Efficient Bit-to-Symbol Likelihood Mappings

A new algorithm that increases decoder speed contributes to the development of high-speed optical communications links.

NASA’s Jet Propulsion Laboratory, Pasadena, California

This innovation is an efficient algorithm designed to perform bit-to-symbol and symbol-to-bit likelihood mappings that represent a significant portion of the complexity of an error-correction code decoder for high-order constellations. Recent implementation of the algorithm in hardware has yielded an 8-percent reduction in overall area relative to the prior design. This gain resulted from changing just two operations in a complex decoder. Larger gains are possible for larger constellations that are of interest for deep-space optical communications. The algorithm struc-
Some non-traditional signal constellations have been proposed for transmission of data over the Additive White Gaussian Noise (AWGN) channel using such channel-capacity-approaching codes as low-density parity-check (LDPC) or turbo codes. (As used here, “constellation” signifies, with respect to a signal-modulation scheme, discrete amplitude and/or phase points corresponding to symbols to be transmitted.) Theoretically, in comparison with traditional constellations, these constellations enable the communication systems in which they are used to more closely approach Shannon limits on channel capacities. Computational simulations have shown performance gains of more than 1 dB over traditional constellations. These gains could be translated to bandwidth-efficient communications, variably, over longer distances, using less power, or using smaller antennas.

The opportunity to effect improvements through use of the proposed constellations arises as follows: The introduction of turbo and LDPC codes during the 1990s made it possible to formulate coding schemes that afford near-Shannon-capacity performance for binary and quaternary phase-shift-keying modulation schemes. However, in these and other channel-capacity-approaching coding schemes, when traditional signal constellations are used, the gap between the achievable performance and the Shannon or the Gaussian capacity increases with bandwidth efficiency (in effect, as more bits are packed into each transmitted symbol). While the channel-capacity-approaching codes are highly optimized, the traditional signal constellations are not optimized.

The amplitude and/or phase intervals between points in a constellation accord-

<table>
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<th>Capacity Maximizing Constellations</th>
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<td>Locations and bit labels of constellation points are optimized jointly.</td>
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The amplitude and/or phase intervals between points in a constellation accord-

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**Gaps Between Parallel Decoding Capacity and Gaussian Capacity**

Quantified as equivalent signal-to-noise-ratio (SNR) gaps were computed for optimized and traditional PAM 2-, 4-, 8-, 16-, and 32-point constellations.