Seven Years of ACTS Technology Verification Experiments Reviewed

The Advanced Communications Technology Satellite (ACTS) was designed to achieve a 99.5-percent system availability rate and signals with less than one error in 10^7 bits throughout the continental United States. To accomplish such a high rate of system availability, ACTS uses multiple narrow hopping beams and very small aperture terminal (VSAT) technology. In addition, ACTS uses an adaptive rain fade compensation protocol to reduce the negative effects of propagation on the system.

To enhance knowledge on how propagation and system variances affect system availability, researchers at the NASA Glenn Research Center at Lewis Field performed technology verification experiments over a 7-yr period (from September 1993 to the present). These experiments include T1VSAT System Availability, Statistical Rain Fade Compensation Characterization, Statistical Characterization of Ka-Band Propagation Effects on Communication Link Performance, and Multibeam Antenna Performance.

T1VSAT System Availability Experiment

Using a performance index such as system fade availability, the T1VSAT System Availability Experiment focused on analyzing the effects of Ka-band system variances and propagation on the performance of seven T1VSAT's that were located in different rain zones. A main objective was to determine the overall availability of the selected T1VSAT's within the various rain zones. It was determined that the amount of rainfall is not necessarily a factor in determining outage; however, the type of rainfall is a large determinate. In addition to rainfall, other factors that contributed to outages included hardware and software anomalies (10 percent). After modifications were made to the T1VSAT and to operational procedures, T1VSAT availability increased by 3 percent.

Statistical Rain Fade Compensation Characterization Experiment

The ACTS adaptive rain-fade compensation protocol was developed to ensure a T1VSAT bit error rate of $<5\times10^{-7}$ for 99.5 percent of the time that the T1VSAT is operational. The protocol is adaptive, has decision-making capabilities, and is implemented to maintain T1VSAT performance during periods when the signal weakens as a result of fade or system effects. As shown by 1 year of collected data, system availability increased by 1.5 percent in an International Telecommunications Union Radiowave (ITUR) medium rain zone. The protocol was considered to be more than adequate for all rain zones within the continental U.S in which terminals were used for short amounts of time (less than 1 month).

Statistical Characterization of Ka-Band Propagation

Effects on Communication Link Performance Experiment

This experiment, which took place over a 5-year period at seven U.S. sites, focused on the effects of rain attenuation at Ka-band frequencies. As the dominant cause for signal impairment, rain attenuation is a function of frequency, elevation angle, rain intensity, raindrop size distribution, and raindrop temperature. Fades of 20 dB or larger were observed at least 0.1 percent of the time in subtropical rain zones and 0.01 percent of the time in a dry rain zone. The effect of clouds was found to be around 2 dB for all rain zones.

Wet Antenna Experiment

Selecting a subtropical rain zone (Cocoa, Florida) and using a tipping bucket rain gauge to collect rainfall data over a 10-month period, Glenn's researchers conducted the Wet Antenna Experiment to analyze the contribution that a wet feed and wet reflector antenna have on the signal path losses at Ka-band frequencies. The receiving signal strength was measured, and a small weather station was operated next to the T1VSAT terminals. The results indicated that feed wetness was the main contributor to system losses, with reflector wetness having less effect. The reflector losses were a result of scattering due to raindrop size at the reflector surface, which distorted the surface and reduced antenna gain significantly. Another observation showed that the cumulative fade distribution with a wet antenna was 3 to 5 dB worse than with a dry antenna.

Multibeam Antenna Performance Experiment

A key technology on ACTS is the multibeam antenna system, which has 3 fixed and 47 rapidly reconfigurable spot beams operating at Ka-band frequencies. One of the most significant aspects of the system design is the accurate estimation of antenna performance degradation. Over a 7-year period, test measurements indicated that the multibeam antenna system operated well within the expected performance range. Thermal and mechanical disturbances affected performance, but could be easily corrected in future designs. Thermal distortions were periodic, which makes it possible to predict and compensate for the impact of these effects on system performance. Other design anomalies were recorded, and can be corrected in future designs of this type of satellite system.

The 7 years of valuable research conducted on the ACTS system will enable designers to tailor a satellite system to provide quality system availability at relatively low cost. Using the ACTS rain fade compensation proved that coding gain can be extremely effective in combating rain fade. Continuing research is being performed on rain fade compensation to allow inexpensive Ka-band system implementation.

Find out more at the ACTS http://acts.grc.nasa.gov/ web site.

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