Technical White Paper

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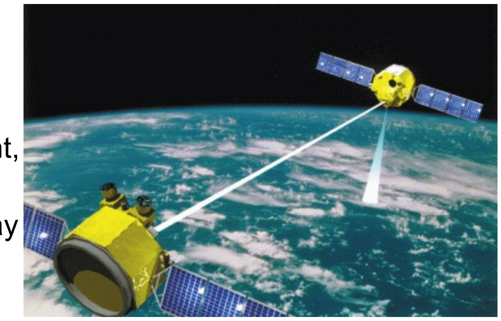
Stable Satellite-to-Ground Laser Communications

Satellite-Based Laser Communications In Inclement Weather



Fog Optics applauds the progress made by NASA and MIT on their satellite to ground laser testing. These groups have made huge break throughs in many areas, including tracking, weight reduction, power management, and sub-systems design. It should be noted, all successful tests have been during fair weather. This may satisfy all current needs of the space program.

Moving forward, it is the observation of Fog Optics research staff that the laser communication system in use will falter during adverse weather. This paper is meant to outline a unique solution, highlight the technical problems with implementing it, and include, in broad strokes, the abilities that Fog Optics has to overcome these issues.

Applying ever increasing power to overcome the atmosphere is not a practical, safe, or efficient solution. Barring eye safety, a laser with a high power draw in space is the most costly option for various reasons. The limited resources available to satellites force every volt to be allocated efficiently and sustainably. A better solution must be found before beginning to think about reliable space-based laser communications. Academically, this starts with prediction and modeling in an effort to look for a whole solution to the requirements needs.

Atmospheric Prediction Issues

Theoretically, in order to predict weak spots in the atmosphere (agreeable to lower-powered solutions overcoming this obstacle) one would have to solve several equations in real-time, which require some knowledge of the atmospheric conditions.[i,ii] The problem is then compounded by the stability of the instantaneous turbulence. Andreas, et all, did extensive theoretical analysis on this topic,[iii] which has since been confirmed by numerous field experiments, primarily from Light Detection And Ranging (LiDAR) testing.[iv],[v]

The end result is that the bulk average equations in use arev valid for approximately 10 minute windows. This turbulence factor is the most consistently changing part of the atmospheric equation. For contaminates, an averaging method must be employed across that region of turbulence stability. From there, one must consider interplay between aerosols and other elements confounding field-based measurements.[vi] All of this makes a purely predictive model approach untenable for live communications in a changing atmosphere.

