

# *Clegg*

**VHF-FM 25WATTS  
143 TO 149MHz**

**PLL AMATEUR TRANSCEIVER**



**FM-88**

**OWNER'S MANUAL**

# SECTION 1. SPECIFICATIONS

## GENERAL

|                          |  |
|--------------------------|--|
| Frequency Coverage       | : 143.00 to 148.995 MHz in 5 KHz steps   |
| Frequency Control        | : Digitally synthesized PLL system   |
| Frequency Stability      | : Temperature: Less than 30 Hz/°C<br>Voltage: Less than 100 Hz for ±15% change |
| Semiconductor Complement | : 4 Transistors; 11 FETs; 13 IC's<br>4 LED Displays, 29 Diodes                 |
| Modulation Type          | : 16F3   |
| Supply Voltage           | : 13.8V DC ±15%, Negative ground   |
| Current Drain            | : Transmit:<br>Hi (7A)<br>LO (2A)<br>Receive: .8A Average                      |
| Antenna Impedance        | : 50 ohms nominal  |
| Size                     | : 2-5/8(H) x 8-5/8(W) x 10-3/4(D) (exclusive of controls)                      |
| Weight                   | : Approx. 7 lbs. net; 9 lbs. shipping  |

## TRANSMITTER

|                           |   |
|---------------------------|---|
| Frequency Control         | : Hetrodyne generated by product of Phase locked VCO and OFFSET Crystal.              |
| Transmit Frequency Offset | : Panel selectable for ±600 KHz; SIMPLEX and 2 optional non-standard Repeater Offsets |
| Modulation                | : Direct FM; Adjustable 3 to 15 KHz deviation (Factory set at 5 KHz)                  |
| Audio Input               | : 600 ohms  |
| Microphone                | : 600 ohm dynamic with push to talk switch  |
| Power Output              | : Continuously controllable from 1 to 25 watts.                                       |
| Spurious Outputs          | : Down 66 dB (typical) 60 dB (min)  |
| Duty Cycle                | : 50% HI POWER; 100% LO POWER   |

## RECEIVER

|                        |  |
|------------------------|--|
| Frequency Scheme       | : Dual conversion superhetrodyne with 16.9 MHz and .455 MHz IF |
| Sensitivity            | : .3 μV (max) for 12 dB SINAD<br>.2 μV Squelch threshold       |
| Spurious Response      | : -65 dB (min)   |
| Selectivity            | : 14 KHz at -3 dB<br>25 KHz at -70 dB                          |
| Audio Output Power     | : 1.5 watts (min) at 10% THD                                   |
| Audio Output Impedance | : 8 ohms   |

## ACCESSORIES

The following accessories for the Clegg FM-88 are included:

|                                |   |
|--------------------------------|---|
| 1) Microphone (dynamic type)   | 1 |
| 2) Microphone hanger           | 1 |
| 3) Spare fuse (7A)             | 1 |
| 4) Mobile bracket and hardware | 1 |
| 5) Instruction Manual          | 1 |
| 6) External Speaker plug       | 1 |
| 7) Accessory plug              | 1 |
| 8) Desk mounting bracket       | 1 |
| 9) DC Power Cables             | 2 |

## SECTION 2. GENERAL INFORMATION

The FM-88 is a 25 watt, frequency synthesized solid state radio set providing transmission and reception over the 143 to 149 MHz range.

Frequency control employing state of the art digital circuitry combined with a precision phase locked VCO provides 1200 receive channels in 5 KHz increments. Receive frequency is displayed in large bright LED numerics.

A unique feature of the FM-88 is its transmit frequency flexibility wherein non-standard Repeater splits up to  $\pm 1.5$  MHz can be accommodated as well as the standard  $\pm 600$  KHz splits and SIMPLEX.

Although basically designed for mobile operation the FM-88 in conjunction with a Clegg Model PS-12A Power Supply makes an ideal base station.

Construction is modularized with individual, easily accessible PC boards for each functional circuit section.

