Space-Time Block Coding in Rayleigh and Rician Fading Channels

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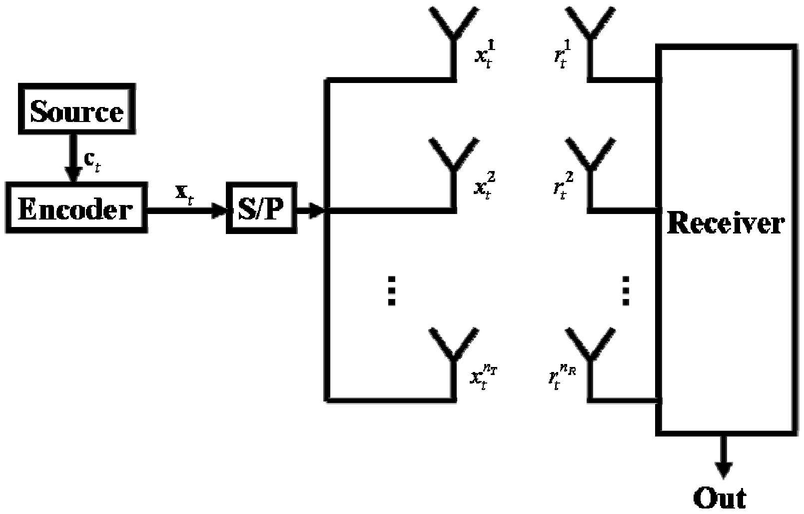
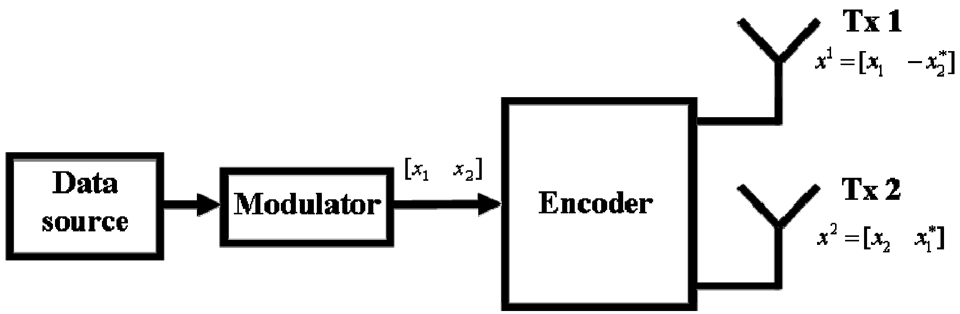
Introduction – space-time coding

- Signal propagation in multipath channels causes the received signal power to fade, leading to severe degradation on signal quality
- Space-time coding, a combination of channel coding and transmit diversity, can be used to reduce the harmful effect of signal fading
- The encoder takes a group of binary information symbols and maps them into modulation symbols
- Encoded data is fed to a serial-to-parallel converter and transmitted simultaneously by multiple antennas
- Different types of STCs: block and trellis codes, layered space-time codes



Space-time block coding

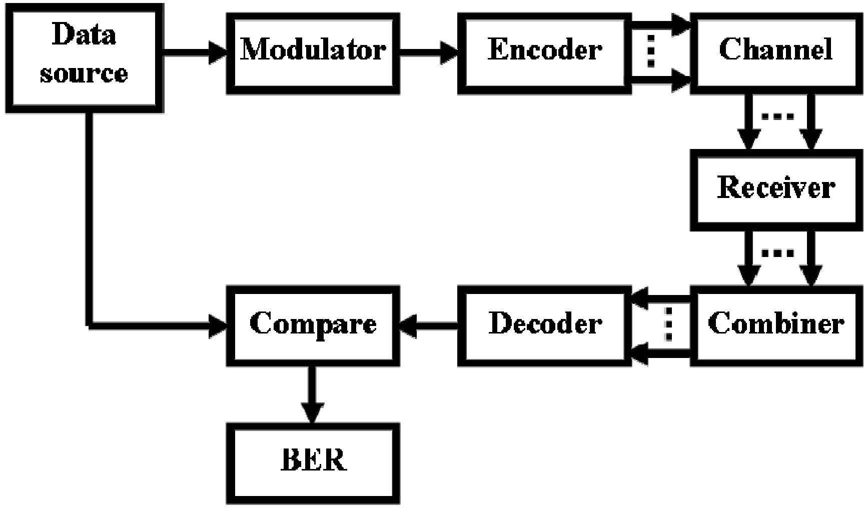
- Space-time block codes are designed to achieve full transmit diversity using an arbitrary number of transmit antennas
- The codes are constructed through orthogonal designs
- Decoding by maximum likelihood algorithms based only on simple linear processing – no channel state information is required at the transmitter
- Example: The Alamouti code for two transmit antennas $\mathbf{X} = \begin{bmatrix} x_1 & -x_2^* \\ x_2 & x_1^* \end{bmatrix}$



