Optical Communications Portion
of
New Technologies Section
of
Communications Satellites Chapter
of
Future Aeronautical and Space Systems AIAA Monograph

As space communications networks and the demands for their services grow, the ability to satisfy those demands with RF technology will become increasingly more difficult. There are two reasons for this. First, the increased information demands will require higher data rate service links utilizing more channel bandwidth. Even if the radio frequency spectrum were available from the regulatory coordination bodies (which is unlikely) the RF components needed to implement such capabilities will require major additional advances relative to the current state-of-the-art, Such improvements are hard to imagine due to the already mature and optimized nature of the RF technology. Second, the inter-connectivity of these networks will require many transceiver terminals on each satellite node, The size, weight and power of RF systems makes this impractical from a host spacecraft accommodation standpoint, and the difficulties of simultaneously tracking multiple companion nodes with large RF transceiver terminals without mechanical interference (either physical or via reaction mass coupling), are problematic,

Optical (laser) communications can enable these future networks with very little impact on the host platforms. The short wavelengths in the optical region (0.5-2.0 microns) results in much more concentration of the transmitted beam compared to RF systems. This effect, when offset by differences in quantum noise detection statistics, results in a theoretical advantage of 71 dB relative to X-band (8 Ghz) communicational. This 71 dB advantage can be used to significantly reduce the sizes of the transmitting and receiving terminals while, at the same time, providing several orders-of-magnitude increase in data rate capability, Additionally, there is more bandwidth at the optical frequencies and there are no frequency regulation restrictions like there are at the RF frequencies.

Research and development of optical communications technology and systems has been in progress in the United States, Europe and Japan. The United States began development of optical communications technology in the 1970's, primarily through the defense department. With the end of the Cold War, many of the defense department programs have been cut back and NASA has taken over much of the lead. The Europeans began studies and technology development in the early 1980's with $C0_2$ lasers, but in the mid-80's switched to laser diode-based systems. They are currently developing space terminals for the Semiconductor Intersatellite Laser communications Experiment (SILEX), an optical link demonstration between the SPOT 4 satellite in LEO and the ARTEMIS satellite in GEO[2]. The Japanese delayed their introduction into the technology until the mid-late 1980's and went directly to designs based on laser diodes. Ironically, the Japanese were the first to actually launch an optical communications terminal into space with the Laser Communications Experiment (LCE) on the ETS VI spacecraft (launched Aug 28, 1994)3, The LCE was to have provided a modest 1 Mbps data rate from GEO-to-ground (the satellite's orbit transfer motor failed, leaving it in the GEO transfer orbit).

Developments of optical communications technology within NASA have concentrated on both NASA mission and commercial systems applications. The NASA missions include both the Earth-orbiting projects like those in the Missions to the planet Earth, and on the much longer range deep-space exploratory missions, In the 1980's, the focus was on providing substantially more data rate than had been provided in the past. However, in the 1990's the emphasis was changed to small, light-weight communications terminals that could support a new breed of microspacecraft, while still providing significant link capacity. To support these missions NASA commenced the development of the Optical Communications Demonstrator (OCD)[4]. The OCD uses a new optical communications terminal architecture that uses only one

2-axis steering mirror and one detector array for spatial beam acquisition, tracking and pointing (most systems in the past used two or more of each). The system was designed to address both the near-Earth and the deep-space applications base.

For the commercial applications base, NASA started an industry-led program called the Laser Communications Demonstration System (LCDS)[5]. This program resulted in parallel industry contracts and began with an assessment of the potential applications base for industry-developed optical communications terminals, This program represented a paradigm change for the NASA communications program where it was believed that NASA could more cost-effectively get its optical communications needs met by asking industry to concentrate on terminals for which it saw a large market, and then designing NASA missions around (or with few changes from) the capabilities that industry could (commercially) supply, The LCDS program is intended to provide for a flight demonstration in the late 1990's.

NASA has also been providing other technology developments and system planning, most notably in the area of ground reception systems. Telescopes in the 1-meter diameter category can be used to support Earth-orbital data dump-to-ground missions[6] and larger, but less precise, 10-meter (photon bucket) telescopes will support deep-space exploratory missions[7]. NASA has also been evaluating the impediments to space-to-ground optical transmission (most importantly the effects of the Earth's atmosphere), In this regard, NASA has deployed a set of three Atmospheric Visibility Monitoring observatories. These observatories measure the intensity of stars on the ground to collect detailed statistics on the atmospheric throughput. By deploying these telescopes in spatially diverse locations (two are in California and one is in Arizona), the benefits of spatial site-diversity can be assessed.

REFERENCES

1. Lesh, J. R., C-C Chen and H. Hemmati, "Optical Communications for NASA's Small Spacecraft Missions of the Future," Proceedings of 7th Annual AIAA/USU Conference on

Small Satellites, Utah State University, September 13-16, 1993.

2. Popescu, A., and B, Furch, "Status of the European Developments for Laser Intersatellite Communications," Proceedings of SPIE OE/Lase'93, Los Angeles, CA, paper 1866-02, January 1993.

3. Arimoto, Y., M. Toyoshima, M. Toyoda, T. Takahashi, M. Shikatani and K. Araki, "Preliminary Results on Laser Communications Experiment Using ETS VI,)' SPIE Photonics West'95, San Jose, CA, February 1995.

4. Chen, C-C. and J. R. Lesh, "Overview of the Optical Communications Demonstrator," Proceedings of SPIE OE-LASE 94, January 1994, paper 2123-09.

5. Lesh, J.R. and R. DePaula, "Overview of NASA R&D in Optical Communications," SPIE Photonics West'95, San Jose, CA, February 1995.

6. Lesh, J, R., "Progress and Plans for the Optical Communications Program at JPL," (Invited) Proceedings of SPIE OE-LASE 94, January 1994, paper 2123-02.

7. Wilhelm, M., K.S.Shaik, and D. Wonica, "Ground-based Advanced Technology Study - Optical Subnet Concepts for the DSN," SPIE Photonics West '95, San Jose, CA, February 1995.

8. T.-Y. Yan, "Atmospheric Transmission Model Through Autonomous Visibility Measurement," Proceedings of SPIE OE/Lase 94, Paper # 2123-35, Los Angeles, CA, January 1994.