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: , SMART- , OFDM, N-OFDM,

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[1].

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R_x ,

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(
 R_x^2).

(5-6),

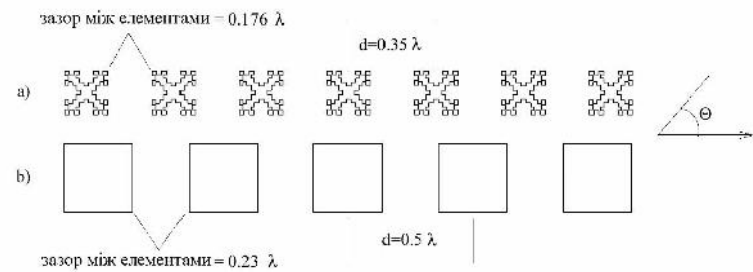
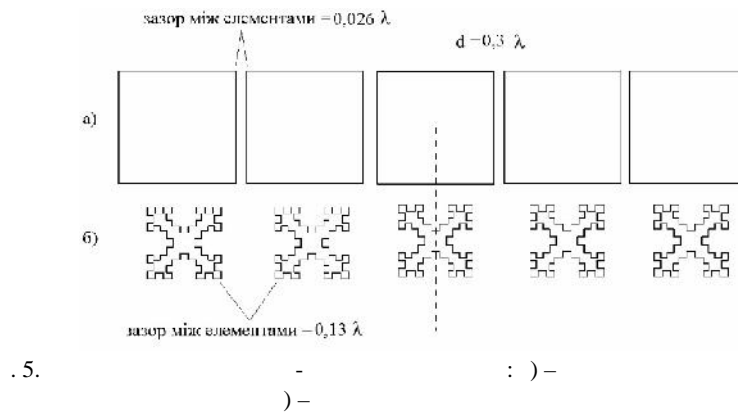
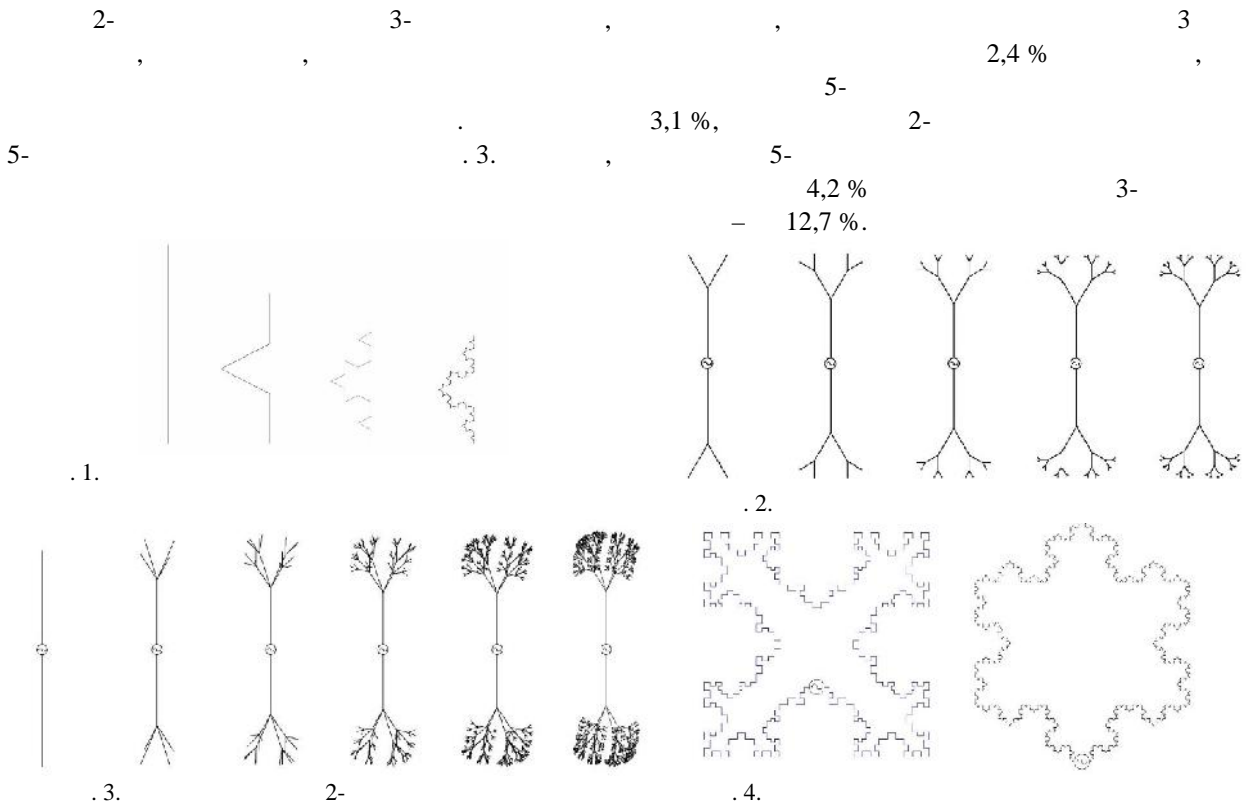
.1

