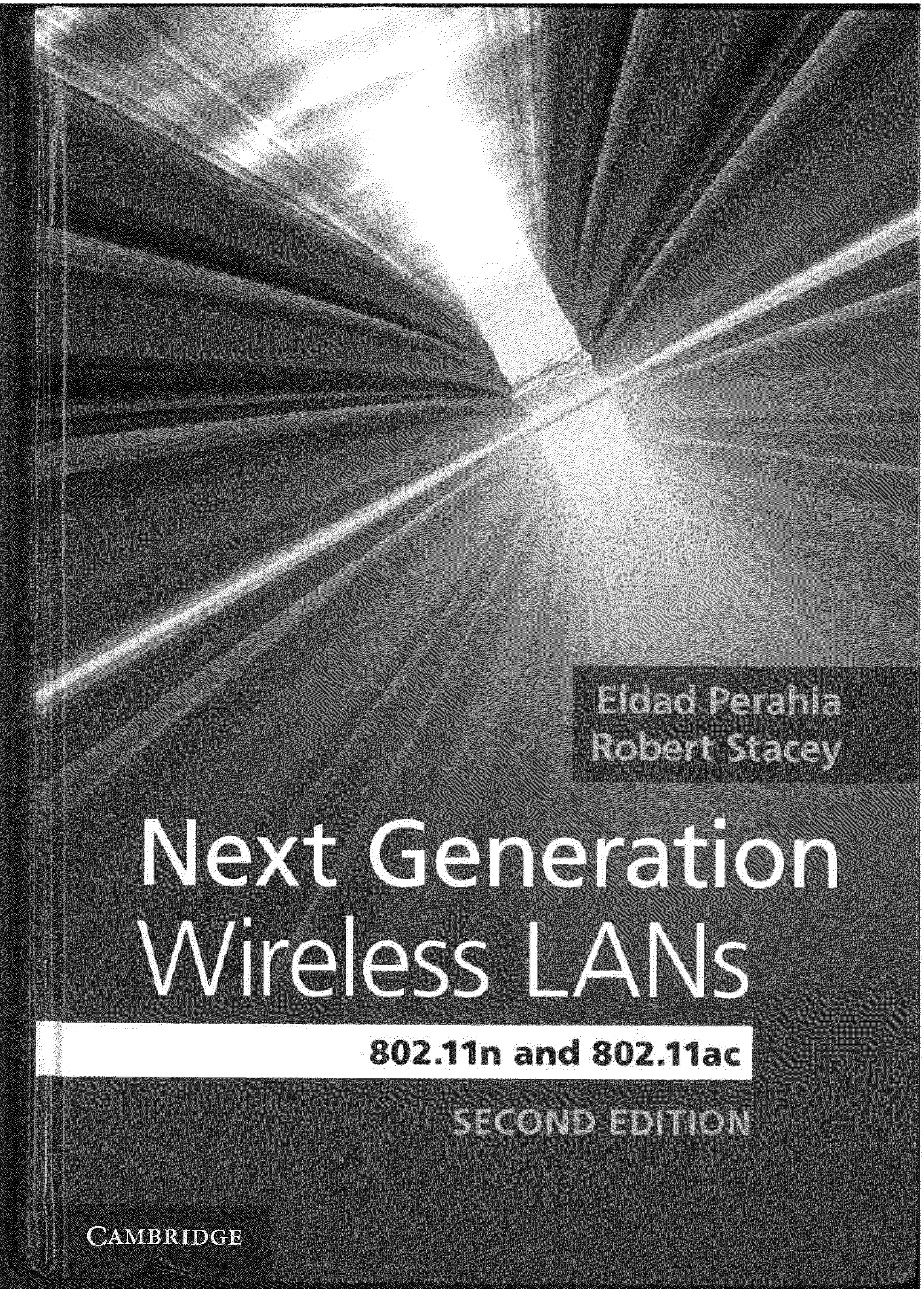

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Next Generation Wireless LANs

802.11n and 802.11ac

SECOND EDITION

CAMBRIDGE

CAMBRIDGE
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781107016767

First published 2008
Reprinted with corrections 2010
Second edition 2013
8th printing 2018

Printed and bound in Great Britain by Clays Ltd, Elcograf S.p.A.

