# McGill

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# Improved Correlation Model for Continuous-Valued Sources in LDPC-Based DSC

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## Motivation

Accurate modeling of the correlation between the sources plays a crucial role in the efficiency of distributed source coding (DSC) systems. When binary codes like LDPC and turbo codes are use for compression, this correlation is commonly modeled in the binary domain by using a "single" binary symmetric channel (BSC), both for binary and continuous-valued sources.

We introduce a more accurate model for the correlation between continuous-valued source, e.g., in sensor networks and video coding.

## Existing and Proposed Correlation Models

The correlation between analog sources $X$ and $Y$ can be defined by

$$Y = X + E, \qquad (1)$$

where $E$ is a real-valued random variable. Specifically, for the Gaussian sources, $E$ is Gaussian. However, when binary codes, e.g., LDPC and turbo codes, are use for compression, this correlation is commonly modeled in the binary domain, as shown below
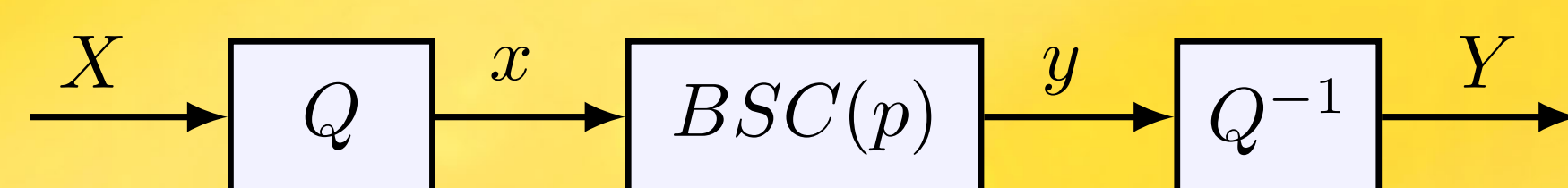


Simulation shows that an independent error in the continuous domain is not translated to an i.i.d. error in the binary domain, and the correlation parameters differ depending on the bit position (bit-plane).
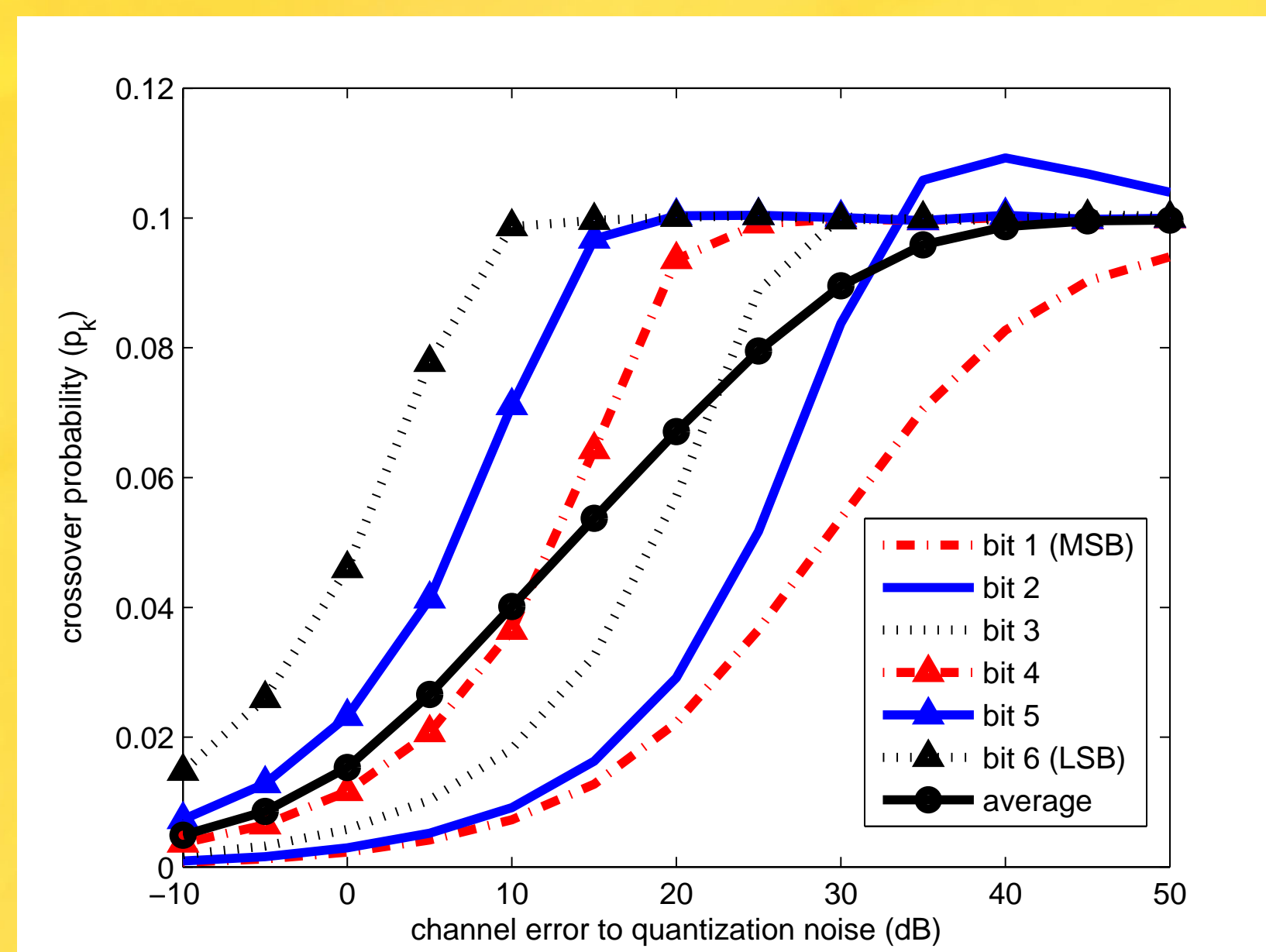


