



MODEL **FS-4**

# **FREQUENCY SYNTHESIZER**



## INSTRUCTION MANUAL

R. L. DRAKE COMPANY, MIAMISBURG, OHIO, U.S.A.

**DRAKE**

## LIMITED WARRANTY

*R. L. DRAKE COMPANY warrants to the original purchaser that this product shall be free from defects in material (except tubes and RF output transistors) or workmanship for ninety (90) days from the date of original purchase.*

*During the warranty period the R. L. DRAKE COMPANY or an authorized Drake service facility will provide free of charge both parts (except tubes and RF output transistors) and labor necessary to correct defects in material or workmanship.*

*To obtain such warranty service, the original purchaser must:*

- (1) Complete and send in the Warranty Registration Card.*
- (2) Notify R. L. DRAKE COMPANY or its nearest authorized service facility, as soon as possible after discovery of a possible defect, of:*
  - (a) The model number and serial number, if any;*
  - (b) The identity of the seller and the approximate date of purchase;*
  - (c) A detailed description of the problem, including details on the electrical connection to associated equipment and the list of such equipment.*
- (3) Deliver the product to the R. L. DRAKE COMPANY or the nearest authorized service facility, or ship the same in its original container or equivalent, fully insured and shipping charges prepaid.*

*Correct maintenance, repair and use are important to obtain proper performance from this product. Therefore, carefully read the Instruction Manual. This warranty does not apply to any defect that R. L. DRAKE COMPANY determines is due to:*

- (1) Improper maintenance or repair, including the installation of parts or accessories that do not conform to the quality and specifications of the original parts.*
- (2) Misuse, abuse, neglect or improper installation.*
- (3) Accidental or intentional damage.*

*All implied warranties, if any, terminate ninety (90) days from the date of the original purchase.*

*The foregoing constitutes R. L. DRAKE COMPANY'S entire obligation with respect to this product, and the original purchaser and any user or owner shall have no other remedy and no claim for incidental or consequential damages. Some states do not allow limitations on how long an implied warranty lasts or do not allow the exclusion or limitation of incidental or consequential damages, so the above limitation and exclusion may not apply to you.*

*This warranty gives specific legal rights and you may also have other rights which vary from state to state.*

**R. L. DRAKE COMPANY**  
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## **CHAPTER I INTRODUCTION**

### **1-1. GENERAL DESCRIPTION.**

The FS-4 is a frequency synthesizer developed for use with the Drake Company "4" line equipment. (R-4 series, T-4X series and SPR-4.) The FS-4 plugs into an unused auxiliary crystal socket in the rear of the receiver or transmitter, and will supply the various injection signals to the equipment and allows continuous coverage without utilizing the accessory crystals.

The frequency readout on the FS-4 displays the received frequency band, and to this is added the frequency readout of the receiver "PTO" to obtain the correct received frequency.

The FS-4 supplies all the crystal oscillator injection signals for the R-4 series and T-4X series in 0.5 MHz steps from 11.1 through 40.6 MHz, and the readout is direct. An accessory kit is available to provide proper injection signals for the SPR-4 receiver.

The FS-4 can be used with the 2-C type receiver over the frequency range of 7 to 30 MHz. When used with the 2-C receiver, the FS-4 frequency readout is not direct, and a correction factor of "7 MHz" must be added to the FS-4 readout to obtain the correct operating frequency. A special accessory kit is necessary to modify the FS-4 for use with the 2-C receiver.

### **1-2. MANUAL COVERAGE.**

This manual is presented in 5 chapters and is arranged for the convenience of the operator and service technician as follows:

**CHAPTER I**     Introduction. (Self explanatory.)

**CHAPTER II**    Installation. Describes the procedures to be followed prior to operation.



**CHAPTER III**    **Operation.** Illustrates and describes front panel controls, and describes operation with Drake receiver/transmitter equipment.

**CHAPTER IV**    **Theory of Operation.** Describes all circuits and networks.

**CHAPTER V**    **Maintenance.** Provides maintenance and alignment instructions.



## **CHAPTER II**

### **INSTALLATION**

#### **2-1. UNPACKING.**

Carefully remove the FS-4 from the shipping carton and examine it for evidence of damage. If any damage is discovered, immediately notify the transportation company that delivered the unit.

#### **NOTE**

Fill out the enclosed registration card and return it to the factory immediately to insure registration and validation of the warranty.

