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National Antenna Association Ukraine

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ANTENNA MEASUREMENTS

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A DUAL-POLARIZATION CHANNELS MODELS OF DIGITAL ANTENNA ARRAYS

[1] Slyusar V. I. and [2] Voloshko S. V.

[1] Central research and development institute of arms and military
Engineering of the Armed Forces of Ukraine, Kiev, Ukraine
E-mail: swadim@inbox.ru, swadim@voliacable.com
[2] Poltava military institute of communications, Poltava, Ukraine

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*×*bp*-matrix $\mathrm{A} = \left[A_{ij}\right]$ and *cg*×*bp*-matrix $\mathrm{B} = \left[B_{ij}\right]$ ($i = 1,\dots,c$; $j = 1,\dots,b$) their transposed block face-splitting products $\mathrm{A} \odot \mathrm{B} = \left[A_{ij} \blacksquare B_{ij}\right]$, where “$\blacksquare$” is symbol of Khatri-Rao matrices product.

The example:

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

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

$$\mathrm{U} = \left[\begin{array}{c} U_H \\ \hline U_V \end{array}\right] = \left\{\left(\left[\begin{array}{c|c} \mathbf{Q_H} & \mathbf{q_{HV} Q_V} \\ \hline \mathbf{q_{VH} Q_H} & \mathbf{Q_V} \end{array}\right] \odot \left[\begin{array}{c|c} \mathbf{V_H} & \mathbf{d_{HV} V_V} \\ \hline \mathbf{d_{VH} V_H} & \mathbf{V_V} \end{array}\right] \odot \left[\begin{array}{c|c} \mathbf{F_H} & \mathbf{F_V} \\ \hline \mathbf{F_H} & \mathbf{F_V} \end{array}\right]\right)\right\} \left[\begin{array}{c} A_H \\ \hline A_V \end{array}\right] =$$

$$= \left[\begin{array}{c|c} (\mathbf{Q_H} \blacksquare \mathbf{V_H}) \blacksquare \mathbf{F_H} & (\mathbf{q_{HV} Q_V} \blacksquare \mathbf{d_{HV} V_V}) \blacksquare \mathbf{F_V} \\ \hline (\mathbf{q_{VH} Q_H} \blacksquare \mathbf{d_{VH} V_H}) \blacksquare \mathbf{F_H} & (\mathbf{Q_V} \blacksquare \mathbf{V_V}) \blacksquare \mathbf{F_V} \end{array}\right] \left[\begin{array}{c} A_H \\ \hline A_V \end{array}\right], \quad (1)$$

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

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

$$\mathbf{Q_V} = \begin{bmatrix} Q_{V1}(x_1) & Q_{V1}(x_2) & \cdots & Q_{V1}(x_M) \\ Q_{V2}(x_1) & Q_{V2}(x_2) & \cdots & Q_{V2}(x_M) \\ \vdots & \vdots & \vdots & \vdots \\ Q_{VR}(x_1) & Q_{VR}(x_2) & \cdots & Q_{VR}(x_M) \end{bmatrix}$$

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

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

$$\mathbf{V_V} = \begin{bmatrix} V_{V1}(y_1) & V_{V1}(y_2) & \cdots & V_{V1}(y_M) \\ V_{V2}(y_1) & V_{V2}(y_2) & \cdots & V_{V2}(y_M) \\ \vdots & \vdots & \vdots & \vdots \\ V_{VD}(y_1) & V_{VD}(y_2) & \cdots & V_{VD}(y_M) \end{bmatrix}$$

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

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$$\mathbf{F_H}=\begin{bmatrix}\dot{F}_{H1}\left(\omega_{H11}\right) & \cdots & \dot{F}_{H1}\left(\omega_{HT1}\right)\\ \vdots & \cdots & \vdots\\ \dot{F}_{HG}\left(\omega_{H11}\right) & \cdots & \dot{F}_{HG}\left(\omega_{HT1}\right)\end{bmatrix},$$

$$\mathbf{F_V}=\begin{bmatrix}\dot{F}_{V1}\left(\omega_{V11}\right) & \cdots & \dot{F}_{V1}\left(\omega_{VT1}\right)\\ \vdots & \cdots & \vdots\\ \dot{F}_{VG}\left(\omega_{V11}\right) & \cdots & \dot{F}_{VG}\left(\omega_{VT1}\right)\end{bmatrix}$$ is matrix of amplitude-frequency characteristics meanings $\dot{F}_{H(V)g}\left(\omega_{H(V)tm}\right)$ of G FFT-filters for R×D identical reception channels; U - block-matrix of voltages of the responses channels in horizontal (H) and vertical (V) polarization,

