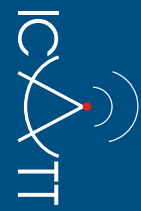




2007
6th International Conference
 on
ANTENNA THEORY
 and
TECHNIQUES

proceedings

Sevastopol, Ukraine
September 17 – 21, 2007



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ICATT'07

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A DUAL-POLARIZATION CHANNELS MODELS OF DIGITAL ANTENNA ARRAYS

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Abstract

This report deals with a compact matrix record of the reception channels responses for the multicoordinate digital beamforming systems with dual-polarization channels of antenna arrays.

Keywords: Digital bearforming, MIMO, N-OFDM, XPI (Cross Polarisation Isolation).

The key technology of modern mobile communications systems is adaptive digital beamforming. When considering the multicoordinate digital beamforming systems with dual-polarization channels of antenna arrays there arises a problem of compact matrix record of the reception channels responses. For the solution of the given problem it is proposed to operate with a special type of the matrices product, named by Slyusar V.I. as "transposed block face-splitting products" [1].

According to the definition [1], for $cs \times bp$ -matrix $A = [A_{ij}]$ and $cg \times bp$ -matrix $B = [B_{ij}]$ ($i = 1, \dots, c$; $j = 1, \dots, b$) their transposed block face-splitting products $A \circ B = [A_{ij} \blacksquare B_{ij}]$, where " \blacksquare " is symbol of Khatri-Rao matrices product.

The example:

$$\left[\begin{array}{c|c} A_{11} & A_{12} \\ \hline A_{21} & A_{22} \end{array} \right] \circ \left[\begin{array}{c|c} B_{11} & B_{12} \\ \hline B_{21} & B_{22} \end{array} \right] = \left[\begin{array}{c|c} A_{11} \blacksquare B_{11} & A_{12} \blacksquare B_{12} \\ \hline A_{21} \blacksquare B_{21} & A_{22} \blacksquare B_{22} \end{array} \right].$$

As an example, the response of flat digital antenna array of MIMO-N-OFDM system with $R \times D$ identical elements and factorized directivity characteristics can be written down through transposed block face-splitting products of matrixes as (without noise):

$$\begin{aligned} U = \begin{bmatrix} U_H \\ U_V \end{bmatrix} &= \left\{ \left[\begin{array}{c|c} \mathbf{Q}_H & \mathbf{q}_{HV} \mathbf{Q}_V \\ \hline \mathbf{q}_{VH} \mathbf{Q}_H & \mathbf{Q}_V \end{array} \right] \circ \left[\begin{array}{c|c} \mathbf{V}_H & \mathbf{d}_{HV} \mathbf{V}_V \\ \hline \mathbf{d}_{VH} \mathbf{V}_H & \mathbf{V}_V \end{array} \right] \circ \left[\begin{array}{c|c} \mathbf{F}_H & \mathbf{F}_V \\ \hline \mathbf{F}_H & \mathbf{F}_V \end{array} \right] \right\} \begin{bmatrix} A_H \\ A_V \end{bmatrix} = \\ &= \left[\begin{array}{c|c} (\mathbf{Q}_H \blacksquare \mathbf{V}_H) \blacksquare \mathbf{F}_H & (\mathbf{q}_{HV} \mathbf{Q}_V \blacksquare \mathbf{d}_{HV} \mathbf{V}_V) \blacksquare \mathbf{F}_V \\ \hline (\mathbf{q}_{VH} \mathbf{Q}_H \blacksquare \mathbf{d}_{VH} \mathbf{V}_H) \blacksquare \mathbf{F}_H & (\mathbf{Q}_V \blacksquare \mathbf{V}_V) \blacksquare \mathbf{F}_V \end{array} \right] \begin{bmatrix} A_H \\ A_V \end{bmatrix}, \quad (1) \end{aligned}$$

where $\begin{bmatrix} A_H \\ A_V \end{bmatrix}$ is a vector of N-OFDM signals [2] amplitude in horizontal (H) and vertical (V) polarization,

$$\mathbf{Q}_H = \begin{bmatrix} Q_{H1}(x_1) & Q_{H1}(x_2) & \dots & Q_{H1}(x_M) \\ Q_{H2}(x_1) & Q_{H2}(x_2) & \dots & Q_{H2}(x_M) \\ \vdots & \vdots & \vdots & \vdots \\ Q_{HR}(x_1) & Q_{HR}(x_2) & \dots & Q_{HR}(x_M) \end{bmatrix},$$