#### **2-2. LOCATION.**

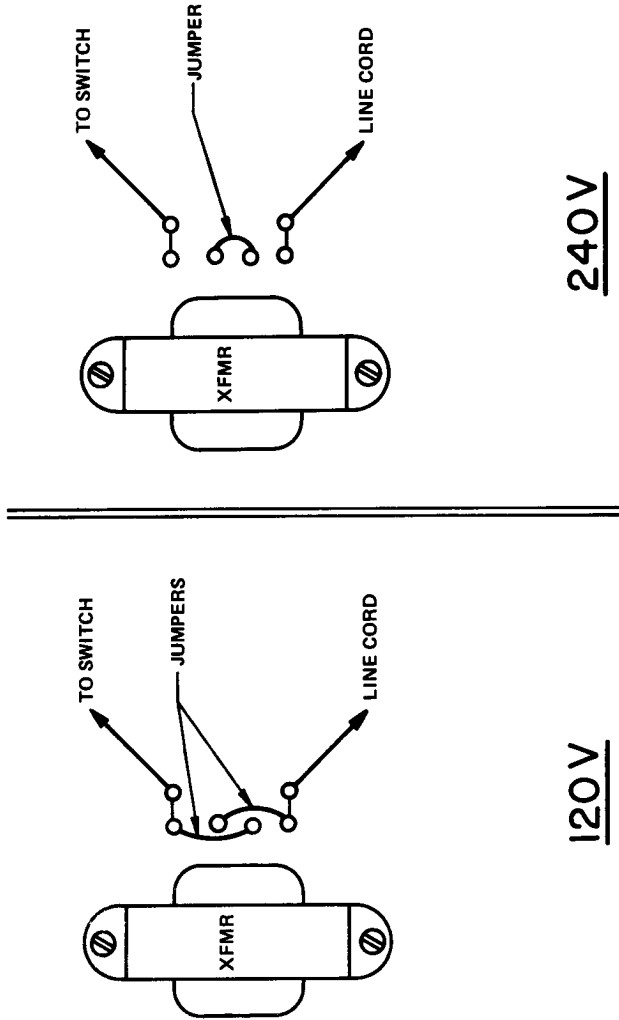
The FS-4 is supplied with a cable approximately 20 inches long that plugs into the accessory crystal socket of the receiver/transmitter. This length allows the user to place the FS-4 on either side of the receiver/transmitter. Placing the FS-4 on top of the transmitter is not recommended, due to heat generated within the transmitter, and the FS-4 will block the air flow.

#### **2-3. POWER REQUIREMENTS.**

The FS-4 is shipped from the factory wired for 120 VAC, 50/60 Hz, operation unless otherwise specified. To operate on 240 VAC make the proper connections at the transformer on the parent board as illustrated in figure 2-1.

#### **2-4. FUSE.**

The power line is fused for 120 VAC operation with a 3AG Type 1/8 A, Slo-Blo. For 240 VAC operation use a 3AG Type 1/16 A, or equivalent.



*Figure 2-1. Power Supply Wiring for 120 VAC and 240 VAC Operation*

## **CHAPTER III OPERATION**

### **3-1. CONTROLS AND DISPLAYS.**

All controls and displays necessary for the operation of the FS-4 are located on the front panel. The three knobs switch the frequency range in .5 MHz steps and provide direct frequency display in MHz at the readout directly above each knob. These knobs switch the frequency in steps of 10 MHz, 1 MHz, and 0.5 MHz from left to right. The 0.5 MHz knob also turns the FS-4 on and off. Refer to figure 3-1.