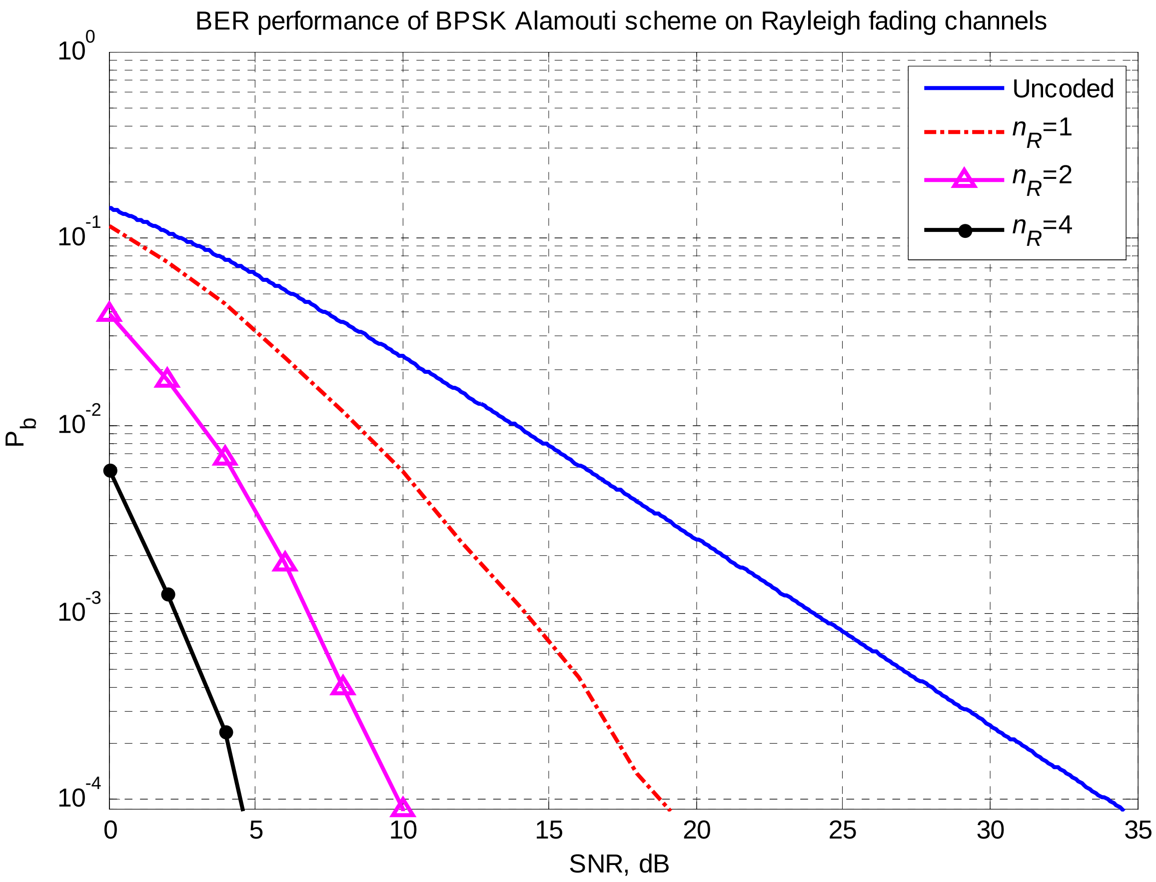
Alamouti encoder

Performance simulations

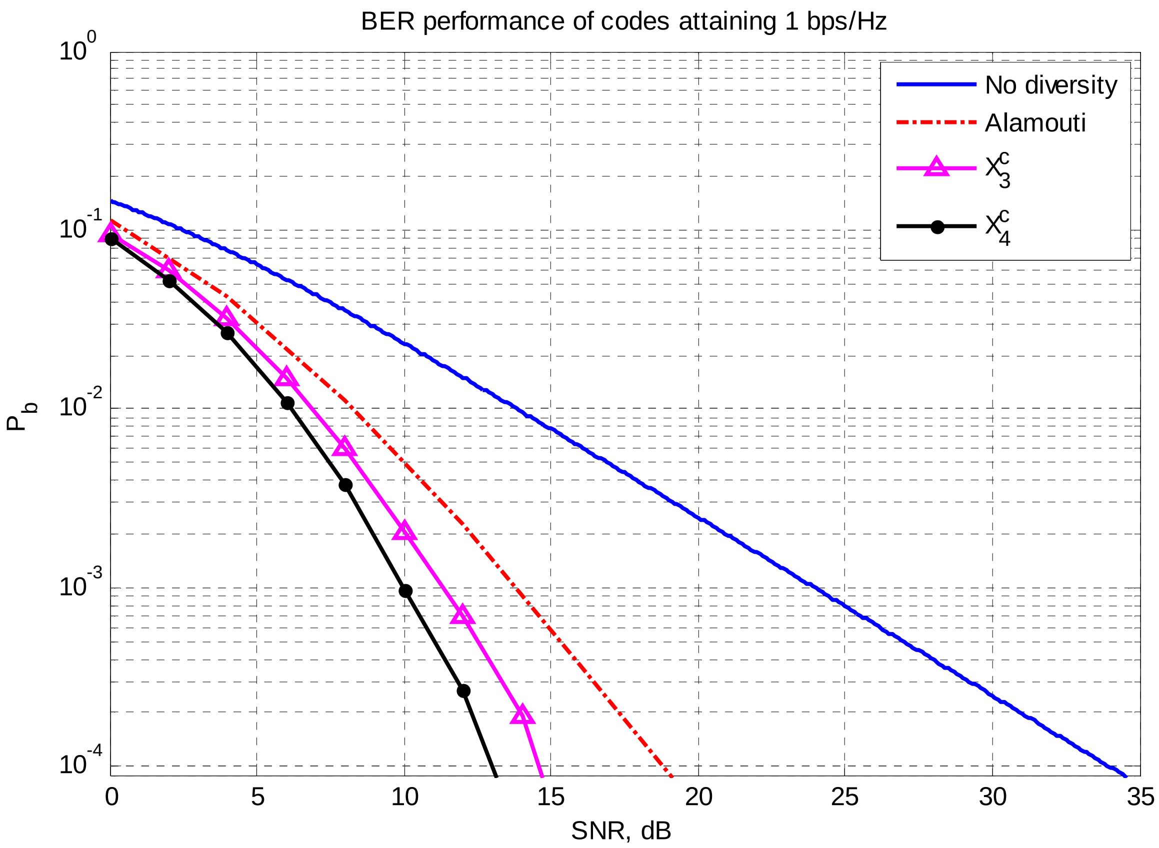
- Alamouti code using different numbers of receive antennas
- Codes for two, three and four transmit antennas using different spectral efficiencies
- The above codes using two-antenna receive diversity
- Slow and flat Rayleigh/Rician fading channel
- Modulation: BPSK/QPSK/16-QAM



