Highly Reliable UWB-OFDM Transmission within a Small Spacecraft

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This paper describes measurements and characterization of ultra-wideband (UWB) radio propagation within a small scientific satellite and simulation of transmission performance based on the propagation measurements. The aim of this paper is to replace (at least partly) wired on-board data buses with wireless links. Adoption of wireless technologies within spacecrafts could contribute to: i) reduction of cable weight and resulting launching cost, ii) reduction in the cost of manufacture and testing, iii) ensuring reliable robust communication due to the effects of route diversity, iv) more flexibility in layout of subsystems, and v) more reliable connection at rotary, moving, and sliding joints.

Narrowband wireless communication systems yield dead spots due to multipath propagation, particularly in metal-enclosed spaces such as inside satellites. In addition, intense long-delayed multipaths could cause inter-symbol interference (ISI) and thus limit the data rate. In order to communicate space mission and control system data, a highly reliable and high-speed transmission system is desired. The combination of UWB and orthogonal frequency division multiplexing (OFDM) technologies is capable of overcoming the dead spots and ISI.

It is necessary to evaluate propagation characteristics with a view to estimating the transmission performance. Frequency responses in a UWB bandwidth (from 3.1 to 10.6 GHz) within a small scientific satellite were measured with a microwave vector network analyzer and low-voltage-standing-wave-ratio UWB monopole antennas. While the transmitting antenna was fixed at a point in the satellite, the receiving antenna was scanned on an 250 mm × 90 mm plane within the satellite at 5-mm intervals (*i.e.* the total points of measurement = 918). The fading was observed to follow Rayleigh distribution in both spatial and frequency domains. Power delay profiles, inversely Fourier-transformed from the frequency responses, were found to attenuate exponentially.

The bit error rate (BER) of a UWB-OFDM wireless transmission was evaluated through simulation using measured propagation data. Major simulation parameters are as follows:

- modulation was quadrature phase shift keying OFDM;
- the center frequency was 3.5 GHz, and the bandwidth 512 MHz;
- the number of OFDM subcarriers was 512 and data subcarriers 500;
- the length of data symbol was 1.00 μs, the length of cyclic prefix 0.25 μs, and data bit rate 400 Mb/s; and
- convolutional coding (coding rate = 1/2), soft-decision Viterbi decoding, and block interleaving were employed.

Simulation results revealed that the system attained BER $\leqq 10^{-5}$ in all the 918 points while allowing a margin of approximately 15 dB to an equivalent isotropically radiated power (EIRP) of -14.2 dBm (= -41.3 dBm/MHz × 512 MHz), where the -41.3-dBm/MHz power density was approved for UWB by the Federal Communications Commission of the United States and many other governments.