screws from the weldment assembly and remove the assembly from the chassis.

j. Remove the cover from the first tripler and disconnect the input and output cables.

At this point, the remainder of the modules can be removed without any specific order.

To reassemble the transmitter, the procedure is reversed.

3.3 SPECIAL TROUBLESHOOTING PROCEDURES

Because of the compactness of the transmitter assembly, it is almost impossible to perform any trouble shooting with the modules assembled in the chassis. Normal troubleshooting techniques of signal tracing should be employed once the transmitter is disassembled.

The dc supply current may be an aid in isolating some types of trouble. The following may be used as a guide in fault isolation:

Supply Current	Power Output	Probable Cause
Normal	Below Normal	Frequency Multipliers
Below Normal	Below Normal	ALC, Predriver/Driver, Exciter/Modulator
Zero	Zero	Predriver/Driver, Exciter/Moudlator

SECTION 4

DRAWING TREE

4.0 INTRODUCTION

Figure 4-1 is a reproduction of the drawing tree showing all of the drawings required for the manufacture and assembly of this transmitter.

SK/LST0490 - Top Assembly 20 Watt Transmitter
- SK/LST0491 - Chassis Detail
- SK/LST0484 - Second Tripler Assembly
  - SK/LST0479 - Second Tripler Detail
- SK/LST0505 - Power Splitter Assembly
  - SK/LST0505 - Power Splitter P/C Master
- SK/LST0482 - Automatic Level Control Assembly
  - SK/LST0508 - Automatic Level Control P/C Master
- SK/LST0488 - RFI Filter Assembly
  - SK/LST0492 - RFI Filter Detail
- SK/LST0510 - Standoff Detail
- SK/LST0516 - Modification Power Supply
- SK/LST0598 - Adapter Plate Isolator
- SK/LST0499 - Exciter/Modulator Isolation Plate Detail
- SK/LST0480 - Exciter/Modulator Assembly
  - SK/LST0496 - Exciter/Modulator P/C Master
  - SK/LST0497 - Exciter/Modulator Detail
- SK/LST0489 - Exciter/Modulator Ring Frame & Cover Detail
- SK/LST0583 - Master ID Tag.Metal Adhesive
- SK/LST0481 - Predriver/Driver, Power Amplifier Assembly
  - SK/LST0494 - Predriver/Driver P/C Master
  - SK/LST0493 - Power Amplifier P/C Master
  - SK/LST0518 - P/C Assembly Detector - ALC
- SK/LST0509 - Bracket Weldment Assembly
- SK/LST0483 - First Tripler Assembly
  - SK/LST0478 - First Tripler Detail
  - SK/LST0507 - First Tripler P/C Master
- SK/LST0506 - Power Adder Assembly
  - SK/LST0506 - Power Adder P/C Master
- SK/LST0485 - Third Tripler A-sembly
  - SK/LST0498 - Third Tripler Detail

FIGURE 4-1 DRAWING TREE 20 WATT TRANSMITTER