THE WAVEGUIDE CO_2 LASER

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A heterodyne laser communication system between a low earth orbiting satellite and a satellite in synchronous orbit is subject to a time-varying Doppler shift, due to the relative motion between the two satellites.

If we consider ERTS (Figure 1) as a typical low earth orbiting satellite, we obtain a peak shift of approximately plus or minus 700 megahertz at the 10.6 micrometer CO_2 wavelength. This peak shift occurs when the orbital plane of the low earth orbiting satellite contains both the synchronous satellite and the earth's polar axis.

At Goddard, we are presently building a double conversion receiver to track this Doppler shift. The transmitter signal is mixed with the laser local oscillator signal in an infrared mixer. The resulting signal is then passed through a wideband IF amplifier into an RF mixer, whose second input is provided by a VCO controlled by a phase-locked Doppler tracking loop.

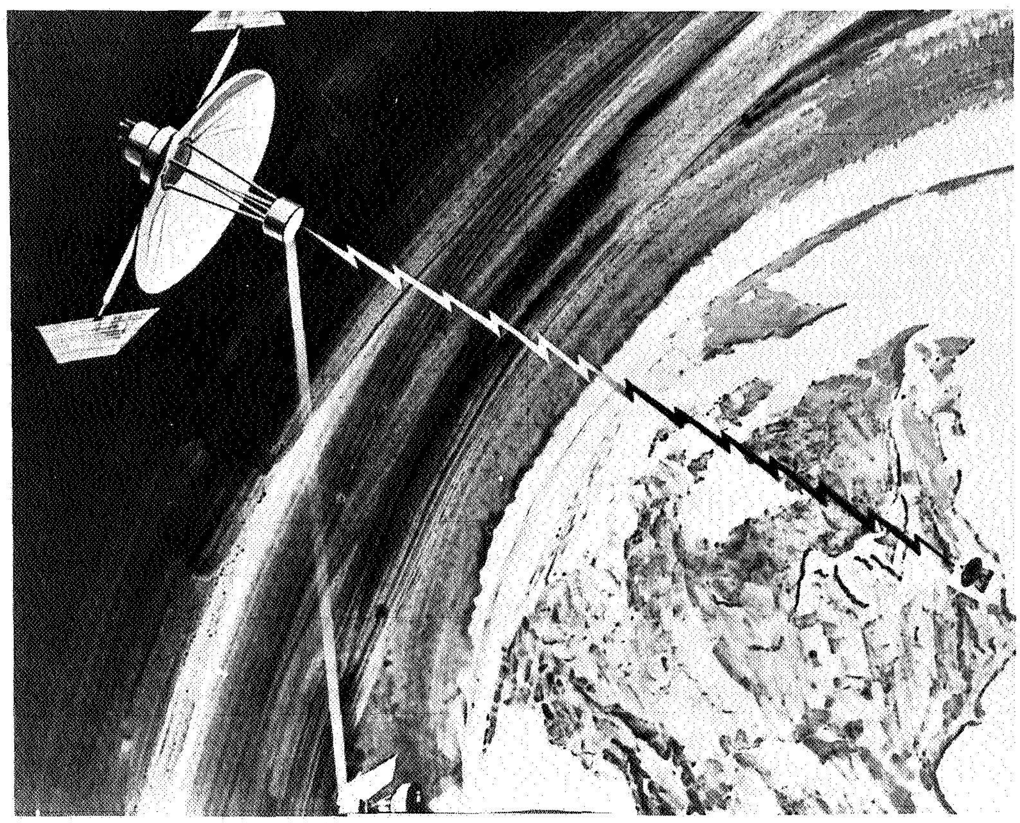

Figure 1. Low earth-orbiting to synchronous satellite laser data transfer line.

The effect of the motion on the frequency spectrum is snown at the top of Figure 2, where we've chosen the origin of the frequency spectrum to coincide with the center of the molecular line on which both the laser transmitter and laser local oscillator are operating.

At the peak Doppler point, the transmitter frequency is shifted by 700 megahertz with respect to line center due to the motion. We have assumed here a 300 megahertz information bandwidth superimposed on the center frequency.