$$\mathbf{Q}_V = \begin{bmatrix} Q_{V1}(x_1) & Q_{V1}(x_2) & \dots & Q_{V1}(x_M) \\ Q_{V2}(x_1) & Q_{V2}(x_2) & \dots & Q_{V2}(x_M) \\ \vdots & \vdots & \vdots & \vdots \\ Q_{VR}(x_1) & Q_{VR}(x_2) & \dots & Q_{VR}(x_M) \end{bmatrix} \text{ is matrix of}$$

a directivity characteristics of primary or secondary channels in azimuth planes H(V)-polarization,

$$\mathbf{V}_H = \begin{bmatrix} V_{H1}(y_1) & V_{H1}(y_2) & \dots & V_{H1}(y_M) \\ V_{H2}(y_1) & V_{H2}(y_2) & \dots & V_{H2}(y_M) \\ \vdots & \vdots & \vdots & \vdots \\ V_{HD}(y_1) & V_{HD}(y_2) & \dots & V_{HD}(y_M) \end{bmatrix},$$

$$\mathbf{V}_V = \begin{bmatrix} V_{V1}(y_1) & V_{V1}(y_2) & \dots & V_{V1}(y_M) \\ V_{V2}(y_1) & V_{V2}(y_2) & \dots & V_{V2}(y_M) \\ \vdots & \vdots & \vdots & \vdots \\ V_{VD}(y_1) & V_{VD}(y_2) & \dots & V_{VD}(y_M) \end{bmatrix} \text{ is matrix}$$

of a directivity characteristics of primary (secondary) channels in elevation angle planes H(V)-polarization,

$$\mathbf{F}_H = \begin{bmatrix} \dot{F}_{H1}(\omega_{H11}) & \dots & \dot{F}_{H1}(\omega_{HT1}) \\ \vdots & \dots & \vdots \\ \dot{F}_{HG}(\omega_{H11}) & \dots & \dot{F}_{HG}(\omega_{HT1}) \end{bmatrix},$$

$$\mathbf{F}_V = \begin{bmatrix} \dot{F}_{V1}(\omega_{V11}) & \dots & \dot{F}_{V1}(\omega_{VT1}) \\ \vdots & \dots & \vdots \\ \dot{F}_{VG}(\omega_{V11}) & \dots & \dot{F}_{VG}(\omega_{VT1}) \end{bmatrix}$$

is matrix of amplitude-frequency characteristics meanings $\dot{F}_{H(V)g}(\omega_{H(V)tm})$ of G FFT-filters for RxD identical reception channels; U - block-matrix of voltages of the responses channels in horizontal (H) and vertical (V) polarization, $\mathbf{q}_{HV}(\mathbf{q}_{VH}), \mathbf{d}_{HV}(\mathbf{d}_{VH})$ - XPI (Cross Polarization Isolation) in azimuth and elevation angle planes, M – number of MIMO-transmitters, T – number of frequencies for one MIMO-transmitter.

In case of non-factorized directivity characteristics the response of flat digital antenna array of MIMO-N-OFDM system can be modified:

$$\mathbf{U} = \begin{bmatrix} \mathbf{U}_H \\ \mathbf{U}_V \end{bmatrix} = \left\{ \left[\begin{array}{c|c} \tilde{\mathbf{Q}}_H & \mathbf{q}_{HV}\tilde{\mathbf{Q}}_V \\ \hline \mathbf{q}_{VH}\tilde{\mathbf{Q}}_H & \tilde{\mathbf{Q}}_V \end{array} \right] \odot \left[\begin{array}{c|c} \mathbf{F}_H & \mathbf{F}_V \\ \hline \mathbf{F}_H & \mathbf{F}_V \end{array} \right] \right\} \begin{bmatrix} \mathbf{A}_H \\ \mathbf{A}_V \end{bmatrix}, \tag{2}$$