Performance of the Alamouti Code



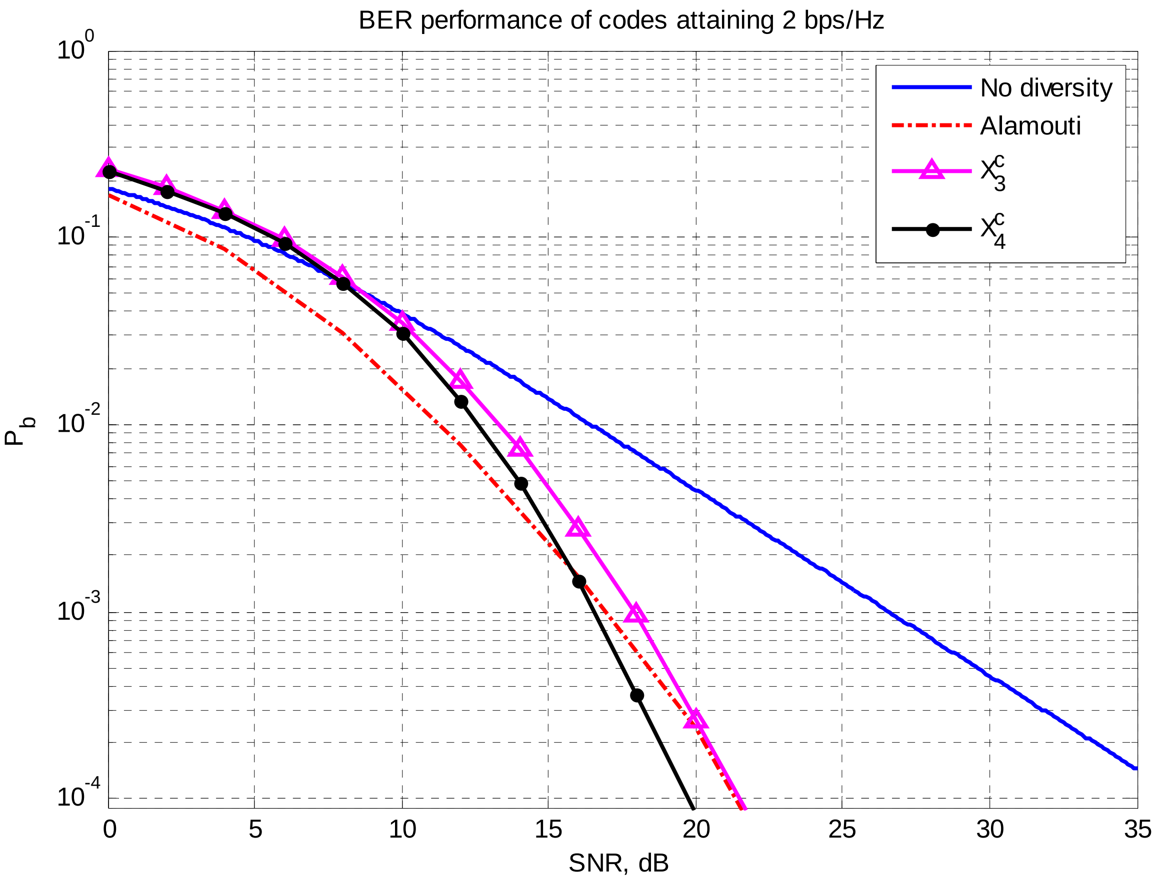
Performance of different codes at spectral efficiency 1 bps/Hz