As the satellite progresses in its orbit, this Doppler shift decreases until at the equator, where there is no longitudinal relative motion between the two satellites, the Doppler shift is zero. At this point, the laser local oscillator, which has been offset from line center by 200 megahertz, shifts operation to the opposite side of the molecular line. This avoids spectral foldover as the satellite proceeds to negative Doppler values.

The difficulty with this scheme is the fact that we must be able to offset the laser local oscillator by an amount greater than one-half the information bandwidth that we're trying to send.

In this case, we've assumed a 200 megahertz offset, which is 50 megahertz more than the 150 we would need. The difficulty with this is that conventional CO_2 lasers have a tuning range of only plus or minus 50 megahertz. This imposes severe restrictions on the information bandwidth that we can send.

This problem has been relieved by the invention of the waveguide CO_2 laser, which is presently being developed at Goddard.

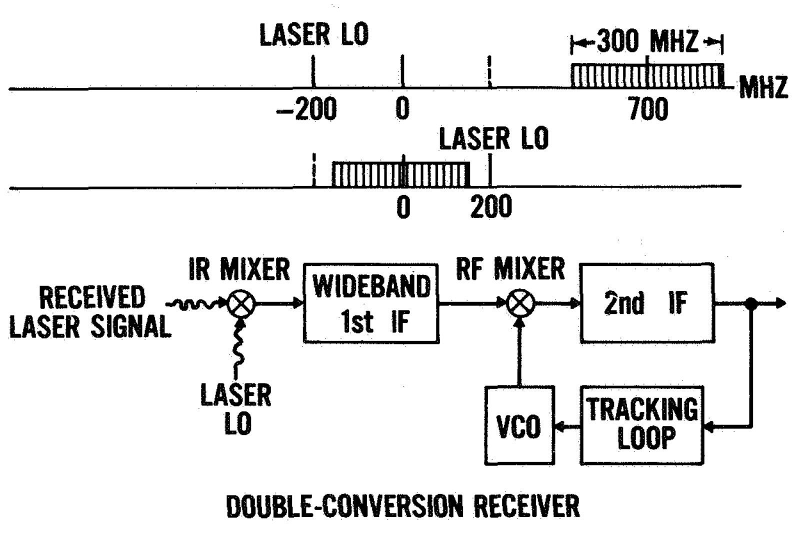

Figure 2. CO_2 laser oscillator tunability requirements and double-conversion receiver.

Briefly, the waveguide laser (Figure 3) is characterized by a very narrow capillary, typically 1 or 2 millimeters in diameter, which contains the laser gas mix. The smaller capillary results in a larger gain per unit length, which allows the device to be operated at pressures as high as 500 torr, compared to about 20 torr for a conventional CO_2 laser.

Pressure broadening of the molecular line accounts for the increased tunability of the laser.

In a waveguide laser, the capillary is placed between two reflectors which provide feedback to support the laser oscillation. Because loss is an important factor in determining the tunability of the laser, we have recently conducted at Goddard an extensive theoretical and experimental program to determine the effect of the various mirror parameters shown here on the coupling efficiency between the waveguide and the resonator.

This has resulted in a series of design guidelines for low-loss waveguide laser resonators. In addition, we've computed the near and far field intensity patterns for this new type of laser, and compared them to experimentally measured intensity cross-sections in the laboratory.

A third contribution that Goddard has made is the development of a new technique to determine two important laser parameters, G_0, the small signal gain, and I_S, the saturation intensity.

These two parameters (plotted in Figure 4) are important in choosing the optimum operating pressure, the optimum discharge current, and also the optimum mirror reflectivity for the laser. Briefly, the method consists of placing a small coupling plate inside the laser resonator, and measuring the power reflected off the plate as a function of the plate angle.