This suggest that "multiple" BSCs can lead to a more accurate model, and thus a better compression.

Given a $b$-bit quantizer, we use $b$ BSCs to model the correlation, where $p_1, \ldots, p_b$ is the parameter of the BSC channel corresponding to the LSB to MSB, respectively.
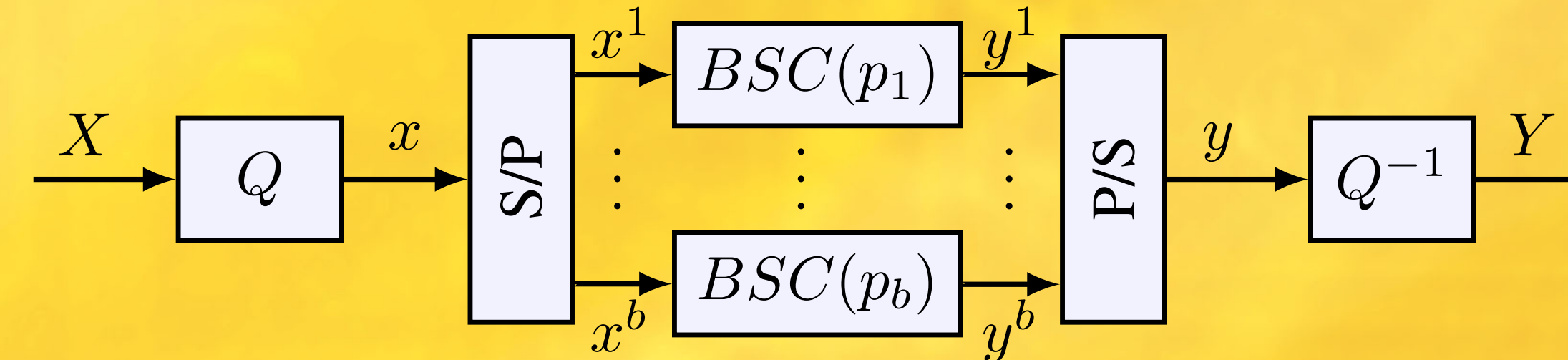


## Decoding Using LDPC Codes

We investigate three different implementations of the multiple BSC model in the Slepian-Wolf coding based on LDPC codes. These are

1. **Parallel Decoding**
2. **Sequential Decoding**
3. **Hybrid Decoding**

In parallel decoding, the complexity increases b times as there are $b$ LDPC decoders each corresponding to one correlation channel. By using sequential decoding, the number of decoders can be reduced to one at the cost of increased delay.