### **3-2. INJECTION CABLE.**

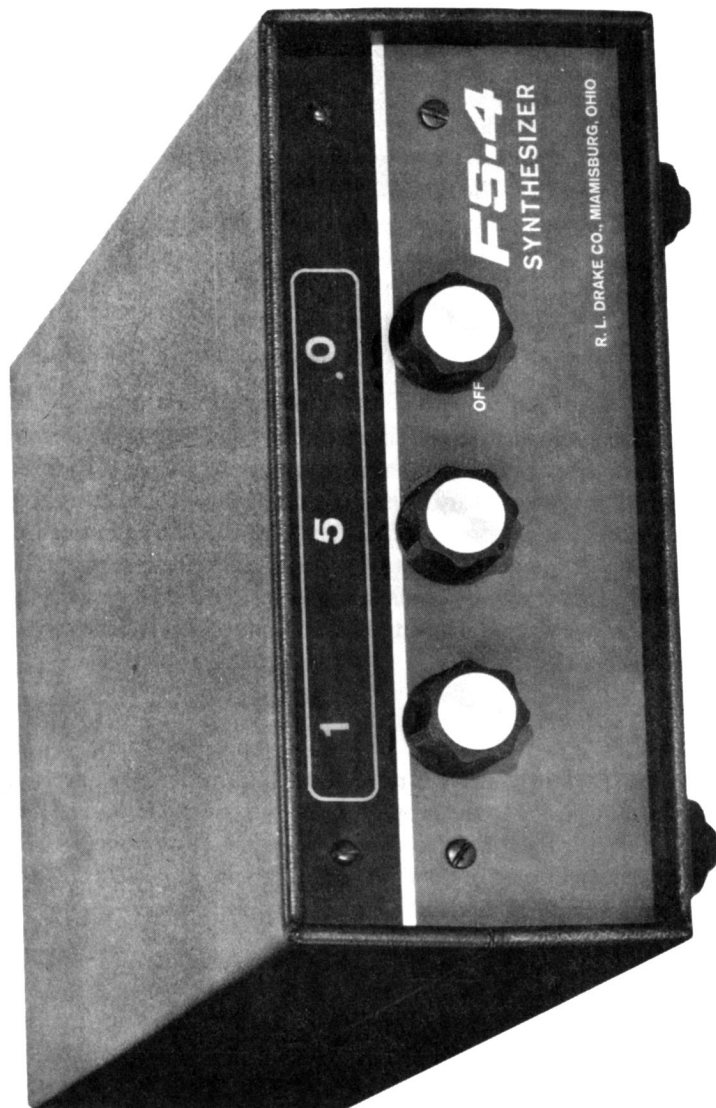
The injection cable supplied is used to connect the FS-4 to an unused accessory crystal socket of the receiver or transmitter. Attach the ground lug to the chassis at the accessory crystal socket and insert the center pin into the selected accessory crystal socket. The receiver or transmitter will operate best when the center conductor is connected to the emitter of the crystal oscillator. This can be determined by noting the S meter reading or power output readout when the injection cable is plugged into each socket of the accessory crystal socket.

### **3-3. BAND SELECT.**

When using the FS-4 to control a receiver or transmitter, the receiver/transmitter must be placed in the proper band as you would in normal use, and the crystal switch must be placed in the position corresponding with the position selected to plug in the FS-4. The RF tune (preselector) of the receiver/transmitter must be tuned the same as in normal use.

### **3-4. PRESELECTOR SETTING.**

A stick-on-decal has been supplied for convenience in locating the positioning of the RF tune (preselector). This may be applied to the receiver/transmitter front panel by removing the knob and aligning the decal on the front panel and firmly rubbing it on.



*Figure 3-1. FS-4 Controls and Displays*

Caution must be used on proper use of the FS-4 when used with transmitters. Consult RF Tune calibration charts in the manual of the T-4X series.

### **3-5. TUNING A RECEIVER AND THE FS-4.**

- a. Switch the FS-4 to the desired operating frequency, as an example: 7.0 for 40 meter amateur band.
- b. Place the R-4 Receiver "Xtals" switch in position 10 (assuming the FS-4 is plugged into accessory crystal socket #10).
- c. Set the R-4 "Band" switch to 7.0.
- d. Set "PRESELECTOR" control between 5 and 6.

The FS-4 and receiver are now correctly set for proper operation. The rest of the operating procedure is called out in the receiver/transmitter instruction manual.

### **3-6. MODIFICATION OF THE FS-4 FOR USE WITH THE SPR-4 or 2-C.**

The FS-4 can be modified from the standard version to operate properly with the SPR-4 or 2-C by simply removing the case of the FS-4 and exchanging the reference crystal as shown in figure 5-1, and substituting the interconnecting cable with one that has a plug which fits the SPR-4 accessory socket. Drill a 1/4" dia. hole in the rear panel of the SPR-4 or 2-C, and insert grommet. Feed the FS-4 injection cable through this hole to an unused crystal socket.

The correct reference frequency crystal for the equipment is shown in the chart below:

| Controlled Equipment | FS-4 Reference Crystal |
|----------------------|------------------------|
| R-4 and T-4X         | 9.6 MHz                |
| SPR-4                | 9.59.                  |
| 2-C                  | 9.5*                   |

\*7 MHz must be added to the FS-4 readout for proper operating frequency.



The FS-4 should be unplugged from the receiver or transmitter if operation is desired from internal crystal control and not by use of the FS-4. The cable capacity of the FS-4 can cause oscillation of the receiver or transmitter that is not controlled by the selected crystal.