.2.

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7,75

(. 4).

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(), [3, 4]:

$$\tilde{R} = \frac{1}{S} \sum_{s=1}^S \dot{x}_s \dot{x}_s^H, \quad (1)$$

\dot{x}_s -

S -

s-

(1)

$S \geq R_x$ [3],

(4)

$$\tilde{R} = \frac{1}{S} \left(\sum_{s=1}^S \dot{x}_s \right) \left(\sum_{s=1}^S \dot{x}_s \right)^H.$$

[2],

-26,8

$\pm 150^0$

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[4],

-30

x_m

m-

($m = \overline{1, M}$),

()

[8]:

$$F(x_m) = [1 \exp(jx_m) \dots \exp(j(R_x - 1)x_m)]^T, \quad (2)$$

R_x -

x_m -

5-

$R_x \times M$

(),

7

(.6).

(2)

[3]:

$$F_H = [F(x_0) \dots F(x_m) \dots F(x_{M-1})], \quad (3)$$

, m-

m-

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[2].

SMART-

[3, 4],

:

$$H(x) = F_H^H \tilde{R} F_H, \quad (4)$$

$H(x)$ -

m-

x -

(

:

F_H -

(),

$$\mathbf{X}, \mathbf{H}$$

(4),

[3]:

$$\hat{\mathbf{X}} = \arg \max_{\mathbf{X}} [\mathbf{F}_H^H \tilde{\mathbf{R}} \mathbf{F}_H], \quad (5)$$

$$\hat{\mathbf{X}} = (\hat{\mathbf{X}}_1 \hat{\mathbf{X}}_2 \dots \hat{\mathbf{X}}_m \dots \hat{\mathbf{X}}_M)^T$$

[4]-

[3]:

$$\hat{\mathbf{X}}_K = \arg \max_{\mathbf{X}} \left[\left(\mathbf{F}_H^H \tilde{\mathbf{R}}^{-1} \mathbf{F}_H \right)^{-1} \right]. \quad (6)$$

[4].

[3]:

$$\hat{\mathbf{X}}_{ME} = \arg \max_{\mathbf{X}} \left[\left(\mathbf{F}_H^H \tilde{\mathbf{R}}^{-1} \right)^{-1} \right], \quad (7)$$

k -

k-

$$\left(\right)^k$$

k-

[4],

$$E \left\{ \hat{x}_k - \sum_{s=1(s \neq k)}^S \hat{x}_s \right\} \rightarrow \min, \quad (8)$$

E{ } -

(7)

k ·

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[4]).

[3, 4].