- Alamouti, BPSK: R=1, m=1
- Xc3, QPSK: R=1/2, m=2
- Xc4, QPSK: R=1/2, m=2

$$\eta = mR$$

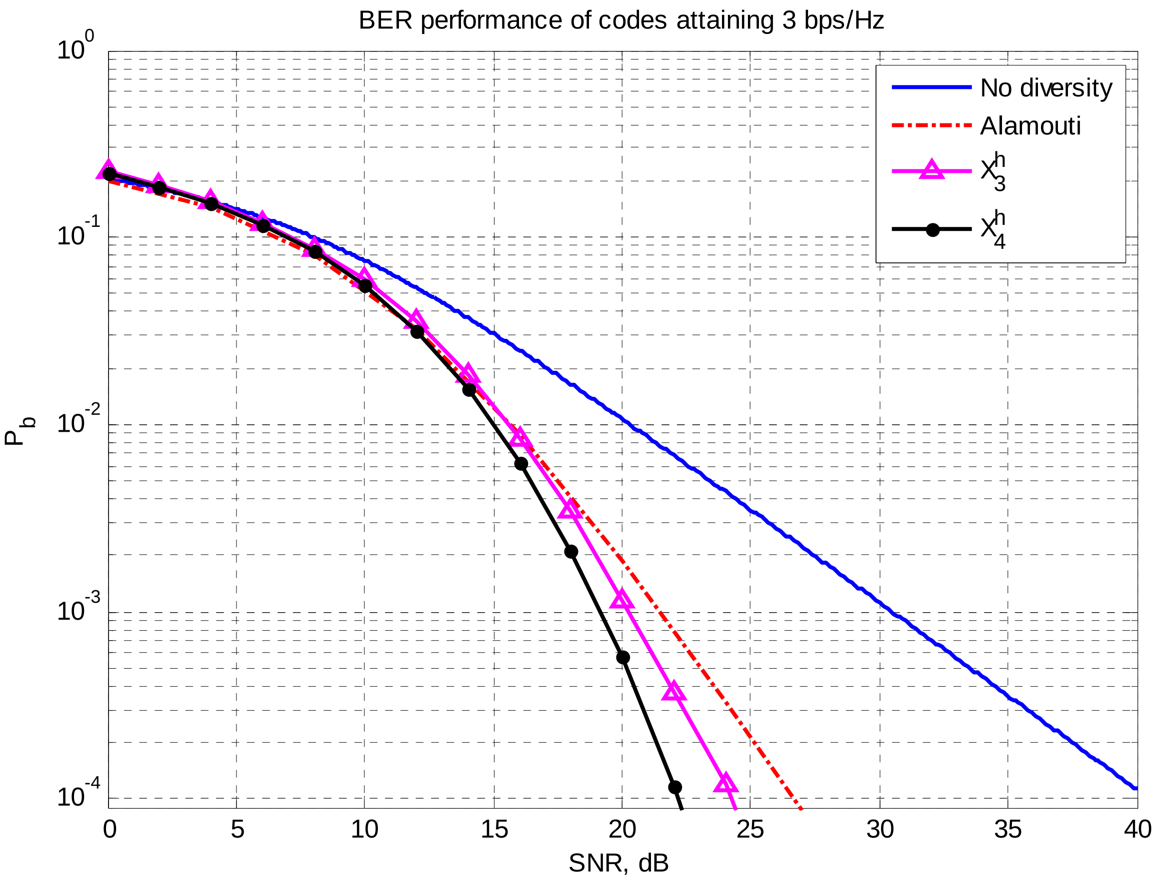
Performance of different codes at spectral efficiency 2 bps/Hz