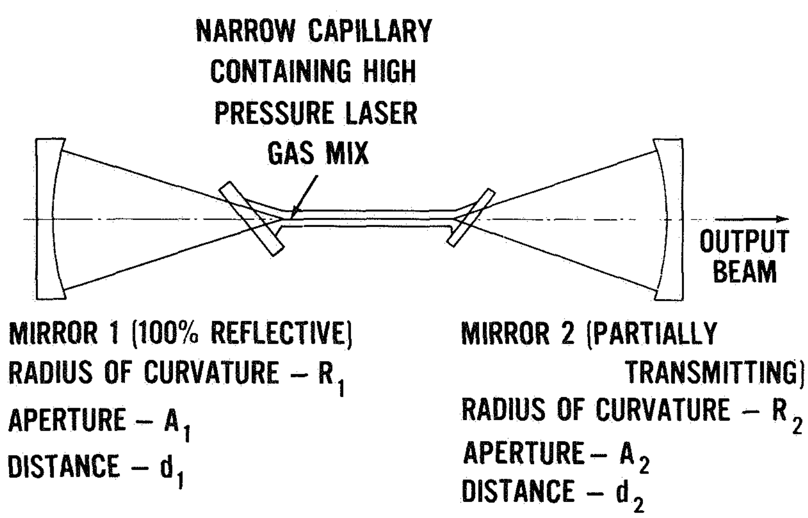

Figure 3. Schematic of a waveguide laser.

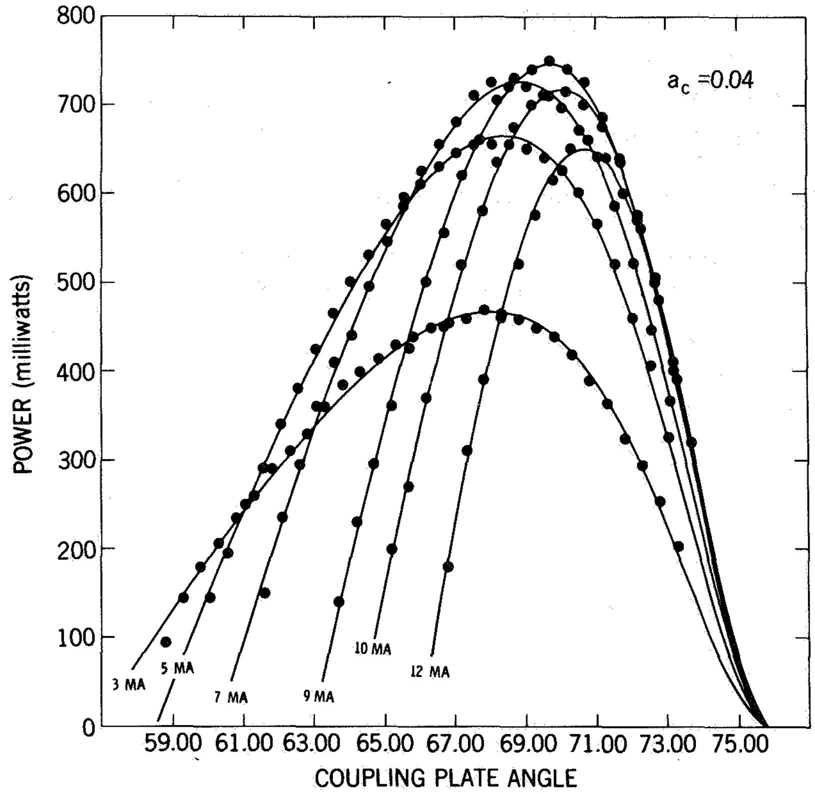

Figure 4. New experimental technique for measuring g_0 and I_s.

The data is then fitted, by a least squares method, to a theoretical curve, which depends on the two parameters of interest. Here we see a plot of the agreement between theory and experiment, where the power output is plotted versus the coupling plate angle. The Brewster angle corresponds to seventy-six degrees.

At the present time, the waveguide laser is capable of a plus or minus 200 megahertz tuning range. This is more than enough to accomodate a 300 megahertz information bandwidth. At the present time we are pursuing low loss methods of frequency selection, which will extend this range even further.

This would allow the transmission of larger information bandwidths and the relaxation of certain stringent mixer requirements.