#### **NOTE**

No tuning of L406 is required when exchanging the reference crystal for use with the SPR-4. Some adjustment may be required when exchanging the crystal for use with the 2-C. See paragraph 5-3, for the proper tuning procedure.

When using the FS-4 to control the frequency of the 2-C the VFO dial always reads on the black scale. The red scale does not apply when using the FS-4.

### **3-7. FREQUENCY ACCURACY.**

All injection frequencies in the FS-4 are derived from the 5 MHz clock and the reference oscillator. Any frequency error in the injection signal is essentially the same at any frequency band. When deriving the injection frequency by use of crystals in the crystal oscillator in the receiver, as is normally done, the frequency error will vary from band to band as different crystals are switched in. This error is compensated for when the PTO is calibrated.

A difference in frequency may be noted when switching between standard operate and FS-4 operate. This error is due to crystal errors as stated above and in general the use of the FS-4 results in the better frequency accuracy.

## **CHAPTER IV**

### **THEORY OF OPERATION**

#### **4-1. GENERAL.**

Refer to the block diagram in figure 4-1 for circuit operation.

#### **4-2. VOLTAGE CONTROLLED OSCILLATOR (VCO).**

The VCO is a voltage controlled oscillator capable of operation over the frequency range of 10.5 to 41 MHz, and is used to provide the crystal oscillator signal required in the receiver/transmitter for proper operation.

#### **4-3. D-BALANCE MIXER.**

A signal from the VCO is applied to the D-Balance Mixer, where it is mixed with the signal from the locked oscillator to produce an output in the frequency range of approximately 11 to 16 MHz.

#### **4-4. LOCKED OSCILLATOR.**

The locked oscillator develops signals of 5, 10, 15, 20, and 25 MHz which are synchronized to a 5 MHz reference signal. The actual output of the locked oscillator is determined by the settings of the front panel switches. The output is zero for settings of 0 to 4.5 MHz, 5 MHz for settings of 5 to 9.5 MHz, etc. This output is mixed with the VCO to produce signals of 11 to 16 MHz which are fed to the bandpass filter.

#### **4-5. BANDPASS FILTER.**

The bandpass filter following the D-Balance Mixer suppresses any higher order products from the mixer as well as the two inputs and their harmonics.