- Alamouti, QPSK: R=1, m=2
- Xc3, 16-QAM: R=1/2, m=4
- Xc4, 16-QAM: R=1/2, m=4

$$\eta = mR$$

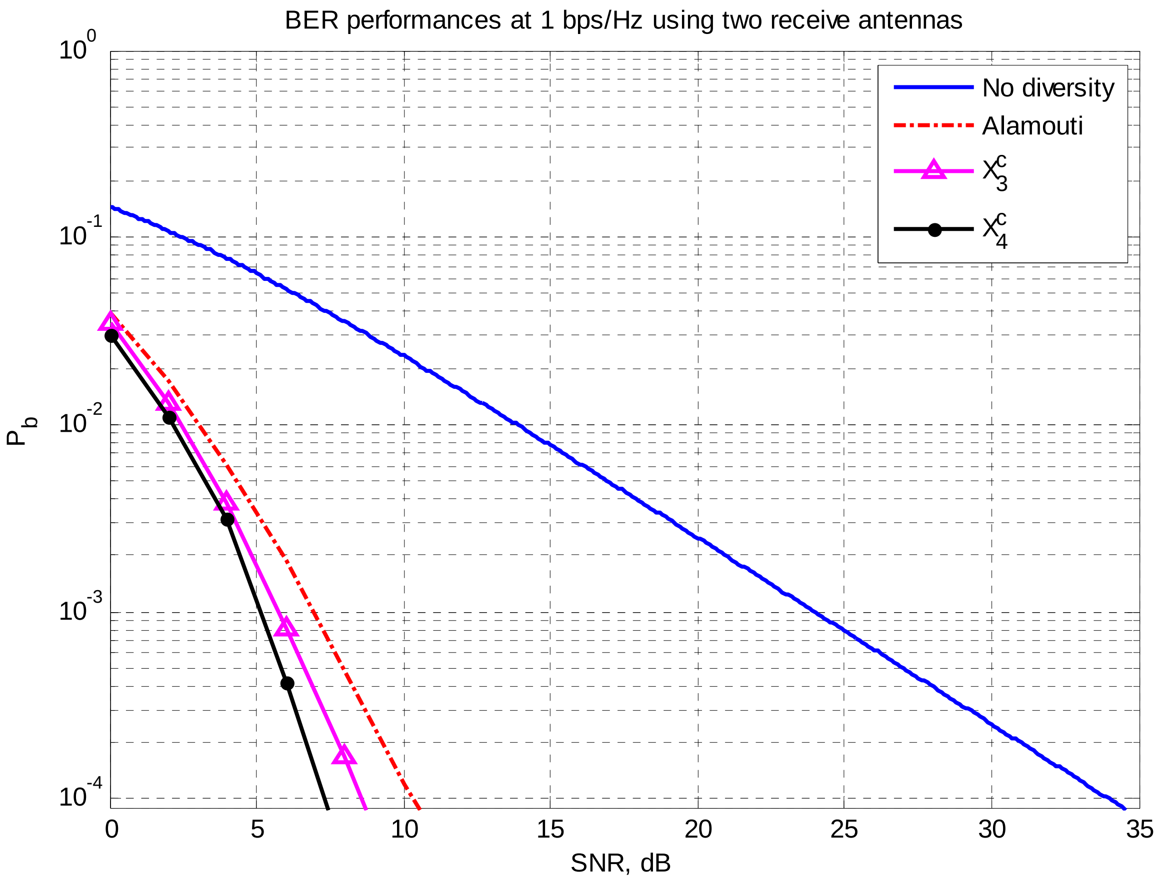
Performance of different codes at spectral efficiency 3 bps/Hz



