

The book cover features a dark, textured background with a central, bright, abstract light effect resembling a lens flare or a tunnel of light rays. The rays are white and grey, radiating from a central point at the top and bottom, creating a sense of depth and movement. The overall aesthetic is modern and technical.

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Next Generation Wireless LANs

802.11n and 802.11ac

SECOND EDITION

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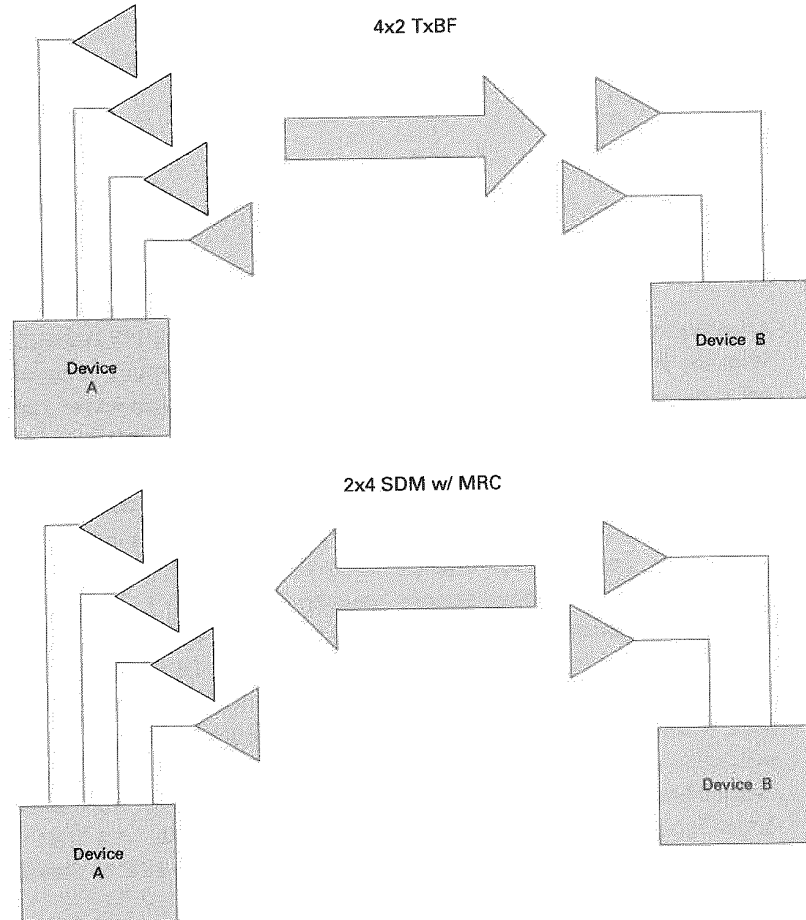


Figure 13.1 System advantage with 4×2 TxBF.

The 802.11n standard does not dictate a specific approach for determining the transmitter weighting matrix. However, the most common approach is using singular value decomposition to calculate the transmitter weights.

13.1 Singular value decomposition

The singular value decomposition (SVD) of the channel matrix H is as follows:

$$H_{N \times M} = U_{N \times N} S_{N \times M} V_{M \times M}^* \quad (13.2)$$

where V and U are unitary matrices, S is a diagonal matrix of singular values, and V^* is the Hermitian (complex conjugate transpose) of V . The definition of a unitary matrix is

Using the property of unitary matrices, we solve for the elements of V as follows:

$$\begin{aligned} \begin{bmatrix} v_1 & v_3 \\ v_2 & v_4 \end{bmatrix} \begin{bmatrix} v_1 & v_2 \\ v_3 & v_4 \end{bmatrix} &= \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \\ \begin{bmatrix} v_1 & v_3 \\ v_1 & -v_3 \end{bmatrix} \begin{bmatrix} v_1 & v_1 \\ v_3 & -v_3 \end{bmatrix} &= \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \\ \begin{bmatrix} v_1^2 + v_3^2 & v_1^2 - v_3^2 \\ v_1^2 - v_3^2 & v_1^2 + v_3^2 \end{bmatrix} &= \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \end{aligned}$$

From $v_1^2 - v_3^2 = 0$, we determine that v_1^2 is equal to v_3^2 . And from $v_1^2 + v_3^2 = 1$, we arrive at the result of $v_1, v_3 = \frac{1}{\sqrt{2}}$. The same steps are taken to solve for the elements of U , which also has the result that $u_1, u_3 = \frac{1}{\sqrt{2}}$. Therefore,

$$\begin{aligned} V &= \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \\ U &= \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \\ S &= \begin{bmatrix} 3 & 0 \\ 0 & 1 \end{bmatrix} \end{aligned}$$

using Eq. (13.2).

Beyond this simple 2×2 example, SVD is computed numerically. LAPACK provides routines to solve SVD (Anderson *et al.*, 1999). The SVD function in Matlab[®] uses LAPACK subroutines.

13.2 Transmit beamforming with SVD

For this section, we assume the transmitter and receiver have full knowledge of the channel state information. Subsequent sections discuss feedback mechanisms to acquire the channel state information. Therefore, given knowledge of H , the matrix V is calculated by SVD according to Eq. (13.2). Subsequently, the first N_{SS} columns of V are used as transmit weights in Eq. (13.1).

The motivation behind using the matrix V calculated by SVD is that it results in maximum likelihood performance with a linear receiver, greatly simplifying receiver design. We prove this as follows.

The maximum likelihood estimate of X from the received signal Y described by Eq. (13.1) is given by the following equation, as discussed in Section 3.7:

$$\hat{X} = \arg \min_X \|Y - H \cdot V \cdot X\| \quad (13.5)$$