## SECTION 3. INSTALLATION

### 3.1 Unpacking:

Carefully remove your transceiver from the packing carton and examine it for signs of shipping damage. Should any shipping damage be apparent, notify the delivering carrier and CLEGG immediately, stating the full extent of the damage. It is recommended you keep the shipping carton for future storage, moving, or reshipment. Accessory hardware, cables, etc., are packed with the transceiver. Make sure you have not overlooked anything.

### 3.2 Location:

Where you place the transceiver in your automobile is not critical and should be governed by convenience and accessibility. Since the unit is so compact, many mobile possibilities present themselves. In general, the mobile mounting bracket will provide you with some guide as to placement. Any place where it can be mounted with metal screws, bolts, or pop-rivets will work. For base station operation, the bracket for desk-top operation places controls at a comfortable position and the internal speaker in an efficient position.

### 3.3 Power Requirements:

VOLTAGE IN EXCESS OF 16V will cause damage to the FM-88. Check supply voltage before connecting power cord!

The FM-88 is supplied ready to operate from any regulated 13.8V DC, 7.0 ampere negative ground source. An automobile, 12 volt, negative ground, system is usually more than adequate. Some note must be taken, however, to the condition of the vehicle's electrical system. Problems such as low battery, worn generator/alternator, poor voltage regulator, etc., will impair operation of your FM-88 as well as the vehicle.

It is recommended that the DC power cable supplied with the FM-88 be wired directly to the vehicle battery terminals. Be certain to observe correct polarity; RED wire is POSITIVE (+) and BLACK wire is NEGATIVE (-). Do not attempt to install the FM-88 in a vehicle employing POSITIVE GROUND ignition system.

Where temporary mobile installation is made and it is not practical to wire directly to the vehicle battery operation is possible in some vehicles by employing such expedencies as a cigar lighter adapter. However, less than full performance of the FM-88 will likely be attained, particularly in the HI PWR transmit mode.

In selecting a base station power supply it is imperative that the unit be sufficiently regulated so that its no load voltage not exceed 15.8 volts and voltage at 7 amps load not drop below 13 volts. Output hum and ripple should be less than 100 millivolts.

The Clegg Model PS-12A is ideally suited as an economical, reliable station supply for the FM-88.

### 3.4 Antenna:

The most important single item that will influence the performance of any communication system is the antenna. For that reason, a good, high-quality antenna of 50 ohms impedance is recommended. When adjusting your antenna, whether mobile or fixed, by all means follow the manufacturer's instructions. There are some pitfalls to be aware of. For example, do not attempt to adjust an antenna for lowest VSWR when using a VSWR meter not engineered for VHF applications. Such readings will invariably have a substantial at 144 MGz. Rather, use an in line meter similar to the Mirage MP-2 or Bird Model 43 with VHF cartridge. Further, when adjusting a mobile antenna, do so with the motor running preferably above normal idling speed. This will insure proper voltage level to the transceiver.

Do not become alarmed if your transceiver fails to transmit at times during the antenna tune up procedure. Remember, your transceiver has a built-in Automatic Protection Circuit (APC) that will disable the transmitter if excessive VSWR, or an open or shorted coaxial line or connector, or other antenna deficiency is present.

The RF coaxial connector on the rear chassis mates with a standard PL-259 connector.

CLEGG COMMUNICATIONS stocks a substantial line of 2 meter antennas and beams. Our sales department will be pleased to advise you as to the best choice for your specific application.

### 3.5 Microphone:

A high quality dynamic microphone is supplied with your transceiver. Merely plug it into the proper receptacle on the front panel. Should you wish to use a different microphone, make certain it is of the low impedance type (600 ohms). Particular care should be exercised in wiring as the internal electronic switching system is dependant upon it. See the schematic for the proper hook up. Under no circumstances use a "gain pre-amp" type microphone. The audio system in your transceiver is more than adequate and additional pre-amplification is unnecessary. To use this class of microphone is to invite distortion and unsatisfactory operation of the transceiver.