$\mathbf{q_{HV}}\left(\mathbf{q_{VH}}\right), \mathbf{d_{HV}}\left(\mathbf{d_{VH}}\right)$ - 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:

$$\mathrm{U}=\left[\begin{array}{c}\mathrm{U_H}\\ \hline \mathrm{U_V}\end{array}\right]=\left\{\left[\begin{array}{c:c}\tilde{\mathbf{Q}}_\mathbf{H} & \mathrm{q_{HV}}\tilde{\mathbf{Q}}_\mathbf{V}\\ \hdashline \mathrm{q_{VH}}\tilde{\mathbf{Q}}_\mathbf{H} & \tilde{\mathbf{Q}}_\mathbf{V}\end{array}\right]\boxdot\left[\begin{array}{c:c}\mathbf{F}_\mathrm{H} & \mathbf{F}_\mathrm{V}\\ \hdashline \mathbf{F}_\mathrm{H} & \mathbf{F}_\mathrm{V}\end{array}\right]\right\}\left[\begin{array}{c}\mathrm{A_H}\\ \hdashline \mathrm{A_V}\end{array}\right], \tag{2}$$

where

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

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

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:

$$\mathrm{U}=\left[\begin{array}{c}U_H\\ \hline U_V\end{array}\right]=\left\{\left(\left(\left[\begin{array}{c:c}\mathbf{Q_H} & \mathbf{q_{HV}Q_V}\\ \hdashline \mathbf{q_{VH}Q_H} & \mathbf{Q_V}\end{array}\right]\boxdot\right.\right.\right.$$

$$\left.\left[\begin{array}{c:c}\mathbf{V_H} & \mathbf{d_{HV}V_V}\\ \hdashline \mathbf{d_{VH}V_H} & \mathbf{V_V}\end{array}\right]\right)[\otimes]\left.\left[\begin{array}{c:c}\mathbf{F}_\mathrm{H} & \mathbf{F}_\mathrm{V}\\ \hdashline \mathbf{F}_\mathrm{H} & \mathbf{F}_\mathrm{V}\end{array}\right]\right\}\left[\begin{array}{c}\mathrm{A_H}\\ \hline \mathrm{A_V}\end{array}\right]=$$

$$=\left[\begin{array}{c:c}\left(\mathbf{Q}_\mathrm{H}\blacksquare\mathbf{V}_\mathrm{H}\right)\otimes\mathbf{F}_\mathrm{H} & \left(\mathbf{q}_\mathrm{HV}\mathbf{Q}_\mathrm{V}\blacksquare\mathbf{d}_\mathrm{HV}\mathbf{V}_\mathrm{V}\right)\otimes\mathbf{F}_\mathrm{V}\\ \hdashline \left(\mathbf{q}_\mathrm{VH}\mathbf{Q}_\mathrm{H}\blacksquare\mathbf{d}_\mathrm{VH}\mathbf{V}_\mathrm{H}\right)\otimes\mathbf{F}_\mathrm{H} & \left(\mathbf{Q}_\mathrm{V}\blacksquare\mathbf{V}_\mathrm{V}\right)\otimes\mathbf{F}_\mathrm{V}\end{array}\right]\left[\begin{array}{c}\mathrm{A_H}\\ \hline \mathrm{A_V}\end{array}\right],$$

where "$[\otimes]$" is symbol of block Kronecker product of matrices, and for (2) receive:

$$\mathrm{U}=\left[\begin{array}{c}\mathrm{U_H}\\ \hline \mathrm{U_V}\end{array}\right]=\left\{\left[\begin{array}{c:c}\tilde{\mathbf{Q}}_\mathrm{H} & \mathbf{q}_\mathrm{HV}\tilde{\mathbf{Q}}_\mathrm{V}\\ \hdashline \mathbf{q}_\mathrm{VH}\tilde{\mathbf{Q}}_\mathrm{H} & \tilde{\mathbf{Q}}_\mathrm{V}\end{array}\right][\otimes]\right.$$

$$\left.\left[\begin{array}{c:c}\mathbf{F}_\mathrm{H} & \mathbf{F}_\mathrm{V}\\ \hdashline \mathbf{F}_\mathrm{H} & \mathbf{F}_\mathrm{V}\end{array}\right]\right\}\left[\begin{array}{c}\mathrm{A_H}\\ \hline \mathrm{A_V}\end{array}\right]=$$

$$=\left[\begin{array}{c:c}\tilde{\mathbf{Q}}_\mathrm{H}\otimes\mathbf{F}_\mathrm{H} & \mathbf{q}_\mathrm{HV}\tilde{\mathbf{Q}}_\mathrm{V}\otimes\mathbf{F}_\mathrm{V}\\ \hdashline \mathbf{q}_\mathrm{VH}\tilde{\mathbf{Q}}_\mathrm{H}\otimes\mathbf{F}_\mathrm{H} & \tilde{\mathbf{Q}}_\mathrm{V}\otimes\mathbf{F}_\mathrm{V}\end{array}\right]\left[\begin{array}{c}\mathrm{A_H}\\ \hline \mathrm{A_V}\end{array}\right].$$

REFERENCES

1. Slyusar V. I. A 'Family of Face Products of Matrices and its Properties,' *Cybernetics and Systems Analysis*, 1999, Vol. 35; Part. 3, P. 379-384.
2. Slyusar, V. I. Smolyar, V. G. 'The method of nonorthogonal frequency-discrete modulation of signals for narrow-band communication channels,' *Radio Electronics and Communications Systems C/C of Izvestiia-Vysshie Uchebnye Zavedeniia, Radioelektronika*, 2004, Vol. 47; PART 4, Pages 40-44, Allerton Press Inc. (USA).

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