https://ntrs.nasa.gov/search.jsp?R=19730019126 2020-03-17T08:55:46+00:00Z

BALLOON ATMOSPHERIC PROPAGATION EXPERIMENT MEASUREMENTS

Peter O. Minott

The use of visible and infrared lasers for communication between ground and spacecraft has advantages over present radio frequency methods of higher bandwidths obtainable and smaller satellite transponders. The Laser Data Systems Branch has been actively developing both the visible Neodymium-Yag laser and the infrared carbon dioxide laser as communication devices.

Figure 1 illustrates the type of systems we have under consideration. The figure shows

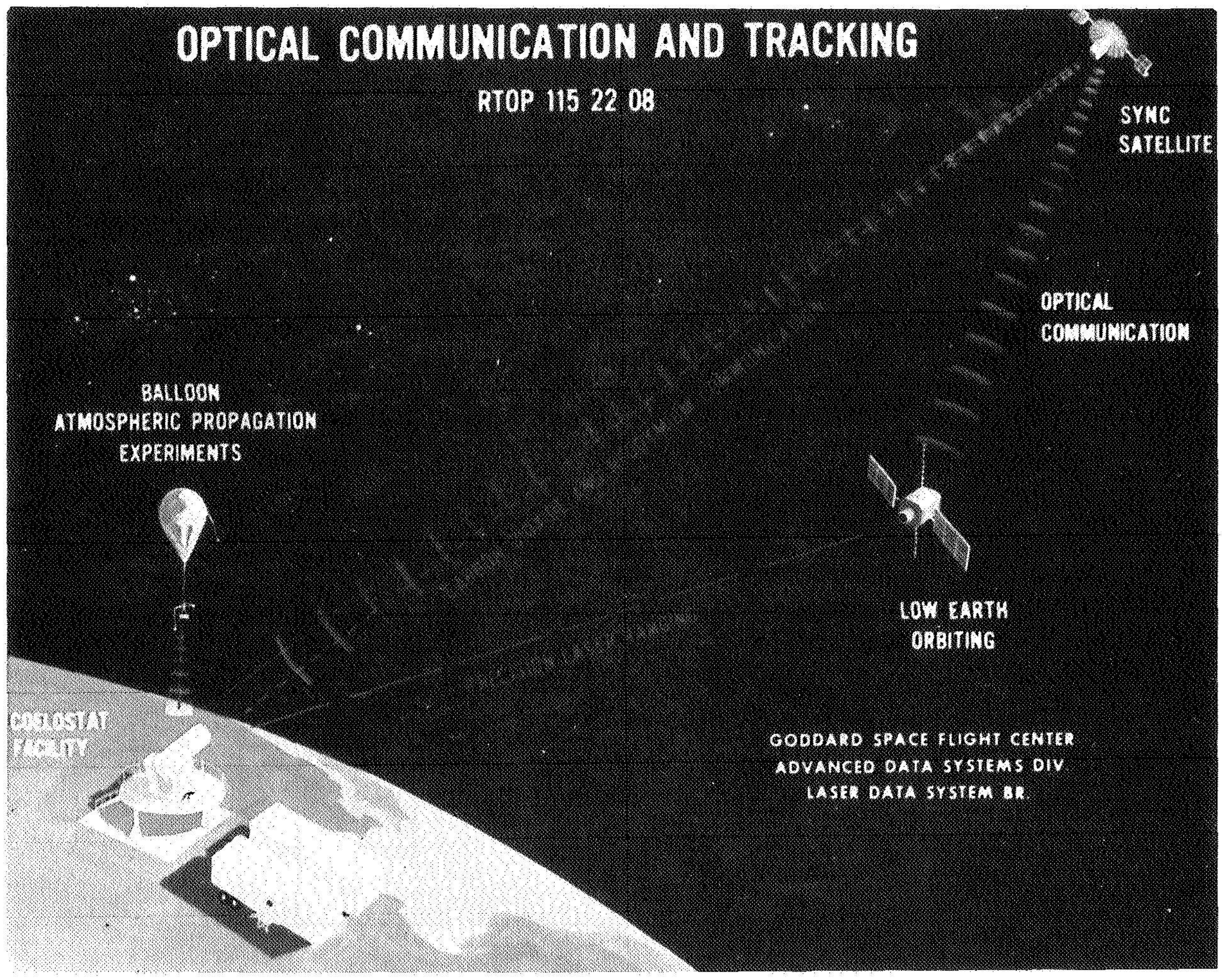

Figure 1. Fading caused by atmospheric turbulence on a space-to-ground laser propagation path seriously degrades pulsed binary laser communications, by a degree which may be much greater than predicted from stellar scintillation studies.

that our interest is in high data rate, in two-way communications between a synchronous spacecraft and the ground; as well as between low earth-orbiting spacecraft and synchronous spacecraft, for data relay purposes.

One of the key problems in using lasers for duplex earth-to-space communications is the fading and distortion of the transmitted signal caused by turbulence in the atmosphere. In order to measure these atmospheric effects, the Laser Data Systems Branch has performed a series of laser propagation experiments, using instrumented payloads on high altitude research balloons. The balloons were well above the altitude at which atmospheric turbulence occurs.

