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# A LOCAL OSCILLATOR SYSTEM FOR A 12.4-18.0 GHz SPECTRAL LINE RECEIVER

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## Introduction

This report describes a Local Oscillator System which is used with a 12.4-18.0 GHz spectral line receiver. The local oscillator consists of a backward wave oscillator (BWO) which is phase locked to the 100th harmonic of an HP 5105A frequency synthesizer. The output frequency can be changed in 10 cps steps anywhere in the frequency range 12.4-18.0 GHz by (1) setting the synthesizer frequency to $\frac{F_{LO}}{100}$ and (2) setting a high voltage power supply to a value determined by $F_0$ which is obtained from a graph. The local oscillator can be switched between frequencies separated up to at least 30 MHz at a 1 cps rate by remote programming the synthesizer and without changing the high voltage power supply setting.

## Description

The Varian VA470M backward wave oscillator, used as the RF power source, can be helix voltage tuned through the entire 12.4-18.0 GHz frequency range. Figure 1 shows a block diagram of the type of loop used; this is conventional except that the offsetting signal is the same as the comb generator drive signal. In practice, two problem areas occur with this arrangement, the most serious being due to the phase noise on the output of the frequency synthesizer. This results from the total sideband power to signal power increasing as the square of the multiplying factor; since the total power is constant, the increased sideband power comes from the carrier and the spectrum (after multiplication) spreads. When the HP 5105A synthesizer output is multiplied by 99X the output phase noise is approximately 40 dB worse than the input and in practice it is difficult to satisfactorily lock a voltage controlled oscillator to it.

The second problem area results from the relatively close spacing (124 MHz minimum) of the comb output signals when compared with the 5600 MHz tuning range of the BWO. This is not as serious a problem as the first one but it does mean that the BWO has to be carefully voltage programmed so that locking is only possible to the 99th harmonic and not an adjacent one.

Both these problem areas were overcome by multiplying $F_0$ by three and then phase locking a transistor voltage controlled oscillator (tuning between 372-540 MHz) to this signal. The VCO then acts as a "clean up" oscillator and at the same time we get a more widely spaced comb since it is now only required to multiply by 33.

Figure 2 shows a detailed block diagram of the final local oscillator system. The BWO is isolated from the load with an isolator; a 10 dB broadwall directional coupler samples the RF for the phase lock loop. A high directivity isolator (40 dB) separates the RHG mixer-preamp from the sampling coupler. It was felt necessary to do this since the comb signals could couple out to the radiometer mixer; however, since the minimum frequency separation is 372 MHz, it is unlikely they would cause trouble. The comb generator is a Varian VSU-9718A and the individual harmonic power level is ≥ -50 dBm. The multiplier is intended for use over the frequency range 100-500 MHz; however, the VSWR is bad and although it proved to be usable, a replacement has been ordered which is optimized for operation in the 372-540 MHz range.

The oscillator is self-contained in an aluminum box to reduce possible radiation of troublesome frequencies; Figure 4 shows a photograph of the unit with cover plate removed. The unit is mounted in the 12.4-18.0 GHz receiver front-end box; the power supply requirements are ± 28 V at ≈ 1.5 A and a variable 270-900 volt, 20 mA (HP 6521A) power supply which is located remotely with the frequency synthesizer.

## 373-540 MHz Phase Lock Loop

The drive signal from the synthesizer is boosted to 100 mW and then split equally between the two phase lock loops. The drive signal for the transistor VCO loop is multiplied by three with a broadband tripler (Fig. 3). The fundamental, second, fourth, etc., harmonics are filtered out by a 372-540 MHz bandpass filter; fortunately the even harmonics are about 15 dB below the third harmonic. A Frequency Sources transistor voltage controlled oscillator is phase locked to this signal; the loop bandwidth is sufficient for pull in from about 50 kHz. The initial errors are considerably larger than this and a sweep/lock circuit is used to lock the VCO. The lock is sensed with a quadrature detector and a voltage sensing circuit which stops the sweep when a lock is attained. The sweep rate is about 100 cps; consequently the maximum locking time for the VCO is generally 100 ms or less. The transistor VCO is roughly programmed by tapping off a fraction of the BWO helix voltage; this reduces the necessary sweep voltage and consequently decreases the tuning rate during the search mode. This results in easier acquisition at the low frequency end where the MHz/volt characteristic is greatest due to non-linearity of the oscillator tuning voltage.

Two problems met with the transistor VCO are worth noting:

1) The unit was supplied with a linearizer which was so noisy that it had to be removed.

