Tutorial 11

Resilient Communication Systems
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Space-Time-Block Coding I

RESILIENT COMMUNICATION SYSTEMS

Problem 1

Consider a point-to-point multiple-input single-output (MISO) system. The transmitter is equipped with $N_T = 2$ antennas. The received signal in symbol interval k can be expressed as

$$y[k] = h_1 x_1[k] + h_2 x_2[k] + n[k],$$

where $x_1[k]$ and $x_2[k]$ denote the signal transmitted by antennas 1 and 2, respectively. h_1 and h_2 are the channel gains between transmit antennas 1 and 2 and the receive antenna, respectively. $n[k]$ is zero-mean additive white Gaussian noise (AWGN) with variance σ_n^2. All signals and systems in this problem are in equivalent complex base-band representation. Assume that h_1 and h_2 are not known at the transmitter. Hence, space-time codes are employed for transmission.

1. Name two different types of space-time codes.
2. Assume transmission of QAM symbols $x[k]$. Specify Alamouti's space-time code matrix and show that the transmitted symbols can be independently decoded.
3. For a simple space-time code, the following sets of code-words are available.

$$\text{Code 1: } \mathcal{X}_1 = \left\{ \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix}, \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix} \right\}$$

$$\text{Code 2: } \mathcal{X}_2 = \left\{ \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix}, \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \right\}$$

   Determine the diversity gain of both codes. Which code is preferable? Justify your answer.
4. Sketch a transmitter architecture that can exploit partial CSI knowledge. Determine the optimal beam-forming matrix for both no CSI and perfect CSI cases.

Problem 2

Consider the following space-time-block coding (STBC):

$$\mathbf{X}(\mathbf{s}) = \begin{bmatrix} s_1 & s_2 & s_3 & s_4 \\ -s_2^* & s_1^* & -s_4^* & s_3^* \\ -s_3^* & -s_4^* & s_1^* & s_2^* \\ s_4 & -s_3 & -s_2 & s_1 \end{bmatrix} \tag{1}$$

1. What is the rate of this code?
2. Is it a quasi-orthogonal STBC (QOSTBC)? Justify your answer.
3. With which assumption, the decoding problem reduces to independent scalars detection? Calculate the rate loss by considering this assumption.

Siavash Alamouti

Siavash Alamouti

Siavash Alamouti is a renowned Iranian-American electrical engineer and innovator, best known for his groundbreaking contributions to wireless communication systems, particularly the development of the Alamouti coding scheme. His work has had a profound impact on modern communication technologies, making them more reliable and efficient.

Born in 1962 in Tehran, Iran, Alamouti demonstrated an early aptitude for mathematics and engineering. He pursued his higher education in electrical engineering at the University of British Columbia in Canada, where he earned his Bachelor's and Master's degrees. Alamouti's passion for solving practical problems in communication systems fueled his subsequent innovations in the field.

One of Alamouti's most significant achievements is the development of the Alamouti space-time block code, a simple yet powerful coding technique for MIMO systems. First published in 1998 in the IEEE Journal on Selected Areas in Communications [1], the Alamouti code became a cornerstone of modern wireless communication standards, including 4G LTE and Wi-Fi. This coding scheme enhances signal reliability by improving performance in environments with fading or interference, making it widely adopted in wireless systems worldwide.

Alamouti's career spans academia, industry, and leadership roles in cutting-edge technology companies. He has worked at notable organizations such as Intel, AT&T Wireless, and Vodafone, where he held senior technical and executive positions. His contributions extend beyond the Alamouti code, as he has been involved in advancing various wireless technologies, including MIMO and 5G networks.

In recognition of his pioneering work, Alamouti has received numerous prestigious awards and honors. He was named an IEEE Fellow for his contributions to wireless communication and has received accolades such as the IEEE Eric E. Sumner Award. His work remains highly cited and continues to influence research and development in wireless technology.

Beyond his technical achievements, Alamouti is passionate about bridging the gap between technology and humanity. He is an advocate for using innovation to improve people's lives and has spoken widely about the ethical and social responsibilities of engineers in the modern era.

Siavash Alamouti's legacy lies in his transformative impact on wireless communication systems, where his visionary contributions have shaped the technologies that connect billions of people around the world today.
Read more in Wikipedia and [1].

References

[1] S. Alamouti, "A simple transmit diversity technique for wireless communications," *IEEE Journal on Selected Areas in Communications*, vol. 16, no. 8, pp. 1451–1458, 1998.