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[3],

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[3]:

$$\hat{\mathbf{X}}_M = \arg \max_{\mathbf{X}} \left[\left(\mathbf{R}_x - \mathbf{F}_H^H \sum_{m=1}^M \mathbf{g}_m \mathbf{g}_m^H \mathbf{F}_H \right)^{-1} \right], \quad (9)$$

\mathbf{g}_m -

()

[3]:

$$\hat{\mathbf{X}}_M = \arg \max_{\mathbf{X}} \left[\left(\mathbf{F}_H^H \sum_{r=1+M}^{\mathbf{R}_x} \mathbf{g}_r \mathbf{g}_r^H \mathbf{F}_H \right)^{-1} \right], \quad (10)$$

\mathbf{g}_r -

()

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[4]

$$\hat{\mathbf{X}} = \arg \max_{\mathbf{X}} \left[\text{tr} \left(\tilde{\mathbf{F}}_H \left(\tilde{\mathbf{F}}_H^H \tilde{\mathbf{F}}_H \right)^{-1} \tilde{\mathbf{F}}_H^H \tilde{\mathbf{R}} \right) \right], \quad (11)$$

$\tilde{\mathbf{F}}_H$ -

\mathbf{F}_H .

[3], (11)

[4].

(5)

[4].

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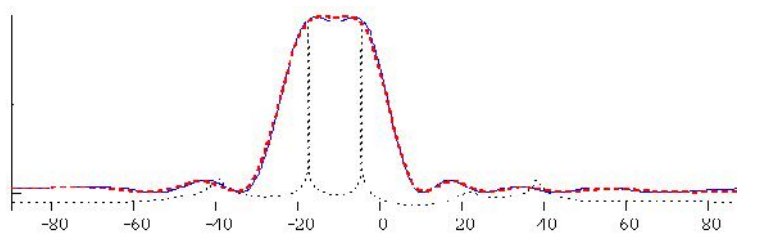
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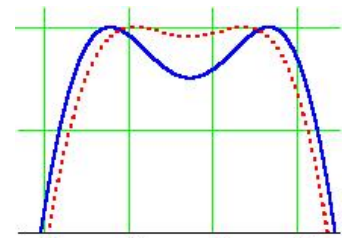
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.7. 6

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(M ≤ R_x), m-

(m = 1, M)

x_m (x_m -

$$U'' = \tilde{P}A, \tag{12}$$

$$\tilde{P} = F_H'' \otimes \tilde{V}(f_{11\dots M}),$$

$$U'' = [U_{11} \dots U_{1S} \mid \dots \mid U_{R_x 1} \dots U_{R_x S}]^T -$$

$$F_H'' = \begin{bmatrix} F_1(x_1) \\ \vdots \\ F_{R_x}(x_1) \end{bmatrix}, \tilde{V}(f_{11\dots M}) = \begin{bmatrix} \tilde{V}_1(f_{11}) & \dots & \tilde{V}_1(f_{1M}) \\ \vdots & \ddots & \vdots \\ \tilde{V}_S(f_{11}) & \dots & \tilde{V}_S(f_{1M}) \end{bmatrix},$$

$$\tilde{V}(f_{11\dots M}) -$$

$$x_1. \tag{12}$$

$$U''' = \tilde{P}'''A, \tag{13}$$

$$\tilde{P}''' = F_H''' \otimes \tilde{V}(f_{21\dots M}), F_H''' = \begin{bmatrix} F_1(x_2) \\ \vdots \\ F_{R_x}(x_2) \end{bmatrix},$$

$$\tilde{V}(f_{21\dots M}) = \begin{bmatrix} \tilde{V}_1(f_{21}) & \dots & \tilde{V}_1(f_{2M}) \\ \vdots & \ddots & \vdots \\ \tilde{V}_S(f_{21}) & \dots & \tilde{V}_S(f_{2M}) \end{bmatrix},$$

$$U''' = [U_{11} \dots U_{1S} \mid \dots \mid U_{R_x 1} \dots U_{R_x S}]^T -$$

$$, A - , F_H''' - , \tilde{V}(f_{21\dots M}) -$$

$$(12) (13) R_x -$$

$$U = PA, \tag{14}$$

$$P = [F_H'' \otimes \tilde{V}(f_{11\dots M}) \mid F_H''' \otimes \tilde{V}(f_{21\dots M})],$$

$$U = [U_{11} \dots U_{1S} \mid \dots \mid U_{R_x 1} \dots U_{R_x S}]^T,$$

$$A = [\hat{a}_{11} \hat{a}_{12} \dots \hat{a}_{1M} \mid \hat{a}_{21} \hat{a}_{22} \dots \hat{a}_{2M}]^T,$$

$$\hat{a}_{11\dots M}, \hat{a}_{21\dots M} -$$

$$(14)$$

OFDM (N-OFDM) [5].