The high altitude balloon is used to simulate the spacecraft end of the propagation link. My discussion today is on the results of these experiments, which are applicable to the visible Neodymium-Yag laser communications systems.

A typical picture of the fading of a light beam propagating through the atmosphere is shown in Figure 2. The data, which was taken by observing a star with a 15-centimeter aperture, demonstrates that the fading is a completely random function of time, and can be quite severe.

Most of the available data comes from observations of stellar fading, or scintillation. But this data is not necessarily the same as would be observed from a laser, because starlight

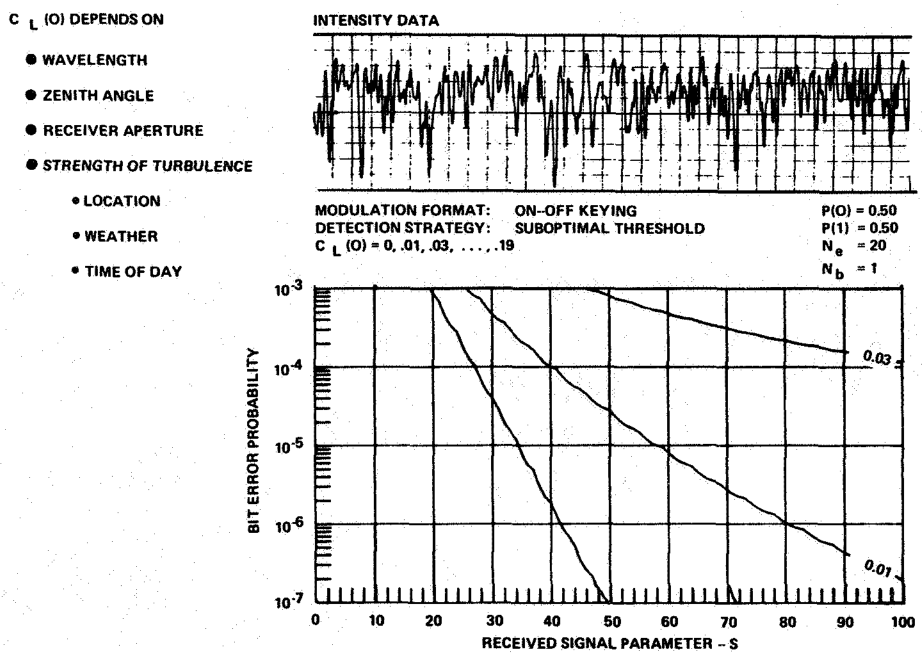

Figure 2. Fading can be predicted based on a knowledge of the strength of fading and the correlation of fading between two points derived from measurements made with a ground-to-balloon propagation experiment.

is not as monochromatic or coherent as a laser.

One of our objectives was to compare stellar fading with laser fading. We know that the strength of fading, which is measured in terms of the mean square deviation of the logarithm of wave amplitude (called "log amplitude variance") is a function of the parameters shown in the list on the left-hand side of the figure.

The graph on the lower right of the figure shows a relationship between system bit error rate and signal photoelectrons per bit for a pulsed Neodymium-Yag communcations system operating in a typical modulation mode.

The graph shows the bit error rate in the presence of various degrees of atmospheric fading. Clearly, even a small amount of fading, as shown by the $C_\ell(0)$, equals 0.03 line. This requires a substantial increase in system margin to maintain a fixed bit error rate in the presence of fading.

In order to characterize the strength of fading, we have obtained the data shown in Figure 3 from our balloon experiment. The first chart shows the cumulative probability of log amplitude variance, and it is plotted in such a manner that a straight line indicates a log-normal distribution of fading.

