COURSE PROJECT REPORT

OFDM and 4x4 MIMO Link Simulation

Alireza Ramyad | Tampere University

Multicarrier and Multiantenna Techniques

Abstract. This project studies uncoded bit error rate (BER) in two MATLAB baseband simulations: a cyclic-prefix OFDM link with training-based channel estimation, and a 4x4 MIMO link with single-stream beamforming and diversity schemes. The saved OFDM output reaches BER 0.005117 at 24 dB. The MIMO figures compare finite-codebook and SVD beamforming, antenna selection and a four-transmit-antenna space-time code. This report summarizes the implemented configuration and its saved results.

1 CP OFDM link over a multipath channel

Waveform	16-QAM; 1,024-point FFT; 600 active subcarriers
Timing	15 kHz subcarrier spacing; 15.36 MHz sample rate; 160-sample CP
Frame and channel	1 BPSK training symbol + 15 data symbols; six-tap Veh-AE block fading
BER evaluation	0-24 dB in 2 dB steps; 1,000 frames per SNR point

The channel is fixed within each frame and regenerated between frames, with tap power normalized in every realization. The CP lasts approximately 10.42 microseconds, exceeding the nominal 10-microsecond maximum path delay. After CP removal and the FFT, least-squares channel estimates are obtained from the training symbol. Zero-forcing equalization divides the data subcarriers by these estimates before QAM demodulation.

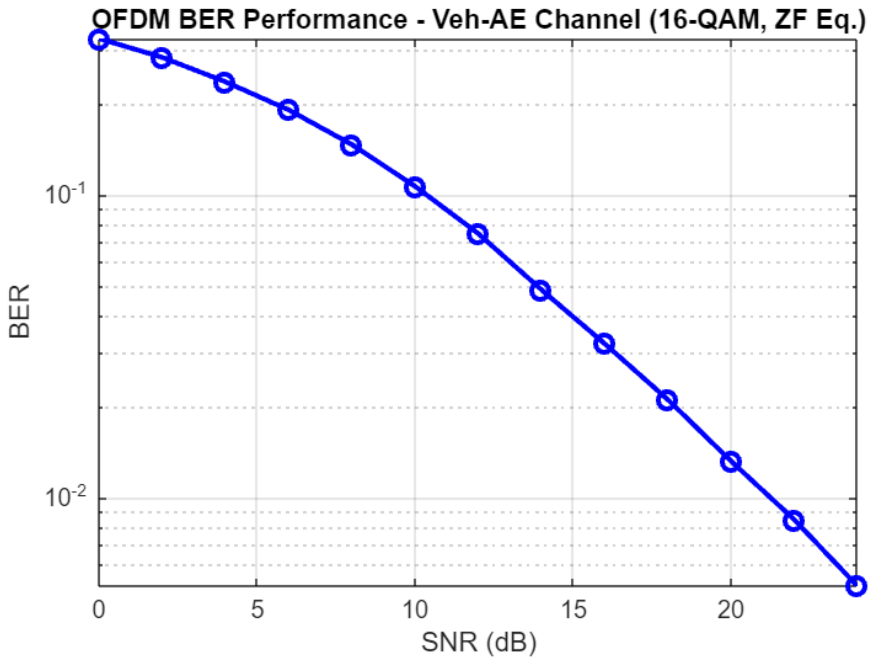


Figure 1. Original saved OFDM plot from the Live Script. SNR denotes the code's measured time-domain received signal-power to noise-power ratio.

Recorded results. BER falls from 0.328717 at 0 dB to 0.074628 at 12 dB, 0.013234 at 20 dB and 0.005117 at 24 dB. Each point includes 36 million data bits across 1,000 independently generated channel frames. The stored run does not reach BER 0.001 within its tested SNR range.

2 Single stream MIMO beamforming

Channel	4 transmit and 4 receive antennas; independent complex Gaussian entries; flat block fading
Modulation and noise	Unit-average-power 4-QAM; AWGN variance = 1/SNR per receive antenna
Evaluation	0-20 dB in 2 dB steps; 100 channel realizations per point; 10,000 symbols per realization
Channel perturbation	Estimated channel = true channel + independent complex Gaussian error; error variance 0.01 per entry

Codebook beamforming. The supplied DFT-based generator creates 64 codewords of size 4x2. The implementation takes the first column of each codeword, giving 64 candidate unit-norm beamforming vectors. It selects the vector that maximizes the squared norm of the effective channel and applies maximum-ratio combining at the receiver.

SVD beamforming. The precoder and combiner are the leading right and left singular vectors. One data stream is transmitted on the strongest mode. Separate cases use the true channel or a perturbed channel estimate when designing these vectors; the code does not implement multi-stream spatial multiplexing.