$$U = PA = ([F_H] [\otimes] [\tilde{V}])A = \begin{bmatrix} F_1(x_1) & F_1(x_2) \\ \vdots & \vdots \\ F_{R_x}(x_1) & F_{R_x}(x_2) \end{bmatrix} [\otimes], \quad (15)$$

$$[\otimes] \begin{bmatrix} \tilde{V}_1(f_{11}) & \dots & \tilde{V}_1(f_{1M}) & \tilde{V}_1(f_{21}) & \dots & \tilde{V}_1(f_{2M}) \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \tilde{V}_S(f_{11}) & \dots & \tilde{V}_S(f_{1M}) & \tilde{V}_S(f_{21}) & \dots & \tilde{V}_S(f_{2M}) \end{bmatrix} A,$$

$$\hat{A} = (P^H P)^{-1} P^H U. \quad (18)$$

N-OFDM (OFDM)

$$P = \begin{bmatrix} F_1(x_1)\tilde{V}1 & F_1(x_2)\tilde{V}2 \\ \vdots & \vdots \\ F_{R_x}(x_1)\tilde{V}1 & F_{R_x}(x_2)\tilde{V}2 \end{bmatrix}, \quad (16)$$

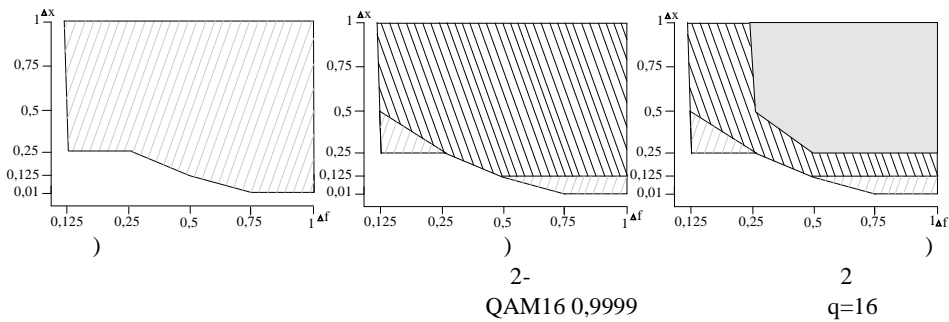
$$\tilde{V}1 = \begin{bmatrix} \tilde{V}_1(f_{11}) & \dots & \tilde{V}_1(f_{1M}) \\ \vdots & \ddots & \vdots \\ \tilde{V}_S(f_{11}) & \dots & \tilde{V}_S(f_{1M}) \end{bmatrix}, \quad \tilde{V}2 = \begin{bmatrix} \tilde{V}_1(f_{21}) & \dots & \tilde{V}_1(f_{2M}) \\ \vdots & \ddots & \vdots \\ \tilde{V}_S(f_{21}) & \dots & \tilde{V}_S(f_{2M}) \end{bmatrix}.$$

(15),

[3]:

$$L = \{U - P\hat{A}\}^H \{U - P\hat{A}\} \rightarrow \min, \quad (17)$$

$$U = [U_{11} \dots U_{1S} \dots U_{R_x 1} \dots U_{R_x S}]^T,$$



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QAM16 0,9999

q=16

QAM16.

QAM64 (

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QAM256 (

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 2. . 62-65.
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 [4], 3. . . .
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[5].

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OFDM, N-OFDM,

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MODEL OF SPATIAL-FREQUENCY SIGNAL PROCESSING IN SMART-ANTENNAS ON FRACTAL BASIS

V.E. Hrebelia, V.P. Volchikov, I.I. Slyusar

The paper identifies particular variants of spatial-frequency processing of signals in systems with a SMART-antennas using antenna elements on the basis of fractal structures.

Keywords: spatial-frequency signal processing, OFDM, N-OFDM, digital beamforming, chart line of industry, SMART-antenna, fractal.