where

$$\tilde{\mathbf{Q}}_H = \begin{bmatrix} Q_{H1}(x_1, y_1) & Q_{H1}(x_2, y_2) & \dots & Q_{H1}(x_M, y_M) \\ Q_{H2}(x_1, y_1) & Q_{H2}(x_2, y_2) & \dots & Q_{H2}(x_M, y_M) \\ \vdots & \vdots & \vdots & \vdots \\ Q_{HR}(x_1, y_1) & Q_{HR}(x_2, y_2) & \dots & Q_{HR}(x_M, y_M) \end{bmatrix},$$

$$\tilde{\mathbf{Q}}_V = \begin{bmatrix} Q_{V1}(x_1, y_1) & Q_{V1}(x_2, y_2) & \dots & Q_{V1}(x_M, y_M) \\ Q_{V2}(x_1, y_1) & Q_{V2}(x_2, y_2) & \dots & Q_{V2}(x_M, y_M) \\ \vdots & \vdots & \vdots & \vdots \\ Q_{VR}(x_1, y_1) & Q_{VR}(x_2, y_2) & \dots & Q_{VR}(x_M, y_M) \end{bmatrix}.$$

All proposed models (1), (2) can be used if every transmitter MIMO-systems has the unique set of frequencies.

If all transmitters use the same set of frequencies, then a proposed models should be modified. The alternative for (1) can be written down:

$$\mathbf{U} = \begin{bmatrix} \mathbf{U}_H \\ \mathbf{U}_V \end{bmatrix} = \left\{ \left[\begin{array}{c|c} \mathbf{Q}_H & \mathbf{q}_{HV}\mathbf{Q}_V \\ \hline \mathbf{q}_{VH}\mathbf{Q}_H & \mathbf{Q}_V \end{array} \right] \odot \left[\begin{array}{c|c} \mathbf{V}_H & \mathbf{d}_{HV}\mathbf{V}_V \\ \hline \mathbf{d}_{VH}\mathbf{V}_H & \mathbf{V}_V \end{array} \right] \right\} \begin{bmatrix} \mathbf{F}_H & \mathbf{F}_V \\ \hline \mathbf{F}_H & \mathbf{F}_V \end{bmatrix} \begin{bmatrix} \mathbf{A}_H \\ \mathbf{A}_V \end{bmatrix} =$$

$$= \left[\begin{array}{c|c} (\mathbf{Q}_H \bullet \mathbf{V}_H) \otimes \mathbf{F}_H & (\mathbf{q}_{HV}\mathbf{Q}_V \bullet \mathbf{d}_{HV}\mathbf{V}_V) \otimes \mathbf{F}_V \\ \hline (\mathbf{q}_{VH}\mathbf{Q}_H \bullet \mathbf{d}_{VH}\mathbf{V}_H) \otimes \mathbf{F}_H & (\mathbf{Q}_V \bullet \mathbf{V}_V) \otimes \mathbf{F}_V \end{array} \right] \begin{bmatrix} \mathbf{A}_H \\ \mathbf{A}_V \end{bmatrix},$$

where “[⊗]” is symbol of block Kronecker product of matrices, and for (2) receive:

$$\mathbf{U} = \begin{bmatrix} \mathbf{U}_H \\ \mathbf{U}_V \end{bmatrix} = \left\{ \left[\begin{array}{c|c} \tilde{\mathbf{Q}}_H & \mathbf{q}_{HV}\tilde{\mathbf{Q}}_V \\ \hline \mathbf{q}_{VH}\tilde{\mathbf{Q}}_H & \tilde{\mathbf{Q}}_V \end{array} \right] \right\} [\otimes] \left[\begin{array}{c|c} \mathbf{F}_H & \mathbf{F}_V \\ \hline \mathbf{F}_H & \mathbf{F}_V \end{array} \right] \begin{bmatrix} \mathbf{A}_H \\ \mathbf{A}_V \end{bmatrix} =$$

$$= \left[\begin{array}{c|c} \tilde{\mathbf{Q}}_H \otimes \mathbf{F}_H & \mathbf{q}_{HV}\tilde{\mathbf{Q}}_V \otimes \mathbf{F}_V \\ \hline \mathbf{q}_{VH}\tilde{\mathbf{Q}}_H \otimes \mathbf{F}_H & \tilde{\mathbf{Q}}_V \otimes \mathbf{F}_V \end{array} \right] \begin{bmatrix} \mathbf{A}_H \\ \mathbf{A}_V \end{bmatrix}.$$

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*НАУКОВЕ ВИДАННЯ
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