tures the bit-to-symbol/symbol-to-bit operations like a tree that forms a portion of a Fast-Fourier-Transform (FFT). Much like an FFT, the parallel computation may be structured in order to reduce repeated computations. Symmetry in the values was noted and allowed for the reduction of the bit-to-symbol mapping by a factor of 2.

This method computes bit-to-symbol likelihood mappings for a soft-in/soft-out decoder that operates over M-ary symbols, but receives and transmits bit-log likelihoods. There are two bit-to-symbol mappings. The first requires $M - 2$ operations and $\log_2 M - 1$ clock cycles. The second requires $O(M \log_2 M)$ operations and $\log_2 \log_2 M$ clock cycles. The symbol-to-bit mapping requires $\log_2 M$ clock cycles and $3M - \log_2 M - 4$ operations. In a pipelined architecture, the reduced operation counts also translate into reduced memory requirement.

This technology can apply to communications channels that use high-order constellations and decode over symbols from that constellation. This would potentially include a large number of communications channels, such as cable modems, disk drives, etc., as well as being a direct improvement to the Optical Communications End-to-End Testbed, which is currently in use to demonstrate, test, and develop deep-space optical communications technology.

This work was done by Bruce E. Moision of Caltech and Michael A. Nakashima of Skillstorm, Incorporated for NASA's Jet Propulsion Laboratory.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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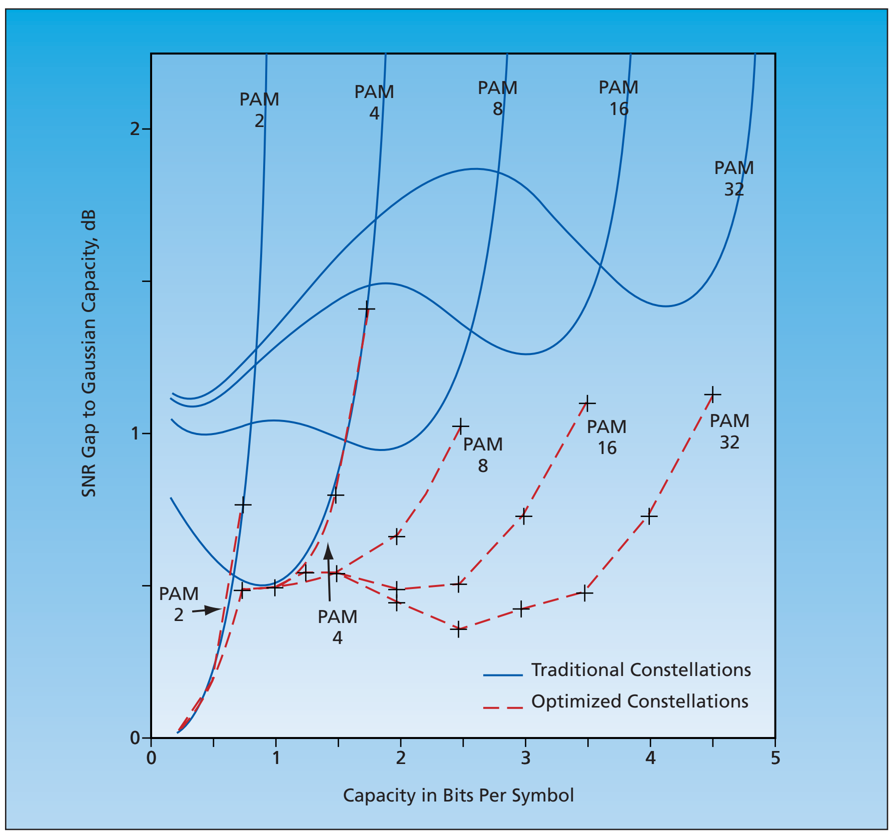
Capacity Maximizing Constellations

Locations and bit labels of constellation points are optimized jointly.

NASA's Jet Propulsion Laboratory, Pasadena, California

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, variously, 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 in-



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.

creases 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 according to the proposal are unequal. Unlike in traditional constellations, both the locations of the points and the bit labels of the points are optimized jointly. In the optimization process, they are chosen to maximize either the joint capacity or the parallel decoding capacity at a target user data rate. Through numerical capacity computations, it has been shown that except in special cases, no constellations are universally optimal for all code rates and that the optimization of a constellation must target a specific code rate.

The proposed constellations have been used in a bit-interleaved coded modulation system employing state-of-the-art LDPC codes. In computational simulations, these constellations were shown to afford performance gains over traditional constellations as predicted by the gap between the parallel decoding capacity of the constellations and the Gaussian capacity (see figure).

This work was done by Maged Barsoum and Christopher Jones of Caltech for NASA's Jet Propulsion Laboratory.

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