2) The frequency/voltage characteristic was critically dependent on the output match and it became necessary to isolate the VCO from the frequency multiplier with an amplifier.

<u>12.4-18.0 GHz Phase Lock Loop</u>

The VA470M BWO can be helix voltage tuned between 12.4 and 18 GHz with a voltage which varies approximately from 270-900 volts. This voltage is supplied by a HP 6521A power supply which has thumbwheel decade switches for setting the output voltage. The voltage is preset to within a volt or so for the desired frequency and the PLL then locks the BWO to the 100th harmonic of the synthesizer. The loop pull in range is limited so that there is no possibility of incorrect operation. The closest lock point is 124 MHz away (when tuned to 12.4 GHz).

The BWO is run with the helix near ground so that an operational amplifier can be used to drive it. The cathode is consequently 270-900 volts above ground; the power supply return is connected to the output of another operational amplifier which supplies the sweep voltage.

A quadrature detector senses a lock as with the lower frequency loop; the sweep voltage is only applied to the BWO when the first loop is locked. This was considered good practice since there should be a possibility of incorrect operation if both oscillators searched simultaneously.

## Use of the Technique at Higher Frequencies

This technique can be used with little change for the frequency ranges 18-26 GHz and 26-40 GHz. At frequencies lower than 12.4 GHz a simpler technique is feasible since the power output from a wideband comb generator would be sufficient to enable a zero frequency offset PLL to be used.

## Conclusion

This Local Oscillator System has been used with a wideband tunnel diode amplifier receiver and has operated satisfactorily for about four weeks on the 140-foot telescope at frequencies throughout the entire range. No failures have occurred and the only remaining problem area is due to hysterisis and low output from the Varian comb generator when driven from 500-540 MHz; consequently the drive power has to be increased to get satisfactory operation in the range 17-18 GHz. Replacement of this component should remove this problem.

No quantitative figures are available at the moment on the noise sidebands. However, the appearance of the signal at 18 GHz is considerably improved over the appearance of the LO signal currently used with the 10,695 MHz receiver at NRAO which is devised by straight multiplication (36X) from a HP 5105 frequency synthesizer.

The suitability of this local oscillator for VLB observations is limited by the phase drift occurring in the synthesizer which is multiplied by 100 by the LO. The phase stability of the LO itself has not been measured but should be good.