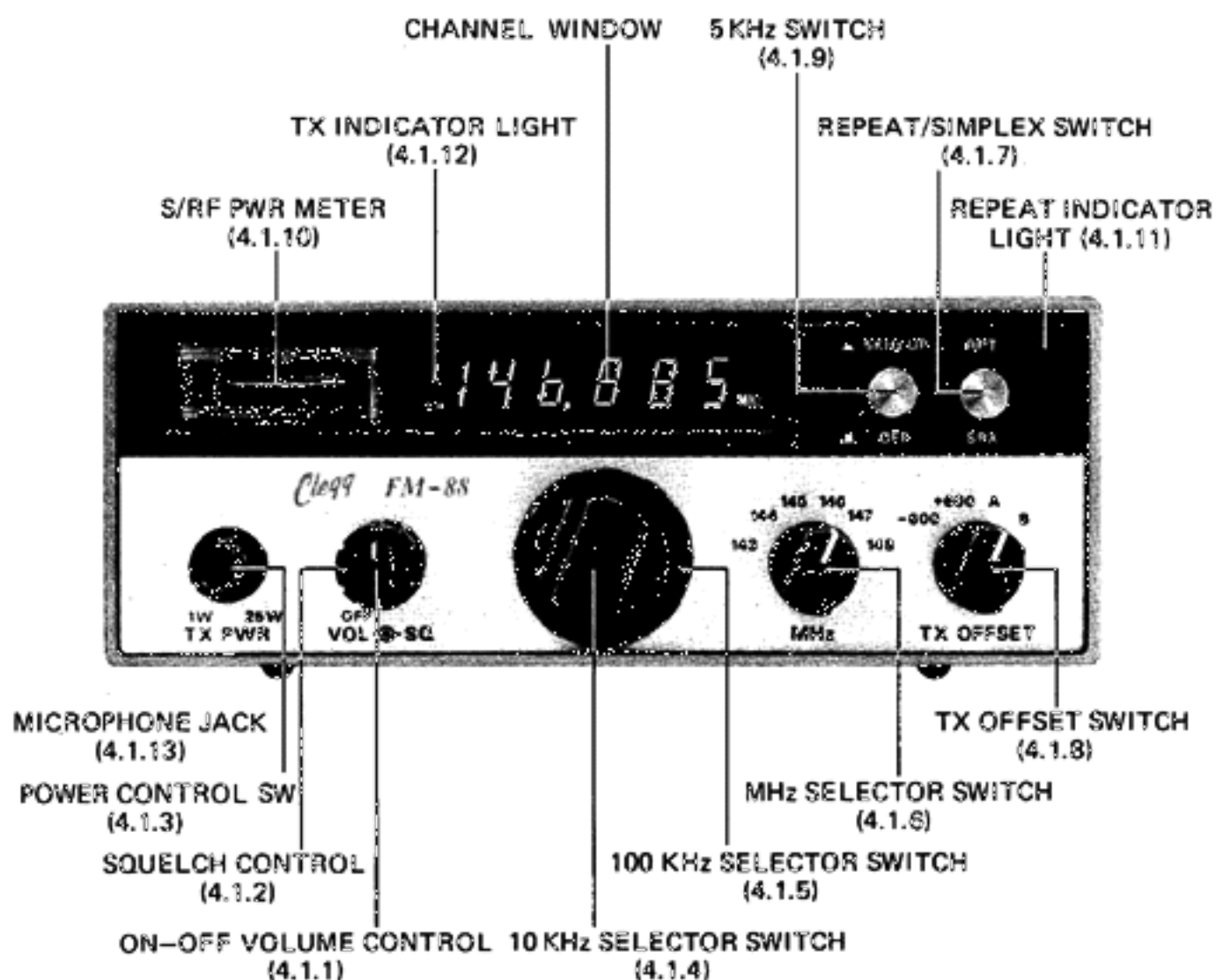
### 3.6 FM-88S:

The FM-88S provides all features and performance criteria of the FM-88 and in addition has versatile Scanner capability as described in the additional data sheet which accompanies the "S" versions of the FM-88.