- Alamouti, 8-PSK: R=1, m=3
- Xh3, 16-QAM: R=3/4, m=4
- Xh4, 16-QAM: R=3/4, m=4

$$\eta = mR$$

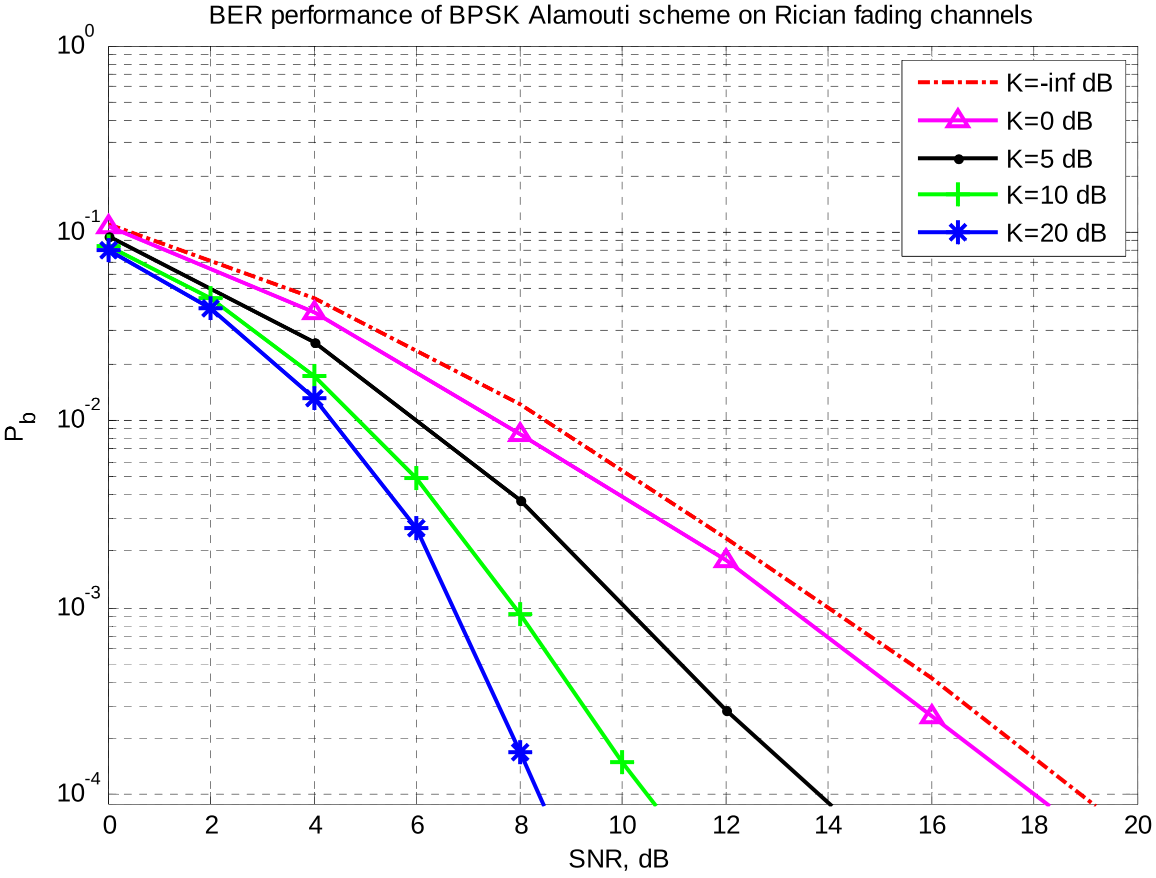
Performance of STBCs using receive diversity