A yet more efficient integration of the new correlation model into the LDPC-based DSC can be achieved just by using a single LDPC encoder/decoder.

## Hybrid Decoding

This is done in two steps, as explained in the following.

▸ *Manipulating the LLRs:*

The parameters of the multiple BSC correlation model can be incorporated into the LDPC decoder by setting the log-likelihood ratios (LLR) sent from (to) the variable nodes as

$$q_{i,0} = \log \frac{\Pr[x_i = 0 | y_i]}{\Pr[x_i = 1 | y_i]} = (1 - 2y_i) \log \frac{1 - p_k[i]}{p_k[i]}, \qquad (2)$$

in which $i = 1, \ldots, n$, $p_k[i] \in \{p_1, \ldots, p_b\}$, and $k$ represents the bit-plane to which $y_i$ (or $x_i$) belongs, as shown here
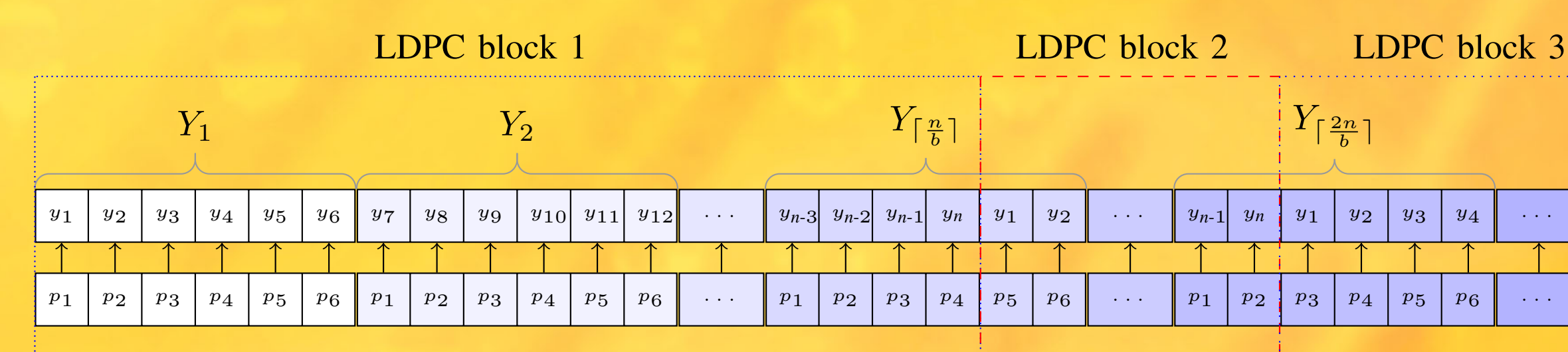


▸ *Interleaving:*

Since the bits corresponding to each error sample are correlated, by interleaving $x$ and $y$ before feeding them into the Slepian-Wolf encoder and decoder, we introduce randomness to the errors. Then, it makes better sense to encode data belonging to all bit planes altogether as in the conventional approach.

The longer the permutation block input the better the performance. Interleaving, however, can increase decoding delay.