Consult Clegg Sales Department regarding adding this option to standard models.

## SECTION 4. CONTROL FUNCTIONS

### 4.1 FRONT PANEL CONTROLS



- 4.1.1 ON-OFF/VOLUME CONTROL:** Applies power to receiver and adjusts desired level of sound
- 4.1.2 SQUELCH CONTROL:** Silences background noise in the absence of a received signal when properly adjusted. Rotation in clockwise direction increases SQUELCH threshold.
- 4.1.3 TX PWR CONTROL:** Provides continuously adjustable transmitter output power from 1 to 25 watts.
- 4.1.4 10 KHz SELECTOR SWITCH:** The inner switch selects the desired frequency in 10 KHz increments from 0 to 9 and simultaneously activates LED display on the channel window.
- 4.1.5 100 KHz SELECTOR SWITCH:** The outer switch selects the desired frequency in 100 KHz increments from 0 to 9 and simultaneously activates LED display on the channel window.
- 4.1.6 MHz SELECTOR SWITCH:** This six position rotary switch selects the desired frequency in 1 MHz increments from 143 to 148 and simultaneously activates LED display on the channel window.  
Note that the digits "14" are fixed and back-lighted when the power is "ON".

#### 4.1.7 RPT/SPX SWITCH

RPT position: Activates TX OFFSET function for displacing transmitter output frequency from receiver frequency for Repeater access and operation. Also activates REPEAT INDICATOR LIGHT.

SPX position: Disables OFFSET function and places both transmitter and receiver on identical frequencies.

4.1.8 TX OFFSET SWITCH: This control selects the frequency difference between the displayed receiver frequency and the transmitter output frequency. (Typically -600 KHz for repeaters below 147 MHz and +600 KHz for repeaters above 147 MHz). To accommodate non-standard repeaters positions A and B can be used by installation of appropriate offset crystals available from Clegg.

4.1.9 5 KHz SWITCH: This switch increases operating frequency by 5 KHz and simultaneously activates 6th digit in LED display on the channel window.

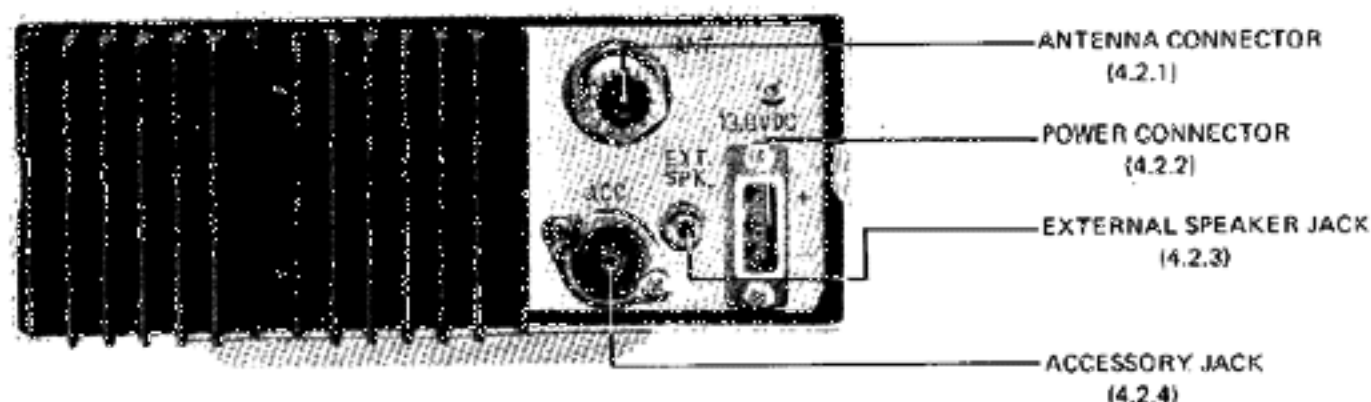
4.1.10 S/RF PWR METER: Shows signal strength of the received signal and relative transmitter RF output power.