- Alamouti, BPSK: R=1, m=1
- Xc3, QPSK: R=1/2, m=2
- Xc4, QPSK: R=1/2, m=2

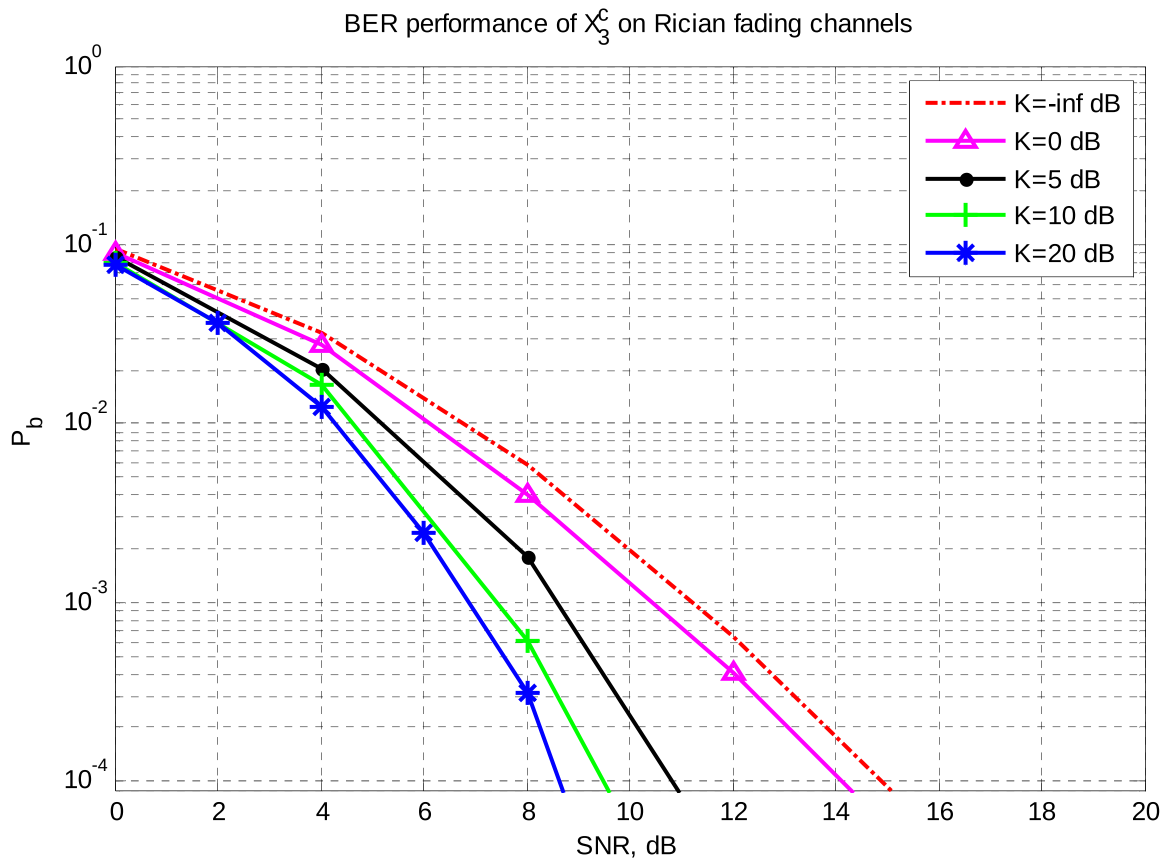
$$\eta = mR$$

Code performance in Rician fading channels: two transmit antennas



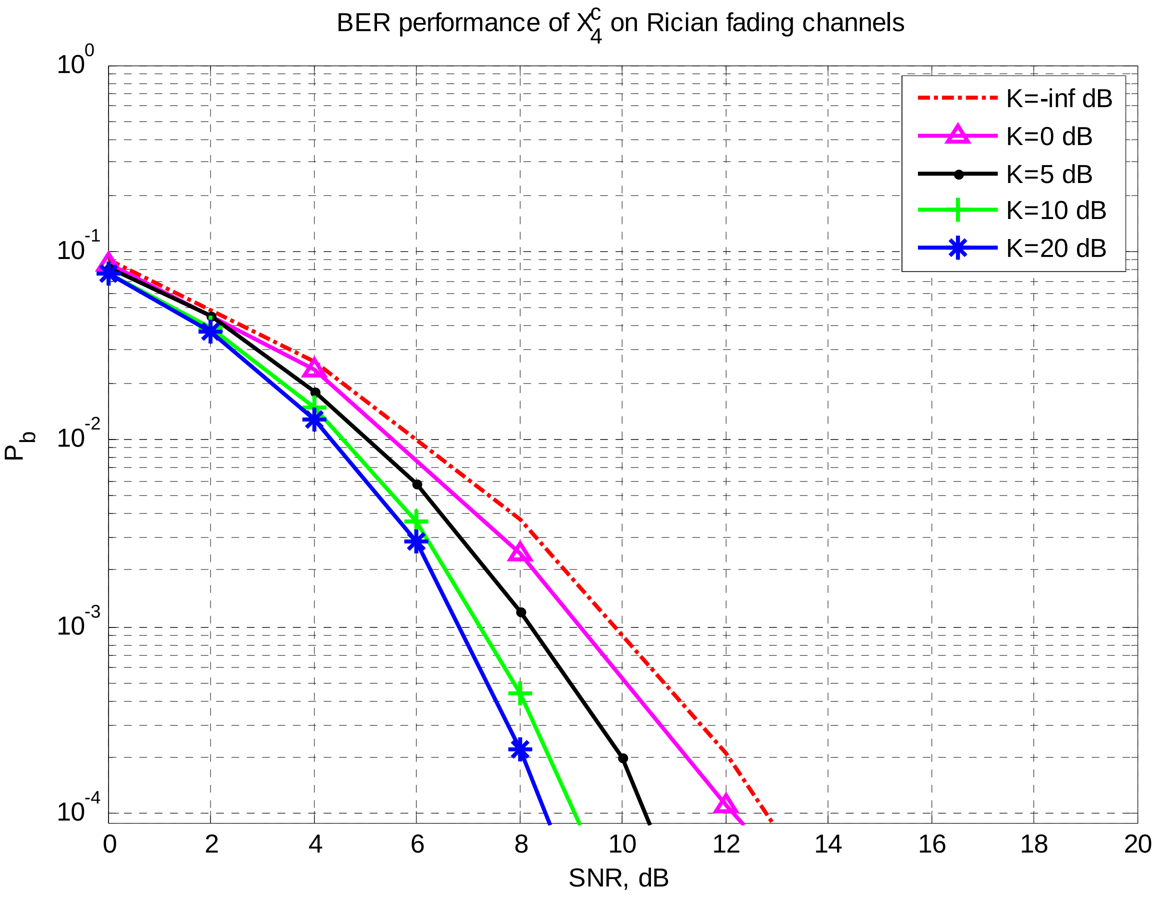
- K=-inf dB: Rayleigh fading channel
- K=20 dB: very strong LOS component

Code performance in Rician fading channels: three transmit antennas



- K=-inf dB: Rayleigh fading channel
- K=20 dB: very strong LOS component

Code performance in Rician fading channels: four transmit antennas



- K=-inf dB: Rayleigh fading channel
- K=20 dB: very strong LOS component

Simulation results / conclusions

- Even a basic STBC system offers a significant gain in performance
- The codes provide radically improved signal quality even in very harsh propagation conditions
- The optimal code depends on the system environment: at low SNRs, using a spectral efficiency >1 bps/Hz, the simplest code (Alamouti with two Tx antennas) is the optimal choice
- Using receive diversity results in larger performance gain than using additional transmit antennas
- When there is a strong line-of-sight component available, signal fading is negligible and space-time coding will not provide any performance gain