Communication with Coarse Quantization

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We investigate two transmitters for communication over frequency-selective channels with additive white Gaussian noise (AWGN):

- Transmitter A corresponds to the upper branch of Fig. 1. The data symbols $\mathbf{u} = [u_1, \ldots, u_N]$, $u_i \in \mathcal{X}$, from the constellation $\mathcal{X}$ are converted from the digital to analog domain via a high-resolution DAC that has $n \gg 1$ bit resolution and operates at a rate $R_\text{s} = 1/T$.
- Transmitter B uses a nonlinear mapping $f : \mathcal{X}^N \to \{\pm 1\}^M$ that converts a length N data vector $\mathbf{u}$ to a length M binary vector $\mathbf{b} = [b_1, \ldots, b_M]$, $b_i \in \{\pm 1\}$, where $M \geq N$. A 1-bit DAC that runs at rate $R'_\text{s} = R_\text{s} N_\text{os}$, $N_\text{os} = M/N$, converts the binary vector $\mathbf{b}$ to a level-constrained signal $x_b(t)$; see Fig. 2.

The coarse DAC greatly reduces hardware cost and energy consumption in Transmitter B. In addition, a power amplifier after the DAC can be operated energy-efficiently, as $x_b(t)$ has a peak-to-average power ratio of 1. We assume that the receiver ADC has infinite precision and samples $y(t)$ at rate R_s to produce the noisy symbols $\hat{\mathbf{u}} = [\hat{u}_1, \ldots, \hat{u}_N]$.

Goal: For a data vector $\mathbf{u}$, find the vector $\mathbf{b}$ that minimizes the MSE, i.e., solves

$$\operatorname{argmin}_{\mathbf{b}} \mathbb{E}\left[\|\mathbf{u} - \hat{\mathbf{u}}\|^2\right], \tag{1}$$

where the expectation is over the noise.

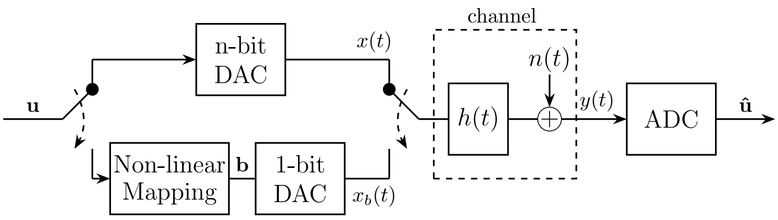

Fig. 1: AWGN channel with filter $h(t)$.

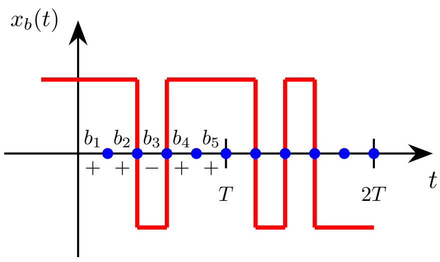

Fig. 2: Choice of a level-constrained signal $x_b(t)$ with $N_\text{os} = 5$.