4.1.11 REPEAT INDICATOR LIGHT: Lights brightly when RPT/SPX switch is in RPT mode.

4.1.12 TX INDICATOR LIGHT: Lights brightly when transmitting.

4.1.13 MICROPHONE JACK: Accepts 4 prong mike plug supplied on microphone.

#### 4.2 REAR PANEL CONTROLS



4.2.1 ANTENNA CONNECTOR: Accepts standard PL-259 coaxial connector

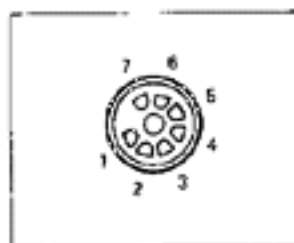
4.2.2 POWER CONNECTOR: Accepts polarized power cord for 13.8V Supply.

4.2.3 EXTERNAL SPEAKER JACK: This jack mates with the accessory Ext. speaker plug supplied for external 8 ohm speaker on headset use. The use of this jack will disable the internal speaker.

4.2.4 ACCESSORY JACK:

Accepts 7 pin plug for interconnecting various accessory devices to the transceiver.

1. Tone Audio Input
2. +12 VDC (During TX only)
3. +12 VDC
4. Transmitter PTT
5. Ground
6. Discriminator Meter
7. Ground



## SECTION 5. OPERATING INSTRUCTIONS

### 5.1. INITIAL PREPARATIONS

- 5.1.1 Connect the microphone to the microphone jack
- 5.1.2 Connect the antenna to the antenna coax connector. Make sure the coax line is of the correct impedance (50 ohms) and is neither shorted nor open circuited.
- 5.1.3 Make sure the volume control is in the off position and the squelch control is in the maximum counterclockwise position. The red lead should be connected to the positive side of the power source and the black lead to the negative side. If these leads are improperly connected, the FM-88 will not function. No damage will be incurred since protection is provided in the FM-88 for this purpose.

### 5.2. OPERATION

- 5.2.1 Rotate the volume control clockwise a few degrees until the switch snaps into the ON position, and LED frequency display on the channel window and S/Rf meter will be illuminated.
- 5.2.2 Adjust MHz, 100 KHz and 10 KHz selector switches to the desired frequency.

### 5.3. RECEIVER

- 5.3.1 Advance the volume control to the desired audio level.
- 5.3.2 Carefully adjust the squelch control clockwise until the audio noise just disappears. This is the proper squelch threshold setting and must be done when no signal is present. Your transceiver will now remain silent until an incoming signal is received which opens the squelch. If the squelch is unstable due to the reception of a weak or unstable station, adjust the squelch control further until the proper threshold is obtained.
- 5.3.3 The S meter indicates the signal strength of the incoming stations and is calibrated in S units. An input signal of approximately 5  $\mu$ V will provide an S9 reading.

### 5.4. TRANSMITTER

The operation of the transmitter and receiver is controlled by the push-to-talk switch located on the side of the microphone. When depressed, the transmitter is placed into operation and, at the same time, the receiver becomes inoperative.

- 5.4.1 Place the REPEAT/SIMPLEX switch in either the REPEAT or SIMPLEX position. In the REPEAT position, TX OFFSET switch is activated and REPEAT INDICATOR LIGHT illuminates. In the -600 position on TX OFFSET switch, the transceiver transmits at the frequency of -600 KHz than Receiver frequency and in the +600 position, the transceiver transmits at the frequency of +600 KHz. Position A and B provide capability to use the FM-88 with non-standard repeater pairs. Consult Clegg Sales Dept.
- 5.4.2 Place the HI-LOW power switch in either the HI or LOW position dependent on the range of desired communications. In the HI position, the transceiver operates at full 25 watt output. In the LOW position, the transceiver operates at one watt of power. (The HI-LOW power switch can be set to the LOW power position and the power output can be adjusted between .1 and 4 watts by means of internal potentiometer RT-552 accessible with bottom cover removal).
- 5.4.3 When pushing the PTT (push to talk) button on the microphone, the TX INDICATOR LIGHT is illuminated and the METER provides an indication of relative power output of the transmitter. The pointer will be on or near the red mark on the meter scale when on high power and just a little over 1 on low power when the the antenna SWR is acceptably low.