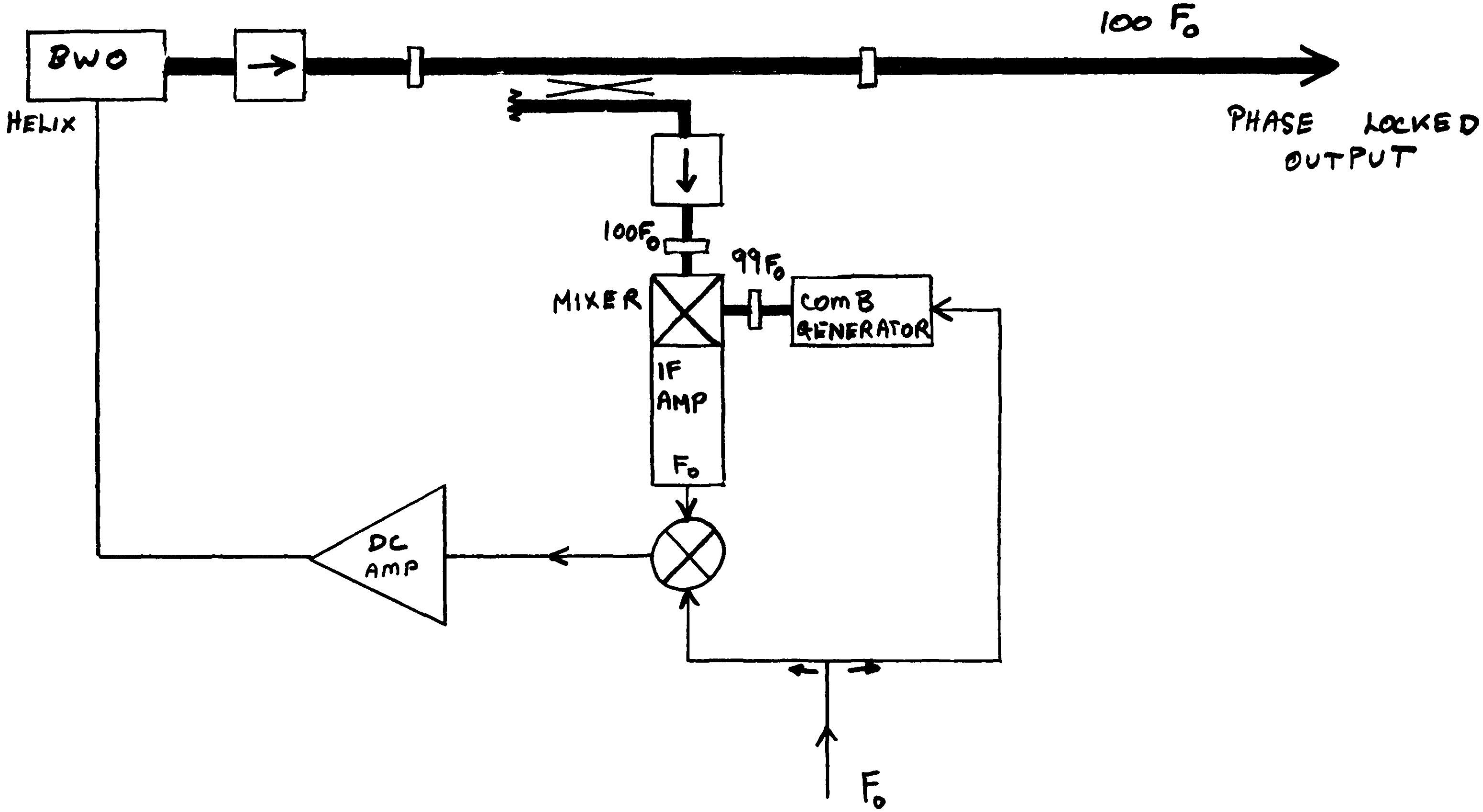



FIG 1 SIMPLIFIED BLOCK DIAGRAM OF L.O. SYSTEM

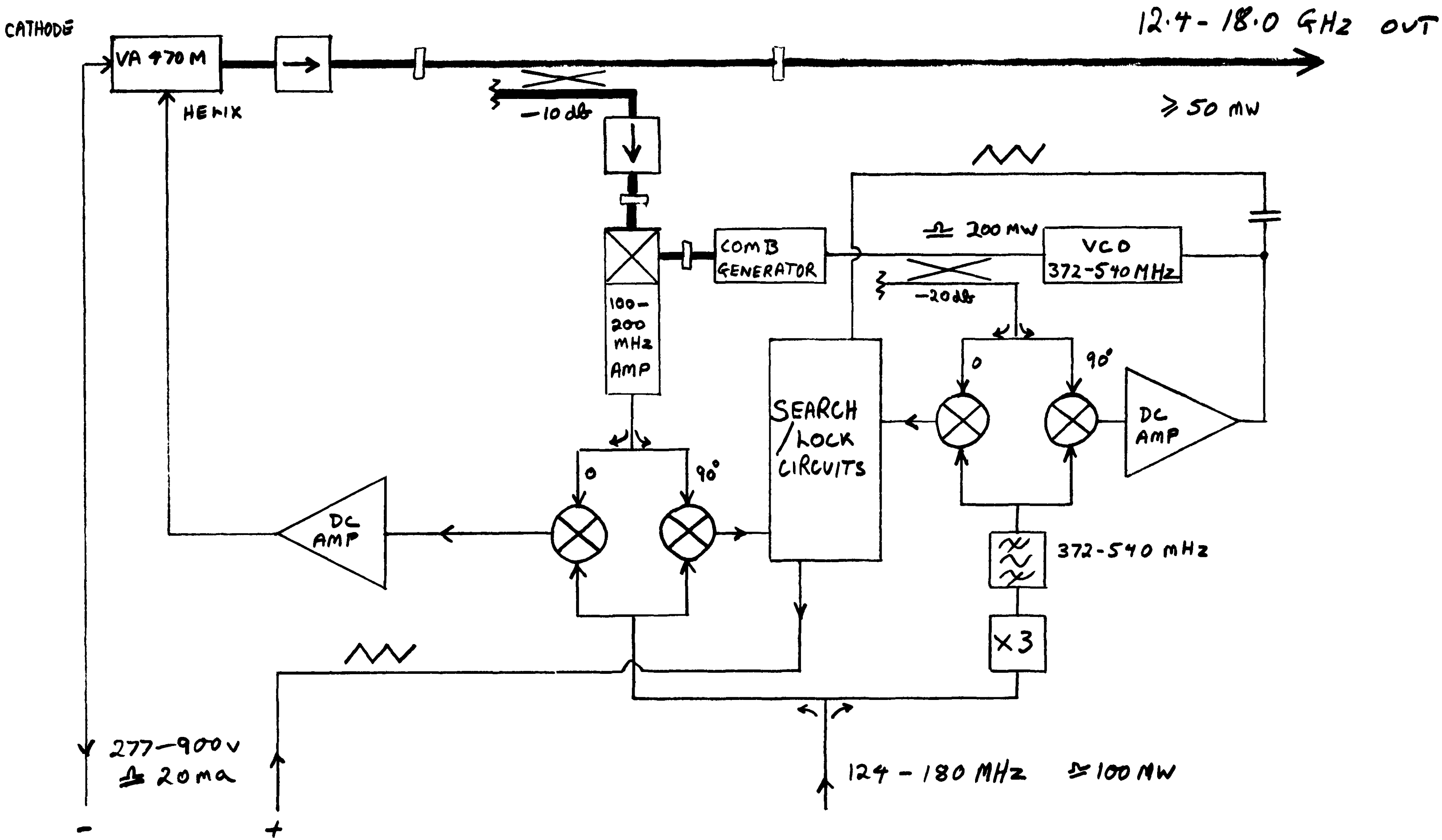