## Simulation Results

Simulations are carried out for a zero mean, unit variance Gaussian source $X$. The correlation between $X$ and $Y$ is defined by Gaussian Erasure channel. The LDPC frame length is $10^4$ and the BER and corresponding MSE are measured after 50 itinerations, for different channel error-to-quantization noise ratio. Both sources are quantized with a 6-bit scalar uniform quantizer.
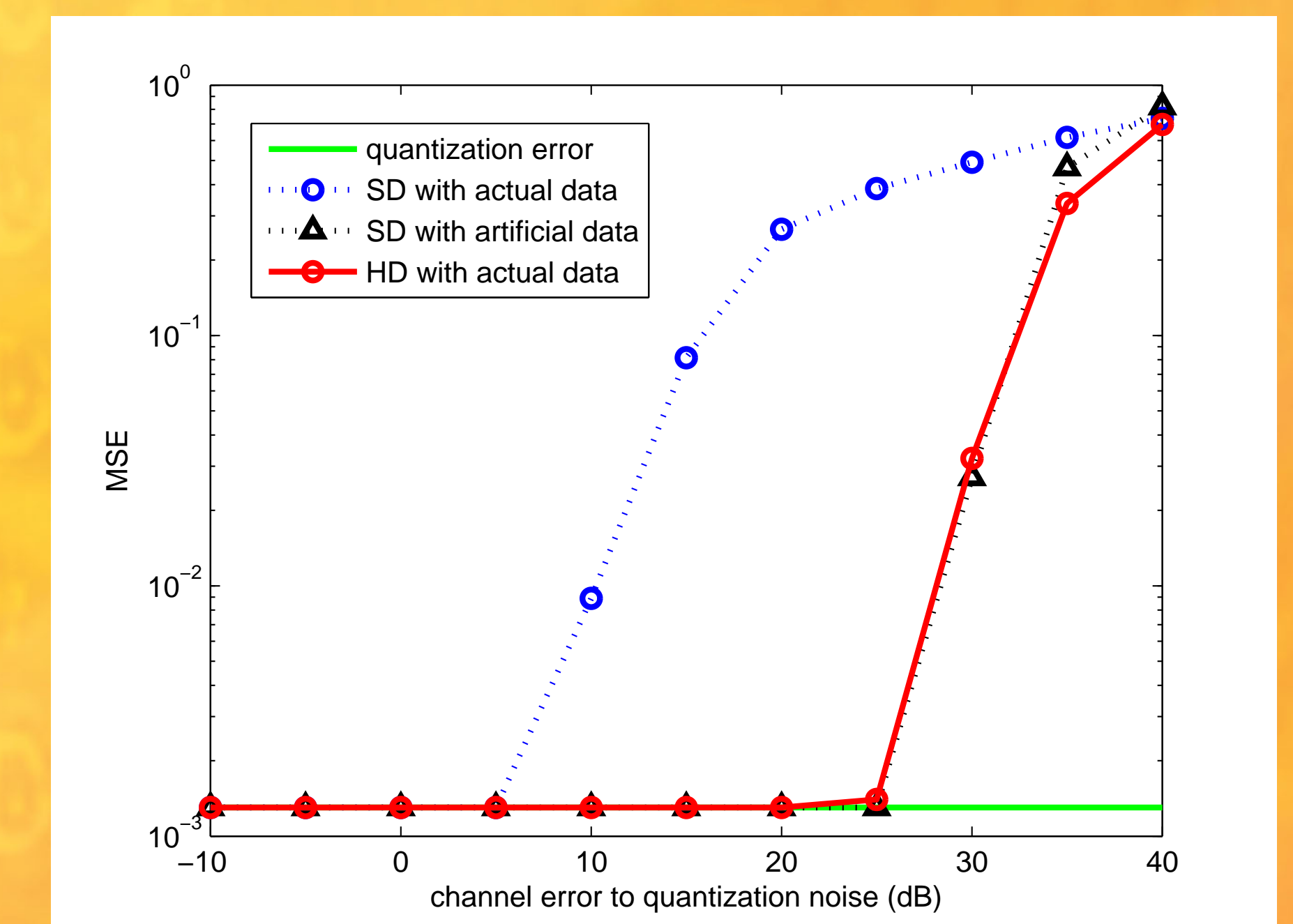


## Conclusions

Using Multiple BSCs to model the virtual correlation between the continuous-valued sources in the binary domain is shown to be more efficient than the conventional single-BSC model, as the new model can deal with the dependency among the bits resulting from quantization of each error sample by converting the error sequence into multiple i.i.d. sequences.

By judiciously setting the LLR and using an interleaver, significant improvement in the BER and MSE is achieved without any increase in the complexity or delay.