**NOTE:** Do not attempt to transmit unless your antenna is properly connected.

## SECTION 6. CIRCUIT DESCRIPTION

### 6.1 RECEIVER CIRCUIT

- 6.1.1 **RF Unit:** Signal from the antenna connector passes through the dual-tuned band pass filter, and is amplified by Q101, and fed into FT101 a 3-section helical resonator. The signal is then mixed with signal from the VCO unit by Q102 first mixer, and produces first IF 16.9MHz.
- 6.1.2 **IF Unit:** Signal from the RF unit passes through FT151 4-Pole monolithic crystal filter, and is amplified by Q151 first IF AMP., and is mixed with signal from Q153, 16.445 MHz. Second IF passes through FT152 ceramic filter, and is limited in amplification by IC151 and 152. The AF signal is detected by FT153 ceramic discriminator, and fed into the AF unit.
- 6.1.3 **AF Unit:** AF signal from the IF unit is amplified by Q203 and IC202, and drives the speaker, while noise signal from the IF unit is amplified by IC201 and Q201, and detected by D201 and D202, and drives switching transistor. Q202 controls Q203 AF amplifier and activates squelch.

### 6.2 TRANSMITTER CIRCUIT

- 6.2.1 **Tx Driver Stage Unit:** Signal from the VCO and Signal which is selected from X701 to X705 and oscillated by Q706 in IF unit are mixed with balanced mixer Q401 and Q402, and produce mixer output in the 146 MHz band. That signal is then amplified by Q403, Q404 and Q405, and drives the final unit.
- 6.2.2 **Final Unit:** Output from the transmit driver unit amplified by Q451, Q452 and Q453 into a 25 watt output which is supplied into the APC unit. Signal from the final unit passes through the SWR Bridge, diode switch D503 and D504, and also passes through 3-section low pass filter, and produces 25 watt output which is supplied into the APC unit.

### 6.3 PHASE LOCKED LOOP CIRCUIT

- 6.3.1 **Local Unit:** Crystals X251 and X252 are selected by switching transistors Q251 and Q252, and are oscillated by Q253. Oscillation output is multiplied three times by Q254, and again multiplied three time by Q255, and then it is fed into PLL mixer Q256. Simultaneously fed into Q256 is the output of VCO unit, and PLL IF (4.000–6.995 MHz) is produced.
- 6.3.2 **Counter Unit:** The PLL IF is amplified by Q304 generated by Q303 and fed into IC304. This signal is divided in half by IC304. It is then program-divided by 301, to produce an output of 25 KHz. On the other hand, X301(10.24 MHz) is oscillated by Q306, and fed into IC304 through driver Q305. Here again, the signal frequency is divided in half by IC304, and fed into IC301, where the output of 1/1024 (5 KHz) is produced.
- 6.3.3 **VCO Unit:** The difference output from the counter unit passes through the active low pass filter (Q351 through Q353), and goes into the VCO D351, D352 and Q354, and controls the VCO frequency. The output of the VCO is amplified by Q356, and fed into the local unit PLL mixer Q256. On the other hand, the output of the VCO is also amplified by Q355, which produces the local frequency for both transmit and receive.
- 6.3.4 **Display Unit:** The desired BCD code is selected by the channel selector, and decoded by IC651 through IC653, and it drives the LED display.

### 6.4 POWER SUPPLY CIRCUIT

DC input from the power connector is regulated by Q551 through Q553, and 13.6V DC is selected for transmit and receive. Q557 and Q558 are worked as protector circuit. When the excessive power happens to be supplied in transmit or receive, Q558 is automatically cut off and protects the circuits from the damage. IC801 is used for a 5V regulator for the TTL and C-MOS. Q554, Q555 and Q801 regulate the final unit as high-low power controller. D553, D554 and Q556 are activated by APC unit, and unlock signal of the counter unit, and regulate Q555 to shut down the transmit power.