FIG 2 BLOCK DIAGRAM OF 12.4 - 18.0 GHz L.O. SYSTEM

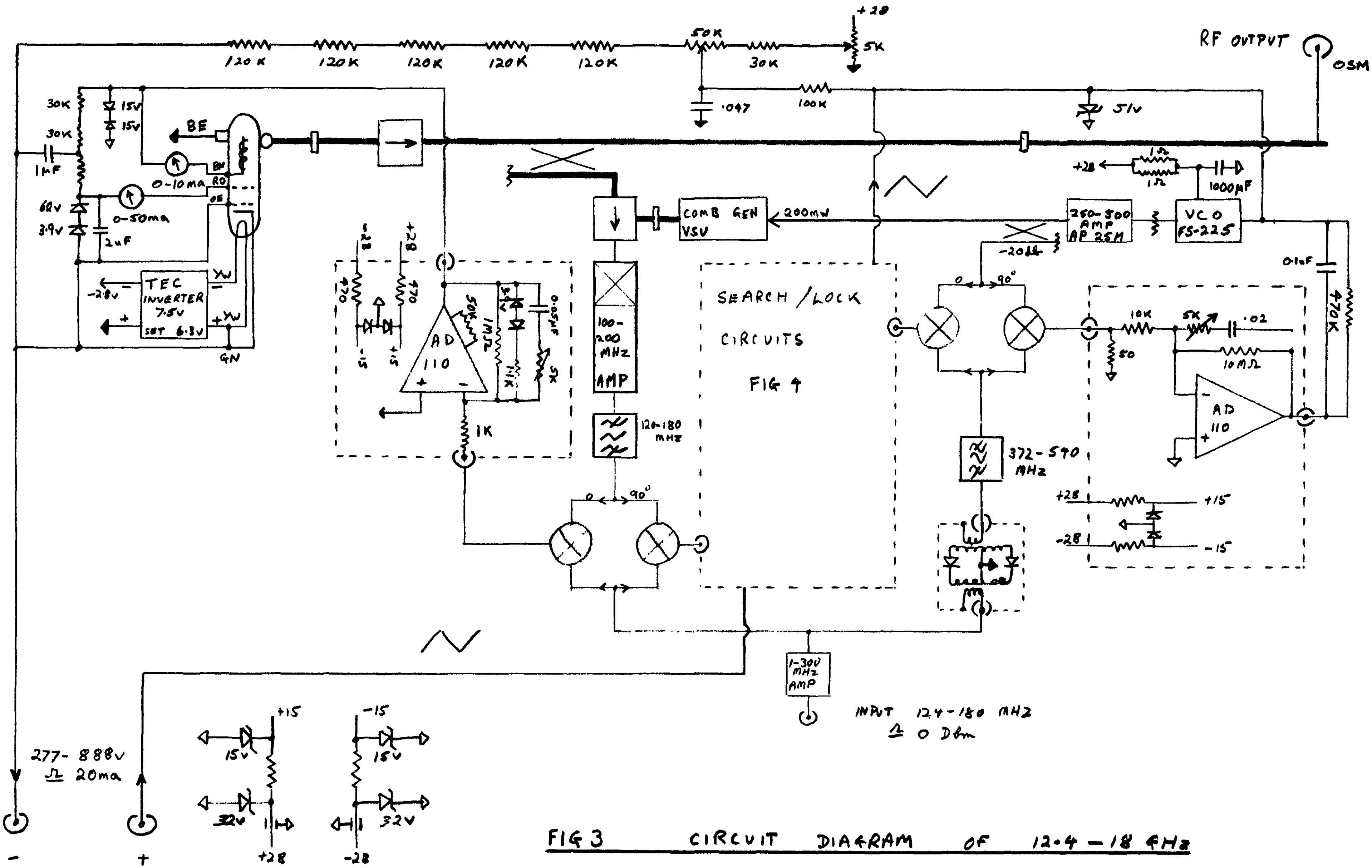



FIG 3 CIRCUIT DIAGRAM OF 12.4 – 18 GHz