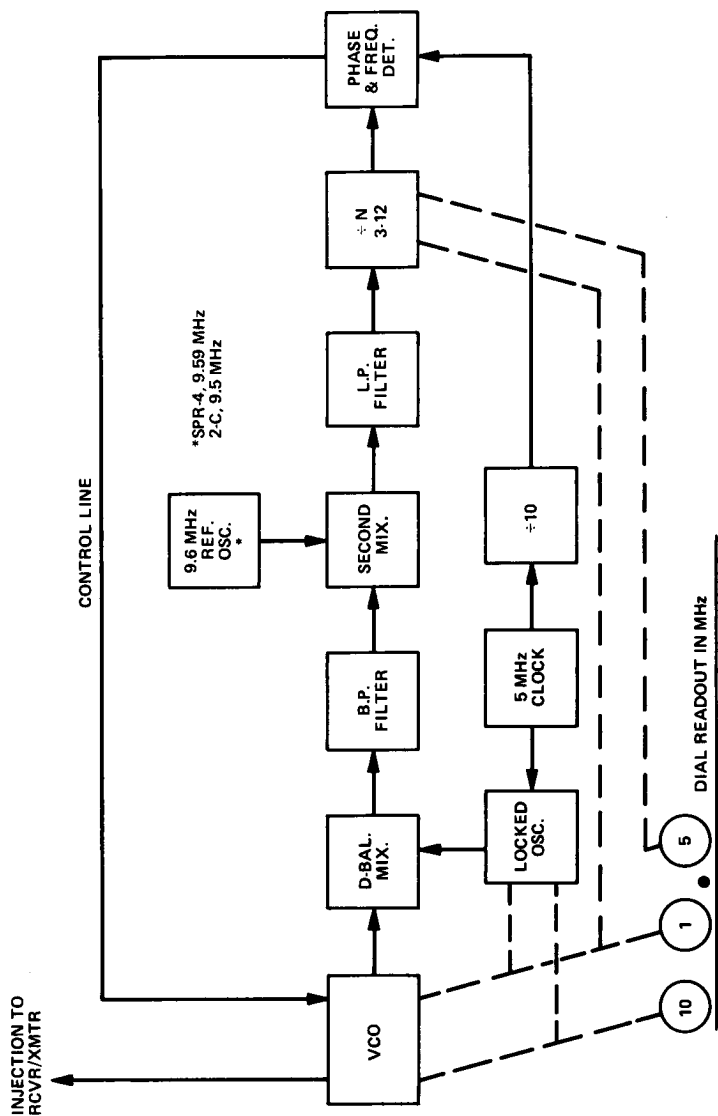


Figure 4-1. FS-4 Block Diagram



#### **4-6. REFERENCE OSCILLATOR.**

The output of the bandpass filter is then mixed in the second mixer with the reference oscillator. The reference oscillator frequency determines the band edges of the injection output, that is, 16.1 as required in an R-4, vs. 16.09 for the SPR-4, vs. 16.0 as required by the 2-C (see paragraph 3-6). The resultant output from the second mixer is in the range of 1.5 to 6 MHz and is applied to the low pass filter to suppress any higher frequency outputs.

#### **4-7. PHASE/FREQUENCY DETECTOR.**

The output of the low pass filter is applied to a programmable counter, which is programmed from the 1 MHz and 0.5 MHz controls, and divides the input by an appropriate number between 3 and 12 to produce an output near 0.5 MHz. The output is applied to the phase/frequency detector, where it is compared in phase and frequency with the resultant 0.5 MHz signal obtained by dividing the 5 MHz clock by 10. An error signal is developed in the phase/frequency detector which is applied to a voltage variable capacitor in the VCO, and forces the frequency to be such that the resultant input to the phase/frequency detector is the same frequency as that derived from the clock (500 kHz).

#### **4-8. PROGRAMMABLE COUNTER.**

The programmable counter is controlled by the 1 MHz and 0.5 MHz controls, and covers a range count of 10, starting at 3, at dial setting 00.0, and progressing one count for an increase in the 0.5 position of a two count for each increase in the 1 MHz control. The counter increases to 12 at the setting of 4.5 and then starts over again at 5.0 and repeats every 5 MHz range of the FS-4.



#### **4-9. SIGNALS PRESENT AT DIAL SETTING.**

The following is an example of actual signals present for the FS-4 set at a dial setting of 12.5 MHz:

Dial setting = 12.5 MHz

VCO Frequency = 23.6

Locked Oscillator = 10 MHz

D-Bal. Mixer Output =  $23.6 - 10 = 13.6$

Second Mixer Output =  $13.6 - 9.6 = 4$

$\div N = 8$

$\div N$  output =  $4/8 = 0.5$

## **CHAPTER V MAINTENANCE**

### **5-1. ALIGNMENT.**

The FS-4 has been carefully aligned and tested at the factory for proper operation and should not be realigned unless required and then only by a knowledgeable and competent technician.

### **5-2. 5 MHz CLOCK ALIGNMENT.**

Tune in and zero beat a signal from WWV using the internal crystal of the receiver. Without moving the frequency dial of the receiver, couple the receiver antenna to the FS-4 case or ground. Tune capacitor C303 for zero beat on the receiver. Refer to figures 5-1 and 5-2.

#### **NOTE**

A higher frequency of WWV signal provides greater accuracy, as the above process provides tuning of the 5 MHz clock by tuning in a harmonic.

### **5-3. REFERENCE OSCILLATOR ALIGNMENT.**

For a high degree of accuracy the reference oscillator should be tuned using a frequency counter connected to the injection output of the FS-4. Set the FS-4 dial to 00.0 and tune L406 for 11.1 MHz.