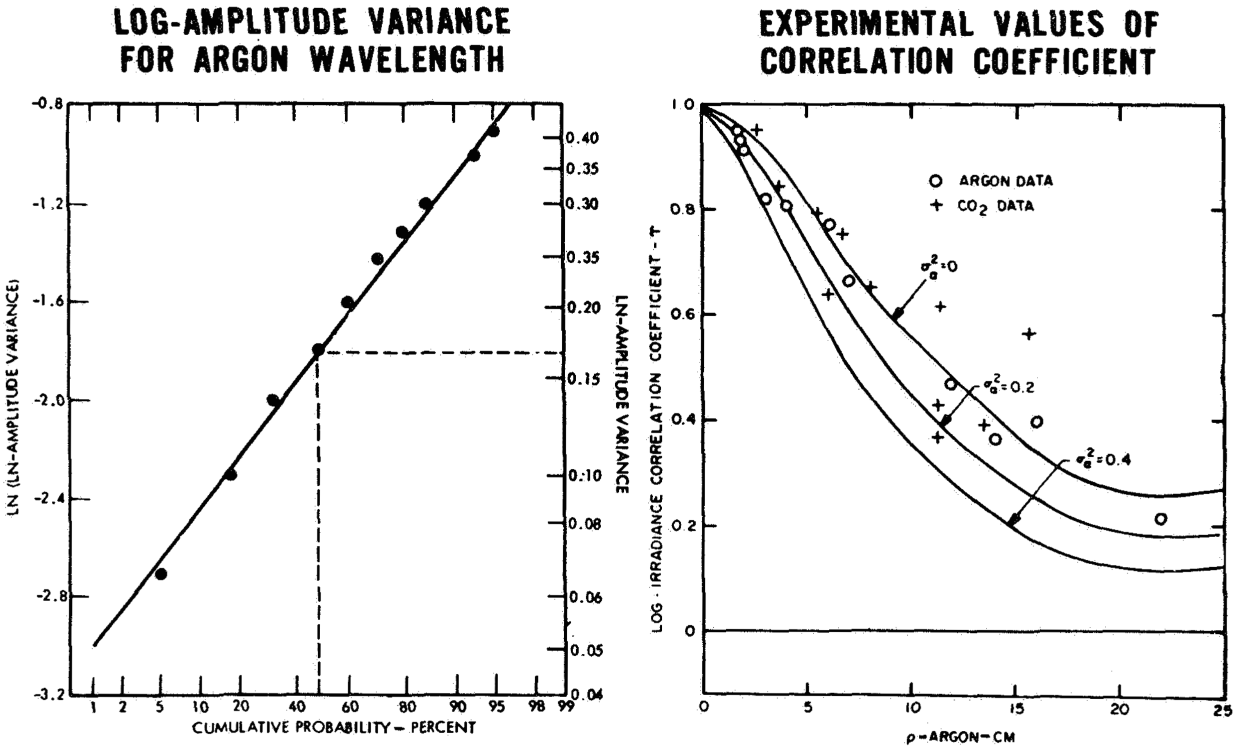

Figure 3. From the results of our experiment, fading caused by turbulence can be predicted for any aperture receiver and is well correlated to stellar scintillation magnitudes.

The second curve shows the correlation between fading at two points in the receiver plane separated by a distance ρ, in centimeters.

The data were taken for both the Argon wavelength, which is 5145 Angstroms, and the CO_2 wavelength of 10.6 microns. Using these data, we can predict the variance of the signal in a large aperture telescope.

Figure 3 shows the result of our study. Strength of fading is predicted for lasers on the basis of the balloon measurements by the three lines shown in the figure.

This upper line is the maximum we expect (a plus 3 sigma value); the solid line is a mean value; and the minimum is a minus 3 sigma value. On the vertical axis, we have the rms signal variation divided by the mean signal level in logarithmic coordinates; and on the horizontal axis, we have the receiver aperture in meters.

The values for stellar scintillation from a number of different authors are plotted in Figure 4 and indicate a good correspondence between stellar and laser scintillation. Beyond an aperture of about ten centimeters, the standard deviation of the signal decreases as approximately the reciprocal of the diameter.

This graph also gives an indication of the magnitude of the strength of scintillation. Using this data, we feel we will be able to predict the bit error rates for Neodymium-Yag laser communications systems.

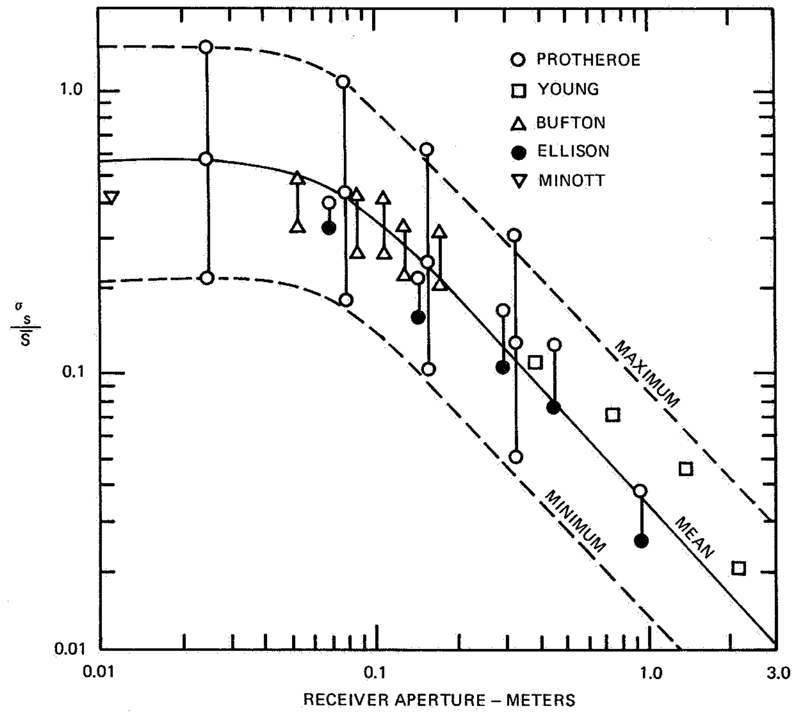

Figure 4. Scintillation as a function of receiver aperture (nighttime – 45° zenith angle).