LOCAL OSCILLATOR SYSTEM

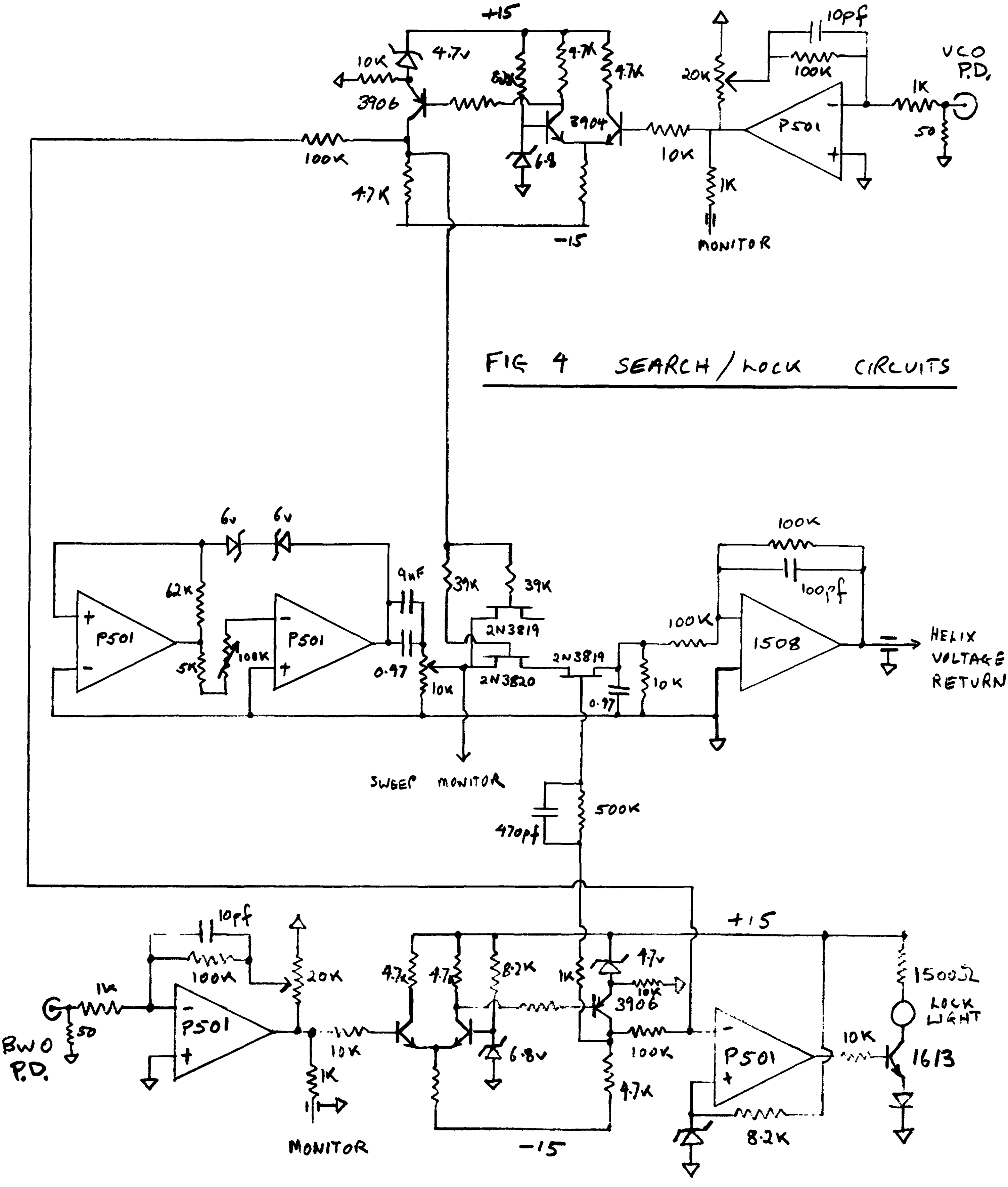
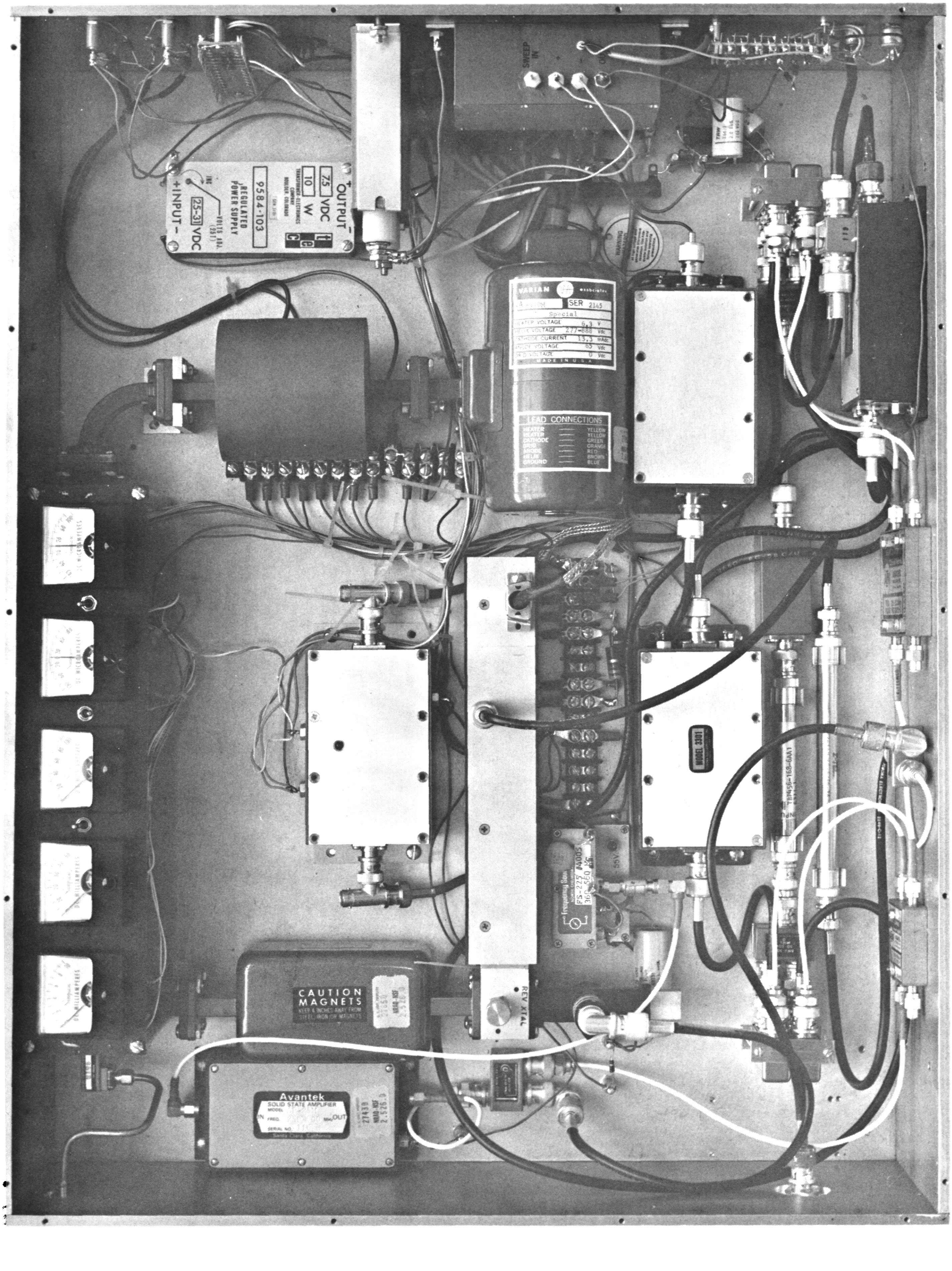



FIG 4 SEARCH / LOCK CIRCUITS


CAUTION
MAGNETS
Avantek
SOLID STATE AMPLIFIER
LEAD CONNECTIONS
VARIAN
REV XTAL
OUTPUT
75 VDC
10 W
9584-103
REGULATED
POWER SUPPLY
INPUT
25-31 VDC
SWEEP