# SECTION 7. ALIGNMENT PROCEDURE

## 7.1 GENERAL

THE FM-88 HAS BEEN FACTORY ALIGNED USING TECHNIQUES AND TEST EQUIPMENTS NOT NORMALLY AVAILABLE TO THE SERVICE TECHNICIAN. IT SHOULD NOT BE NECESSARY TO PERFORM ANY ALIGNMENT ON THE UNIT AS RECEIVED FROM THE FACTORY. IN THE EVENT OF COMPONENT FAILURE, ANY REALIGNMENT WILL BE MINIMAL. IF IT APPEARS THAT ANY LARGE DEGREE OF REALIGNMENT IS REQUIRED, THOROUGHLY CHECK THE REPLACEMENT COMPONENT BEFORE PROCEEDING.

## 7.2 PHASE LOCKED LOOP CIRCUIT

### 7.2.1 Equipment Required:

- a) 13.8V DC Power Source (3A).
- b) Synchroscope (DC to more than 150 MHz)
- c) Frequency Counter (More than 150 MHz)

### 7.2.2 Set up:

- a) Initial front panel controls should be set in the following manner.

- \* POWER SWITCH (OFF—Volume) : Off
- \* 10KHz & 100KHz SELECTOR SWITCH : Any position
- \* BAND MHz SELECTOR SWITCH : Any position
- \* 5 KHz SWITCH : Either position
- \* REPEAT-SIMPLEX SWITCH : Simplex
- \* TX OFFSET SWITCH : Any position
- \* TX PWR Control : Any position

- b) Connect the power cable to the 13.8V DC power source.

- c) In the VCO unit.

c-1) Remove the wire of either J353 or J303

c-2) Remove the connector plug of J352 and connect to Synchroscope using coaxial cable with 2-P connector to be fitted to the terminals, 6 (HOT) and 7 (GROUND).

c-3) Connect VTVM and 200K ohm variable resistor to TP351 as described below:

### 7.2.3 Procedure:

- a) Apply power to the unit.
- b) Adjust 200K ohm variable resistor connected to TP351 for 5.5 Volt VTVM reading and L352 for 131.1 MHz  $\pm$  0.2 MHz frequency counter reading.
- c) Adjust 200 K ohm variable resistor for 129.1 MHz  $\pm$  0.2 MHz frequency counter reading and L354 for maximum synchroscope amplitude.
- d) Remove the connector from J352 6 and 7 and reconnect it to J352 4 and 5. Then, adjust L353 for maximum.
- e) Connect TP251 to 10 : 1 probe of synchroscope and adjust L253 and 254 for maximum synchroscope amplitude, and adjust them so as to be within 20% of amplitude difference when 145 and 146 MHz bands are alternately switched.
- f) As for TP-252, adjust L255 and 256, the same to above.

g) Conduct frequency adjustment in the following manner:

1) Connect frequency counter to the plug (P401) of J401.

2) Measure and adjust frequency on following channels.

- \* 144.005 MHz: f = 127.105 MHz. . . . . CT254
- \* 144.000 MHz: f = 127.100 MHz. . . . . CT251
- \* 147.005 MHz: f = 130.105 MHz. . . . . CT253
- \* 147.000 MHz: f = 147.000 MHz. . . . . CT252

NOTE: Repeat the procedures 144.005 MHz, 144.000 MHz and 147.005 MHz, 147.990 MHz.