A catalog record for this publication is available from the British Library

Library of Congress Cataloging-in-Publication Data
Perahia, Eldad, 1967 – author.
Next generation wireless LANs : 802.11n, 802.11ac, and Wi-Fi direct / Eldad Perahia, Intel Corporation,
Robert Stacey, Apple Inc. – Second edition.
pages cm
ISBN 978-1-107-01676-7 (hardback)
1. Wireless LANs. I. Stacey, Robert, 1967 – author. II. Title.
TK5105.78.P47 2013
621.39′8–dc23
2012033809

ISBN 978-1-107-01676-7 Hardback

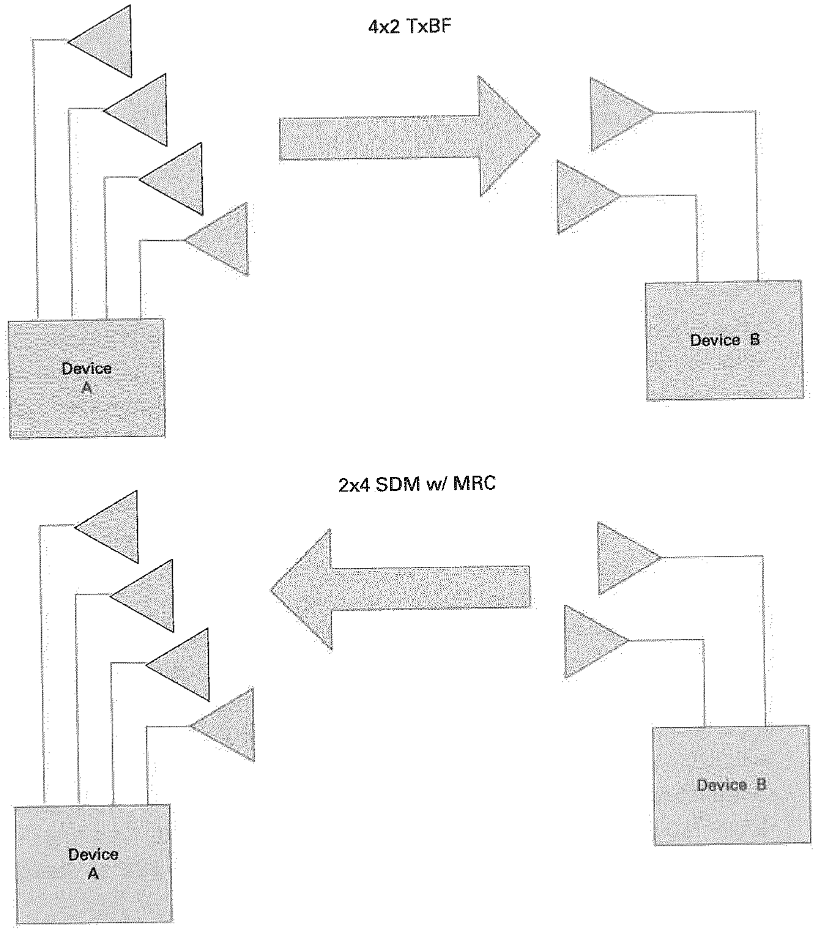

Figure 13.1 System advantage with 4 × 2 TxBF.

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:

$$H_{N\times M} = U_{N\times N} S_{N\times M} V^{*}_{M\times M} \tag{13.2}$$

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:

$$\begin{bmatrix} v_1 & v_3 \\ v_2 & v_4 \end{bmatrix} \begin{bmatrix} v_1 & v_2 \\ v_3 & v_4 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} v_1 & v_3 \\ v_1 & -v_3 \end{bmatrix} \begin{bmatrix} v_1 & v_1 \\ v_3 & -v_3 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

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

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,

$$V = \begin{bmatrix} \frac{-1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} \\ \frac{-1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix}$$

$$U = \begin{bmatrix} \frac{-1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} \\ \frac{-1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix}$$

$$S = \begin{bmatrix} 3 & 0 \\ 0 & 1 \end{bmatrix}$$

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:

$$\hat{X} = \arg\min_{X} \|Y - H \cdot V \cdot X\| \tag{13.5}$$