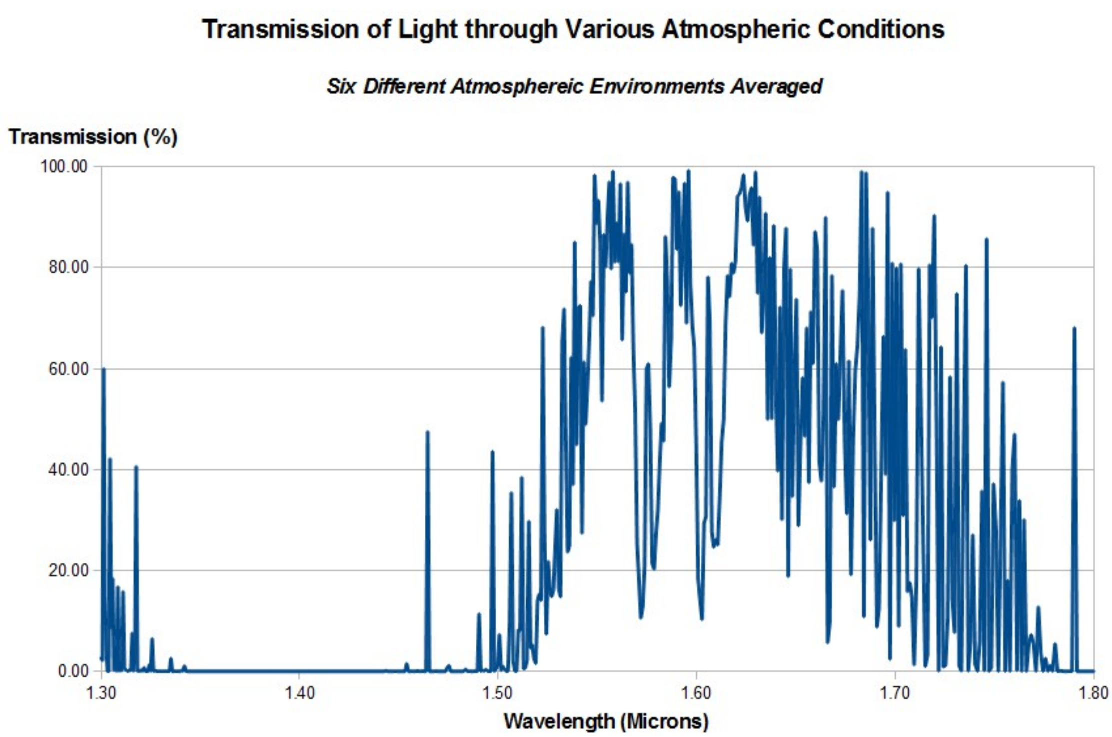
Real World Data

Field measurements that have resulted in precise, consistent data, such as those in the peer reviewed and validated HiTran Spectral Absorption Database use bulk approximations and extrapolations. Actual lab measurements, testing differing fine spectral area, have consistently deviated from these established generalized models and formulas. These deviations in actual measurements have indicated the presence of weak portions of the atmosphere, for a variety of reasons.[vii, viii,ix,x,xi]

In 2011, Lockheed Martin attempted to replicate the claims of various labs which re-engineered systems to allow light to travel through the atmosphere better in a real world environment at the US Army Picatinny Arsenal in New Jersey.[xii] The real-world test showed the lab-based claims to be incongruous.[xiii,xiv,xv,xvi]

Atmospheric Opportunities

Currently accepted models aggregate and therefore loose needed information to accurately predict the effects observed in several labs and documented in numerous scientific papers. Researchers can draw bulk conclusions from the aggregate data available, such as those from the HiTran database (pictured below); but, given the volatility of the atmosphere, relying on this data to be a true indicator of the atmosphere on any given day, or any given 10-minute window of that day, is a mistake.



Pictured on page 3 is a transmission graph in six different atmospheric conditions, taken from data in the 1992 HiTran Database. There are 3 intuitive wavelengths to look for absorption "weak spots": 1540-1565 nm, 1575 nm – 1600 nm, and 1620-1640 nm.[xvii] While an encouraging start, a clear plan and predicted extension of the observed lab-based observations needs to be understood, field tested, and implemented.

Fog Optics reviewed raw data presented in a variety of papers from multiple sources, acquired additional original data from those and other sources, and contrasted it with the Lockheed-Martin data that was made available. This allowed Fog Optics to refine our models with hundreds of gigabytes of privately captured field data enabling a new set of systems designs that vastly improves laser communication quality in extreme atmospheric events; including clouds, fog, and snow.

Partnership Advantages

Fog Optics is confident a laser communication system can be custom built in the next 5 years which will both meet NASA's unique space operating standards and component list, while also providing 99.999% up-time to ground stations. This prototype can be tested at one of several terrestrial facilities for adverse atmospheric conditions performance before the expense of a launch. The NASA design teams and their partners will work to field the Fog Optics enabled systems with the existing space-tested support systems. This will enable the future communication systems to have a higher reliability, be eye safe, and operate at a lower cost.

NASA and its partners have extensive knowledge of materials and system designs that have launch survivability, reasonable power standards, minimal weight, and mitigation against other engineering lessons learned for systems operating in space. Fog Optics technologies will provide a distinct enhancement to mission capabilities, cost, and reliability.

Fog Optics has proprietary recommendations on the receive sub-systems as well as several proprietary specifications and system redesigns for the laser to be used, and is ready to discuss a partnership providing good faith details of our proprietary technologies under NDA.

Contact

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