EXHIBIT I TO
RFP TL-241

LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Technical Note	LIGO-T960071-00 - C	2/27/96

1 40 METER REFERENCE SOURCE SYSTEM.

Richard S. Abbott

Distribution of this draft:

A. Abramovici, R. Bork, J. Camp, J. Heefner, A. Kuhnert, J. Logan, F.J. Raab, M. Rakhmanov, R. Spero, S. Whitcomb, M. Zucker

California Institute of Technology
LIGO Project - MS 51-33
Pasadena CA 91125
Phone (818) 395-2966
Fax (818) 304-9834
E-mail: info@ligo.caltech.edu
WWW: http://www.ligo.caltech.edu

LIGO 32.7 MHZ SOURCE SPECIFICATION.

Background:

The Laser Interferometer Gravitational Wave Observatory (LIGO) is soliciting quotations for a 32.7 MHz reference source. A total of two of these units will be purchased. The manufacturer is to build, test and deliver documented units to LIGO's specification.

Application:

The unit will be used as part of a reference frequency distribution system. It will amplify a signal from a contained reference oscillator and drive a modulating cell to modulate a laser beam. The unit will receive five RF inputs that are heterodyned down to DC using mixers internal to the unit. The phase and amplitude shall be adjustable as outlined in the specification. The unit will be operated in a remote computer controlled interface as outlined in the specification. It is very desirable that the design be flexible such that future versions of the unit might be adaptable to a frequency within the band of 10 MHz to 80 MHz by replacement of frequency sensitive components.

General Information.

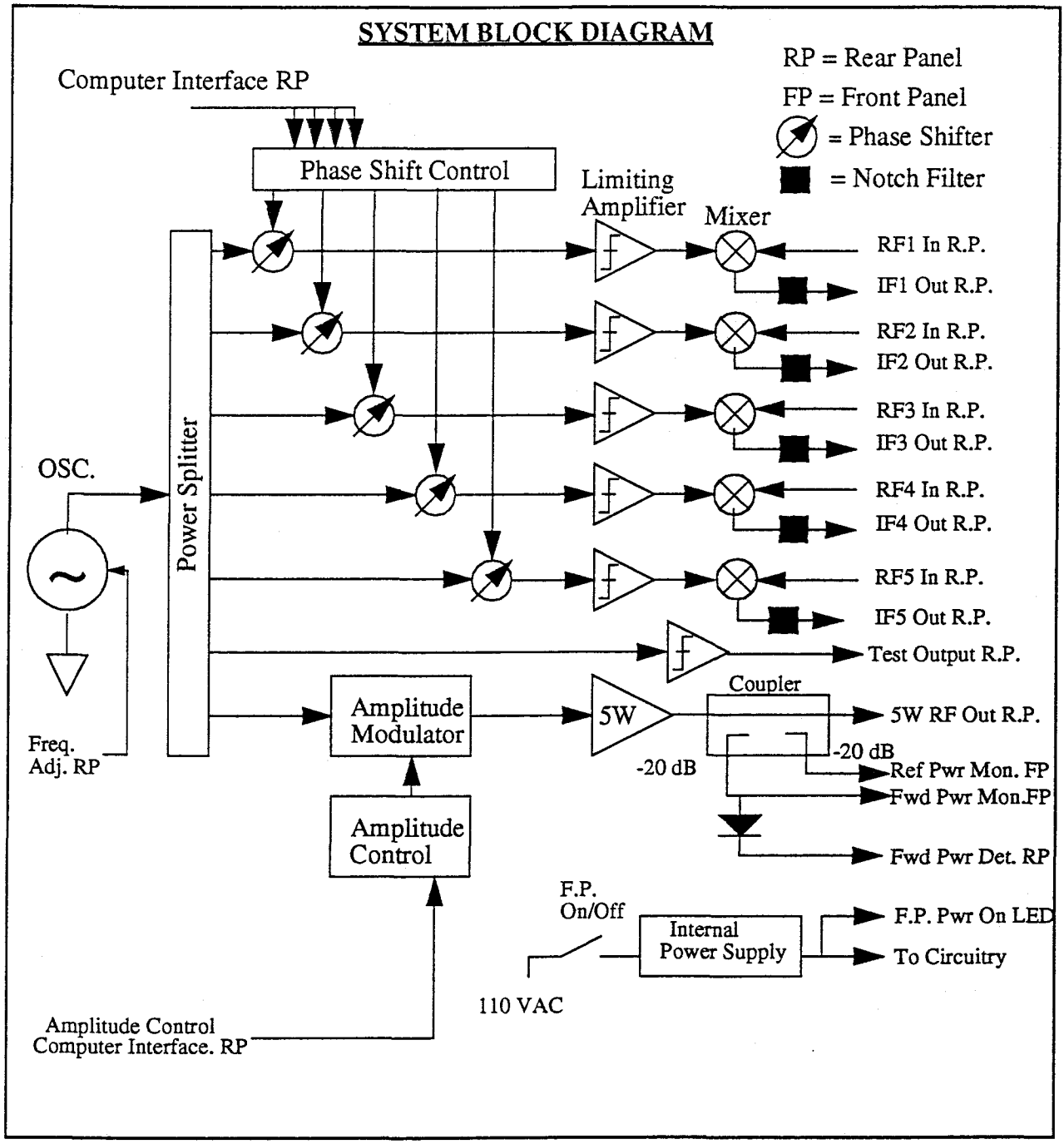
Subcontractor responsibility:

- To package the amplifier in a 19 inch rack mountable assembly using the most efficient technique.
- To verify that all requirements of the LIGO specification have been met.
- It is requested that during the design and manufacturing of the units, the manufacturer give feedback to LIGO for those areas of the design that prove technically restrictive, or to be significant cost drivers. It is the goal of LIGO to work as closely as needed with the manufacturer to ensure timely and efficient delivery of the units.

Deliverables:

The subcontractor is to furnish to LIGO, in addition to the reference source and its associated power supply, the following items:

1. During the design and manufacturing phase, a progress report should be faxed to LIGO at least every other week. The report should contain as a minimum: progress since last report and any technical difficulties encountered or foreseen.
2. Technical documentation containing detailed schematics such that LIGO could facilitate the repair of a failed unit.
3. The results of the acceptance tests and any other test results that may be pertinent.


SYSTEM BLOCK DIAGRAM
RP = Rear Panel
FP = Front Panel
= Phase Shifter
= Notch Filter
Computer Interface RP
Phase Shift Control
Limiting Amplifier
Mixer
RF1 In R.P.
IF1 Out R.P.
RF2 In R.P.
IF2 Out R.P.
RF3 In R.P.
IF3 Out R.P.
RF4 In R.P.
IF4 Out R.P.
RF5 In R.P.
IF5 Out R.P.
Test Output R.P.
OSC.
Power Splitter
Freq. Adj. RP
Amplitude Modulator
5W
Coupler
5W RF Out R.P.
-20 dB
-20 dB
Ref Pwr Mon. FP
Fwd Pwr Mon.FP
Fwd Pwr Det. RP
Amplitude Control
F.P. On/Off
Internal Power Supply
F.P. Pwr On LED
To Circuitry
110 VAC
Amplitude Control Computer Interface. RP

32.7 MHZ Reference Source Specification

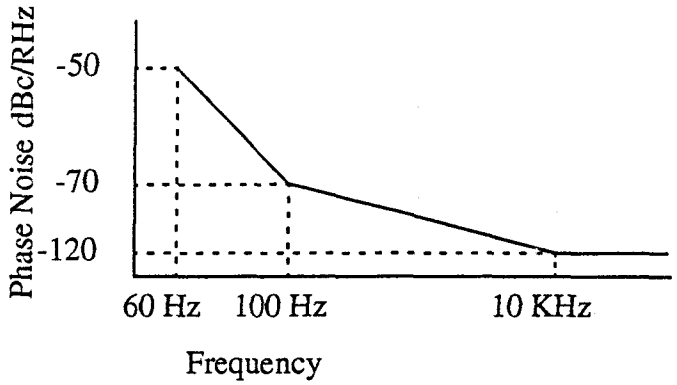
Item:

1. **Operating Frequency:** 32.700000 MHz.
2. **Frequency Stability:** Less than 10 Hz drift per year.
3. **Frequency Adjustment:** Plus or minus 300 ppm minimum from the operating frequency. The frequency adjustment should be accomplished by a 0 to 10 volt control voltage applied differentially through a rear panel connector. A wider tuning range is acceptable, but not at the expense of significant degradation of the resultant phase noise. This input has no specific bandwidth requirements, so it can be heavily filtered if needed.
4. **Power at 1 dB gain compression point:** 5 W minimum (37 dBm) at RF output.
5. **Output Impedance:** 50 ohms.
6. **Duty factor:** 100%
7. **Output VSWR:** Less than 2.5:1.
8. **Power step increments:** The output power of the source shall be adjustable in 5% increments from 0 W to 5 W with 10% precision.
9. **Power adjustment interface:** The interface for the power adjustment shall be via a TTL compatible parallel data bus with internal 10 K ohm pull up resistors. A high state shall be a logic one. The output power of the source shall be at its maximum with all inputs high. The power adjustment interface connector shall be on the rear of the unit and shall be supplied with the mating connector.
10. **Amplitude Noise Spectrum:** The AM component of the RF output and the internal mixer inputs as measured in a one hertz bandwidth, shall conform to the following spectral limits:

    20 Hz to 50 Hz ---- Less than -130 dBc
    50 Hz to 100Hz --- Less than -150 dBc
    100 Hz and above --- Less than -160 dBc

    Exception shall be given for 60 Hz and 120 Hz. 60 Hz shall be less than -130 dBc, and 120 Hz less than -140 dBc. The AM noise spectrum limits shall apply over the range of output powers of 1 to 5 watts. Below 1 watt, the AM noise limits can become linearly less restrictive.
11. **Amplitude stability over ambient temperature range:** The amplitude drift due to temperature of the RF output from the source shall be less than plus or minus 10% over the specified ambient temperature range with the high power output at 5 W.
12. **Phase step increments:** The phase angle of the internal mixer inputs, must be individually adjustable monotonically through a minimum of 360 degrees relative to the RF output. The step size of the phase adjustment is to be one degree plus or minus 10%, with an over all non-linearity of less than 10%.
13. **Phase adjustment interface:** The interface for the phase adjustment shall be via a TTL compatable parallel data bus with internal 10 K ohm pull up resistors. A high state on the parallel input bus shall be a logic one. The remote phase control input shall be on the rear of the unit. The mating connector should be supplied with the unit.
14. **Phase noise spectrum:** The single sideband phase noise spectrum measured in a one hertz bandwidth of the RF output or the internal mixer drives, shall conform to the following plot.

At frequencies of less than 60 Hz offset from the carrier, the phase noise can increase by 1/F from the number on the plot (-50 dBc). At frequencies greater than 10KHz, the phase noise in a one hertz bandwidth shall be less than -130 dBc. All phase noise measurements pertain to the unit operating at full rated output power (5W).



15. **Phase vs. Amplitude:** The phase change of the 5W RF output vs. RF attenuator shall be less than 5 degrees over the full attenuator range.
16. **Phase stability over ambient temperature range:** The phase drift due to temperature of the internal mixer inputs, shall be less than plus or minus one degree relative to the RF output over the specified ambient temperature range.
17. **Built in protection:** Over temperature, output VSWR.
18. **Load VSWR tolerance:** The source shall be capable of withstanding full output power reflection for extended periods of time at any phase angle and sustain no degradation in performance characteristics.
19. **Stability:** The output amplifier shall be unconditionally stable for any combination of positive real and positive or negative imaginary impedance at the output connector.
20. **Monitoring ports:** Two BNC ports shall be provided on the front of the unit to provide forward and reflected power monitoring of the high power RF output with a -20 dB RF coupler. The directivity of the RF coupler shall be greater than 17 dB. These monitoring ports shall be designed to drive a 50 ohm load. The ports shall be labeled "FORWARD POWER" and "REFLECTED POWER" respectively. In addition, a detected forward power output for the high power output shall be present on a rear panel BNC. The detected output shall range over 0 to 10 volts +/- 10% for 0 to 5 W of output power. The detected output can be from a simple buffered diode rectifier, but must be capable of driving a 1Kohm load
21. **Test Output:** A single output on the rear panel shall be provided as a monitor of the LO. The circuitry used in this output should be identical to that used in the internal LO drives minus the phase shifter as illustrated in the system block diagram.
22. **High power output:** The 5W output is to be via an SMA connector mounted on the rear of the unit.
23. **Internal Mixer:** The five internal mixers are required to be level 23 (23 dBm LO level) or greater for their LO inputs. The internal mixer LO inputs shall be of a level appropriate for the mixer. RF signal inputs to the unit could be as high as 15 dBm. The level of RF input dictates the choice of level 23 mixer so as not to cause excessive distortion in the mixer at the higher RF input levels. As the mixers are used in a coherent detection scheme, the DC offset of the mixers should be less than 7 mV with the LO port driven at nominal level and the RF port ter-

MHz centered at the system operating frequency. The measurement bandwidth should be reported

c. Data on output power measured at every five steps of the internal attenuator as measured at the 5 W output and the rear panel detected output.

d. Data on the RF output phase relative to each of the internal mixer inputs at every ten degrees of the respective internal phase shifters ranges through 360 degrees.

e. AM noise spectrum in a one hertz bandwidth from 10 Hz to 100 KHz offset from the carrier.

f. Second and third harmonics of the operating frequency at 5 W output power for the RF output only.

g. MTBF calculations must be supplied

h. The source shall undergo an operating burn in test for 48 hours minimum with no degradation in specified performance. This test shall be conducted at no less than 5 Watts RF output power. During this test, the ambient air temperature shall be 50 degrees C.