## 7.3 RECEIVER

### 7.3.1 Equipmant Required:

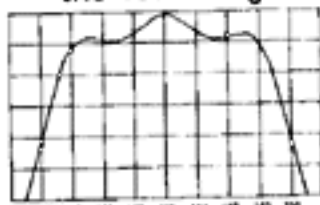
- a) 13.8V DC Power Source (3A)
- b) VHF Sweep generator and all accessories
- c) Signal generator (144-148 MHz)
- d) AF measurement equipments — 4 ohm dummy load  
V.T.V.M.  
Oscilloscope  
Distortion Meter  
Audio Oscillator
- e) DC Volt Meter

### 7.3.2 Set-up:

- a) Initial front panel controls should be set in the following manner:
  - \* POWER SWITCH (Off-volume) : Off
  - \* SQUELCH CONTROL : Fully counterclockwise
  - \* OTHER SWITCHES : Any position
- b) Connect the power cable to the 13.8V DC power source.
- c) Connect all of AF measurement equipments (See 7.3.1 - d) to external speaker jack.
- d) Detach J351 in VCO unit.
- e) Connect 'scope vertical to case of Q102
- f) Connect RF cable from sweep generator to ANT connector and adjust to 146 MHz center freq. with about 12 MHz sweep width.

### 7.3.3 Procedure:

- a) Apply power to the unit and turn on power switch.
- b) Adjust L101, L102 and FT101 to obtain a wave form as illustrated below on the following measurement conditions.



- \* Input level . . . . . 5.6 mV rms
- \* Marker . . . . . increment by 1 MHz
- \* Center frequency . . . . . 146 MHz
- \* Oscilloscope . . . . . x 1 range (max.)

- c) Then, detach the sweep generator and remove the cable from the case of Q102 in RF unit, and connect the signal generator (146.00 MHz, 3.3 KHz deviation at AF 1 KHz) to the antenna terminal and replace J351 in VCO unit. Set MHz, 100 KHz and 10 KHz controls to 146.00.

- d) Increase the output level of the signal generator for one third reading of indicator on the S-Meter scale and adjust L103, L104, L151 and L152 several times for the peak power.
- e) Adjust the signal generator for the 5  $\mu$ V input and adjust RT152 to make the meter read 59.
- f) Adjust RT151 for convenient SQUELCH control range.

## 7.4 TRANSMITTER

### 7.4.1 Equipment Required:

- a) 13.8V DC power source (8A)
- b) RF power meter (Bird Watt Meter 50W 150 MHz)
- c) Frequency Counter (More than 150 MHz)
- d) FM Linear detector
- e) AF distortion meter
- f) VTVM
- g) AF oscillator
- h) Spectrum analyzer (1.2G Hz)
- i) Microphone or TX Switch
- j) DC volt meter
- k) Feed through dummy load (more than 30 watts)
- l) RF attenuator

### 7.4.2 Set-up:

- a) Initial front panel controls should be set in the following manner:
 

|                             |   |              |
|-----------------------------|---|--------------|
| * POWER SWITCH (OFF-volume) | : | Off          |
| * TX PWR Control            | : | Maximum      |
| * RPT/SPX SWITCH            | : | SPX          |
| * OTHER SWITCHES            | : | Any position |
- b) Connect the power cable to the 13.8V DC power source.
- c) Connect the power meter to the antenna terminal.
- d) Connect the FM linear detector and the frequency counter.
- e) Connect the TX switch, the AF oscillator and the VTVM to the microphone connector (Mike connector pin No. 1 – Audio, 2 & 3 – Ground, 4 – PTT.).

### 7.4.3 Procedure:

- a) Before the power switch is on, make the preliminary adjustment as follows :
  - a-1) Adjust L401 through L407 so that the core enters about 1.2mm below the can.
  - a-2) Turn the semi-fixed resistors as follows:
 

|                 |   |                        |
|-----------------|---|------------------------|
| RT551 and RT553 | : | Fully clockwise        |
| RT351 and RT552 | : | Fully counterclockwise |
| RT401           | : | Middle position        |
  - a-3) Set the trimmer CT401, CT402, CT451, CT452, CT453; CT454 and CT501 at the position of half capacitance.
- b) Turn on the power switch and set the channel to the 146.00 MHz.
- c) Keep the unit in TX with the microphone or the TX switch and adjust L401 through L406 for the maximum voltage at the TP401.