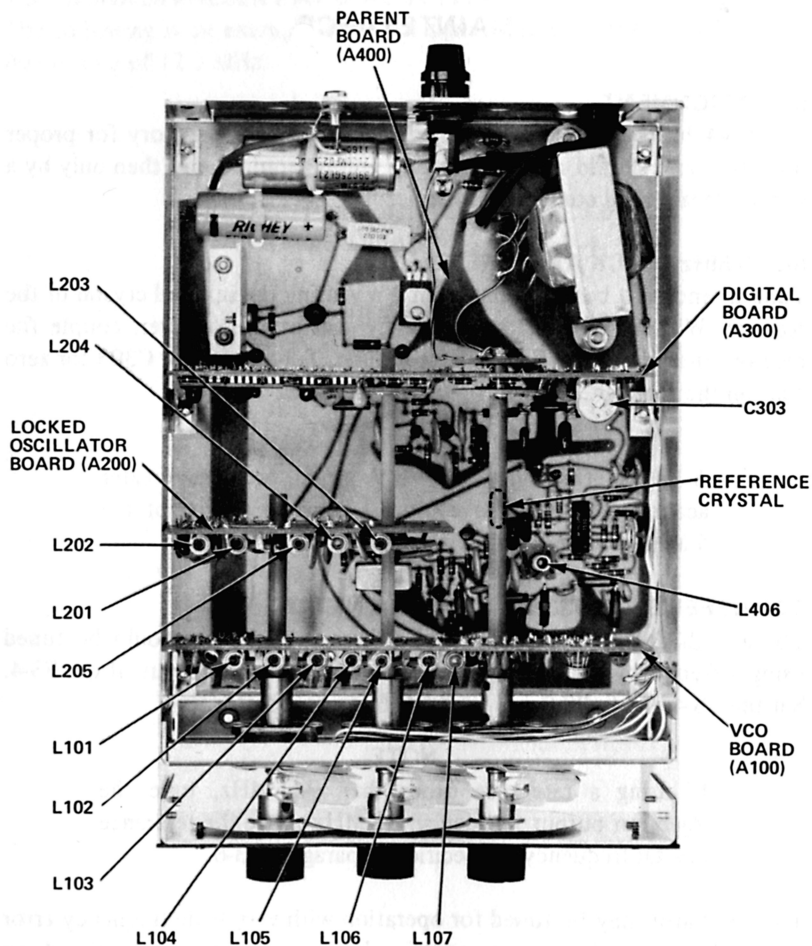
#### **NOTE**

If using a reference other than 9.6 MHz, tune the injection output frequency 1.5 MHz above the reference crystal frequency as specified in paragraph 3-6.

This oscillator may be tuned for operation with very little frequency error merely by tuning for maximum RF voltage measured at test point A on bottom of parent board.

#### **NOTE**

It is not necessary to realign the oscillator when changing the crystal as specified in paragraph 3-6.



*Figure 5-1. Top View with Case Removed*

#### **5-4. LOCKED OSCILLATOR ALIGNMENT.**

Tune the indicated coils for maximum RF output voltage measured at test point B (on bottom of parent board) when the FS-4 is tuned to the indicated dial setting:

| <u>DIAL SETTING MHz</u> | <u>TUNE COIL</u> |
|-------------------------|------------------|
| 05.0                    | L205             |
| 10.0                    | L202             |
| 15.0                    | L204             |
| 20.0                    | L201             |
| 25.0                    | L203             |

#### **5-5. VOLTAGE CONTROLLED OSCILLATOR ALIGNMENT.**

The VCO may be tuned using a frequency counter connected to the injection output of the FS-4. If the system is operational on most dial settings, the oscillator may be aligned by monitoring the control line voltage under locked conditions.

#### **FREQUENCY COUNTER METHOD.**

Disconnect the control line cable at the VCO board and apply a well filtered DC voltage of 1.5 V to the control line input of the VCO. (This may be obtained by using a potentiometer of at least 5 k $\Omega$  connected across the 12 volt supply to ground.) Tune the oscillator for the indicated frequency when tuned to the specified setting:

| <u>DIAL SETTING</u> | <u>TUNE COIL</u> | <u>FREQUENCY</u> |
|---------------------|------------------|------------------|
| 00.0                | L105             | 10.6 MHz         |
| 01.0                | L106             | 11.6 MHz         |
| 03.0                | L107             | 13.6 MHz         |
| 05.0                | L103             | 15.6 MHz         |
| 07.0                | L104             | 17.6 MHz         |
| 10.0                | L101             | 20.6 MHz         |
| 20.0                | L102             | 30.6 MHz         |

**LOCKED LOOP METHOD.**

If the FS-4 is operational on most frequencies, the VCO may be tuned by monitoring the voltage at the control line under locked conditions. Do not disconnect the control line as in the method above. Connect a DC volt meter to the control line at the VCO board and tune the indicated coil for the specified control line voltage:

| <u>DIAL SETTING</u> | <u>TUNE COIL</u> | <u>CONTROL LINE<br/>VOLTAGE</u> |
|---------------------|------------------|---------------------------------|
| 00.0                | L105             | 2.9 VDC                         |
| 01.0                | L106             | 2.7 VDC                         |
| 03.0                | L107             | 2.4 VDC                         |
| 05.0                | L103             | 2.3 VDC                         |
| 07.0                | L104             | 2.3 VDC                         |
| 10.0                | L101             | 3.0 VDC                         |
| 20.0                | L102             | 2.6 VDC                         |

## **NOTES**

