Some non-traditional signal constellations have been proposed for transmission of data over the Additive White Gaussian Noise (AWGN) channel using 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.)

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 log₂ M – 1 clock cycles. The second requires $O(M \log_2 M)$ operations and $\log_2 M$ 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.

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 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-
ing 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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