# A 10.6-MICROMETER LASER RECEIVER RF SUBSYSTEM

**D. E. Santarpia**

There has been a good deal of effort made to develop optical communication systems. Several of the obvious benefits of these systems are low power requirements, small equipment packaging, and high data rate capability.

These systems also have some problems. One of the problems is how to cope with the exceedingly high Doppler shifts that can be expected. A typical low earth orbit-to-ground station communication link having an optical wavelength of 10.6 $\mu$m, which incidentally corresponds to a carrier frequency of $28 \times 10^{12}$ Hz, has Doppler shifts which will approach 1 GHz at rates to 12 MHz/s.

Such a system, therefore, requires a receiver that has a predetection bandwidth of 1 GHz. Since data bandwidths are typically much smaller than the Doppler shift, the receiver must also be a coherent phase-lock receiver to avoid a degradation of SNR by the detector. In our attempt to develop such a receiver, we asked ourselves two questions.

(1) Can we build a phase-lock receiver capable of tracking 1 GHz in frequency with conventional loop components?

(2) What is the practical loop bandwidth and how does it compare to the theoretical minimum loop bandwidth needed to track 12 MHz/s?

Figure 1 describes a simplified laser receiver, the carrier tracking loop of which has been designed and tested. The laser carrier is optically mixed with a locally generated 10.6-$\mu$m signal, thereby translating the received signal to an IF signal that varies between dc and 1 GHz. This signal is fed to a second-order carrier tracking loop that is functionally not unlike the receivers NASA is currently using.

Several components of the loop presented a difficult design challenge. The mixers, signal and LO amplifiers, and the loop VCO were designed to operate over a 1-GHz range. The most significant component developed was the VCO.

The VCO is a conventional transistor LC oscillator that is tuned by a varactor over a 1-GHz range. Normally the tuning range is limited to an upper frequeney bound determined by the transistor output capacitance; however, by the use of transmission line techniques, the shunt capacitance is used to advantage, thereby greatly increasing the upper frequency bound and, hence, the tuning range of the oscillator.

Shown in Table 1 are theoretical and measured values of several important loop parameters; the one-sided loop noise bandwidth $B_L$, the loop tracking rate $\Delta\dot{f}$, and the loop received signal threshold $P_{TH}$. In order to track Doppler rates of 12 MHz/s with a loop having a noiseless VCO, a 5-kHz loop bandwidth is needed. On the basis of a loop SNR of 6 dB and a receiver noise figure of 6 dB, the threshold sensitivity of this loop is $-122$ dBm. Laboratory tests indicated that a 20-kHz loop was needed to maintain a high lock confidence level. The calculated threshold sensitivity for a 20-kHz loop is $-116$ dBm. Measurements taken indicate the threshold to be $-110$ dBm; the 6-dB difference is attributed to the VCO, which is noisy. Data bandwidths are typically 1 MHz or greater, which corresponds to a minimum data threshold of $-100$ dBm. We can, therefore, still take data 10 dB above receiver threshold.

The object of building this receiver was to determine if conventional phase-lock receivers could operate in a high Doppler environment. I feel that on the basis of the test results obtained, I can confidently give an affirmative answer to this question.

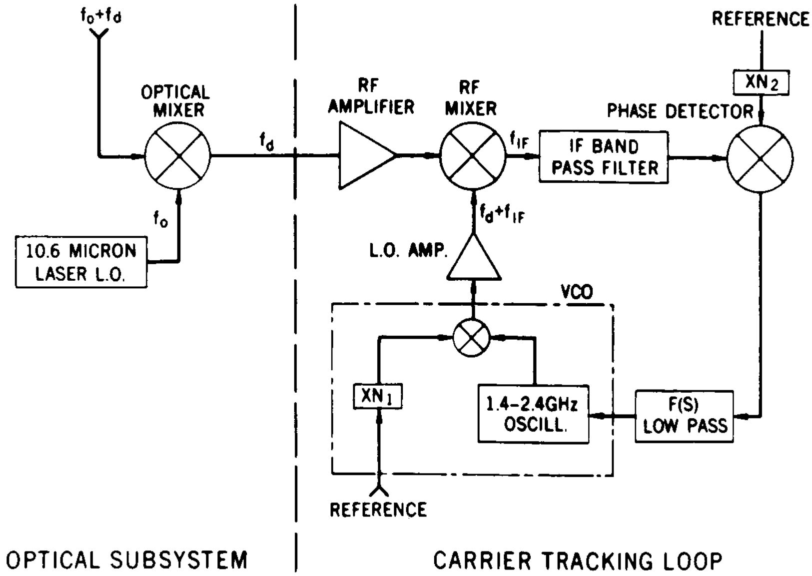


Figure 1–Simplified block diagram of a laser receiver.

Table 1–Tabulated data.

| | THEORETICAL (NOISELESS VCO) | | MEASURED |
|---|---|---|---|
| LOOP NOISE BANDWIDTH, $B_L$ | 5 KHz | 20 KHz | 20 KHz |
| LOOP SWEEP RATE, $\Delta\dot{f}$ | 12 MHz/sec | 120 MHz/sec | 110 MHz/sec |
| LOOP THRESHOLD SENSITIVITY, $P_{th}$ | -122 dbm | -116 dbm | -110 dbm |