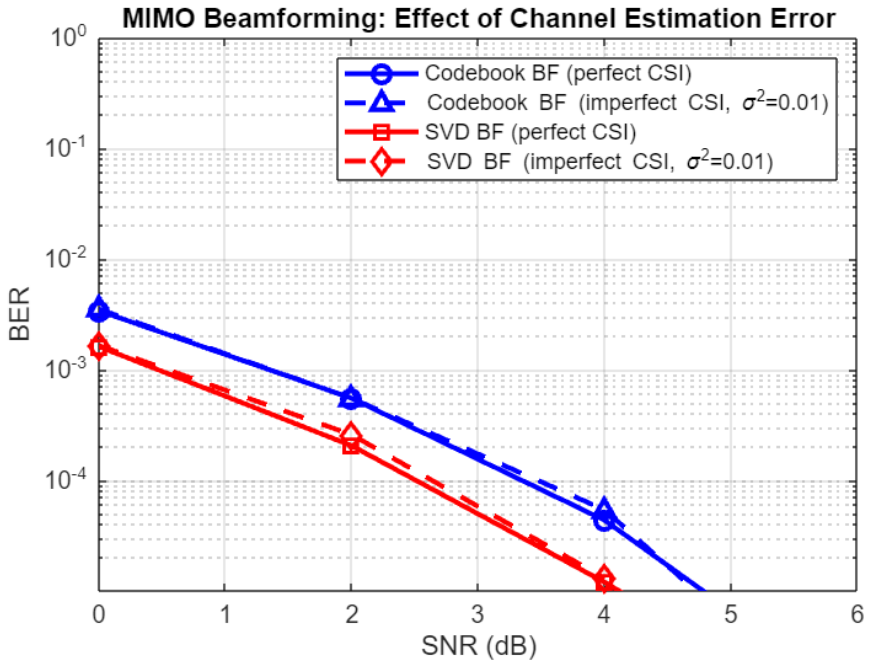


Figure 2. Original saved beamforming comparison. The legend's "imperfect CSI" cases perturb beamformer design; the receiver still uses true effective-channel information as described below.

Observed behavior. At the visible low-SNR points, the saved SVD curves lie below the finite-codebook curves. The perturbed-estimate curves remain close to their corresponding true-channel cases in this run. Exact MIMO BER values and numerical SNR gains are not quoted because the Live Script stores these results as figures rather than printed data tables.

Receiver assumption. For codebook beamforming, combining uses the true effective channel even when codeword selection uses the estimate. For perturbed SVD beamforming, the receiver uses estimated singular vectors but normalizes by the true effective scalar channel. The comparison therefore isolates part of the channel-estimation effect; it is not an end-to-end imperfect-CSI receiver test.

3 Diversity comparison and interpretation

Strongest-mode transmission uses the same estimated-channel SVD rule as the perturbed beamforming case, with a separate noise draw. **Antenna selection** chooses the transmit-receive pair with the largest estimated channel magnitude and detects using the true selected coefficient. The **four-transmit-antenna space-time code** sends three 4-QAM symbols over four time slots, with exhaustive maximum-likelihood detection over 64 symbol triples and true receiver channel knowledge.

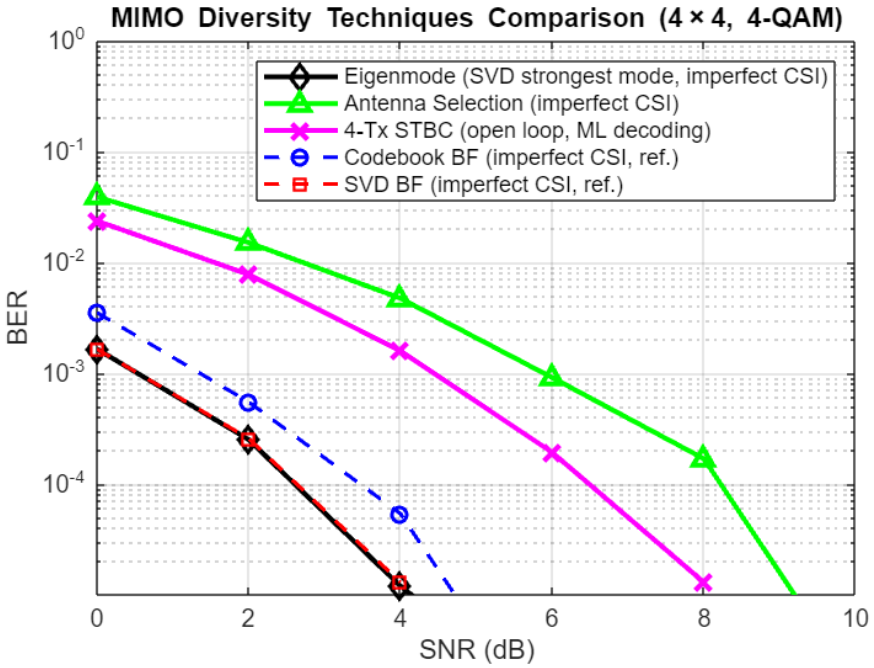


Figure 3. Original saved diversity comparison. The strongest-mode and perturbed SVD curves nearly overlap because they implement the same transmission principle.

Observed behavior. In this saved run, the space-time-code curve lies below antenna selection over the visible range, while the strongest-mode curves show lower BER. These observations describe the implemented configurations; they do not establish a general ranking at equal spectral efficiency and transmit power.

Scope limitations and reproducibility

Comparison conditions. The space-time code has rate 3/4, and its implemented factor of 1/sqrt(4) gives total transmit energy 0.75 per time slot for unit-energy 4-QAM symbols, versus 1 for the single-stream methods. Power and rate must be aligned before claiming a fair performance advantage.

OFDM scope. The report uses the actual 600-subcarrier, 16-QAM implementation; it does not claim the exercise's 80 Mbps design target. Its time-domain SNR is not corrected to the active-subcarrier bandwidth convention specified in the exercise. No THz propagation, large-array geometry or near-field channel model is included. [1]

Reproducibility. The figures and BER values are taken from the saved MATLAB simulation run. The code uses random data and channels without a fixed random seed, so BER estimates may differ between runs. The MIMO results are saved as plots with a lower BER limit of 10^{-5}. Values below this limit are not visible and should not be interpreted as proof of error-free transmission.

Source materials

[1] Tampere University, *COMM.SYS.450 Multicarrier and Multiantenna Techniques, Final Project*, 2026, 4 pages.