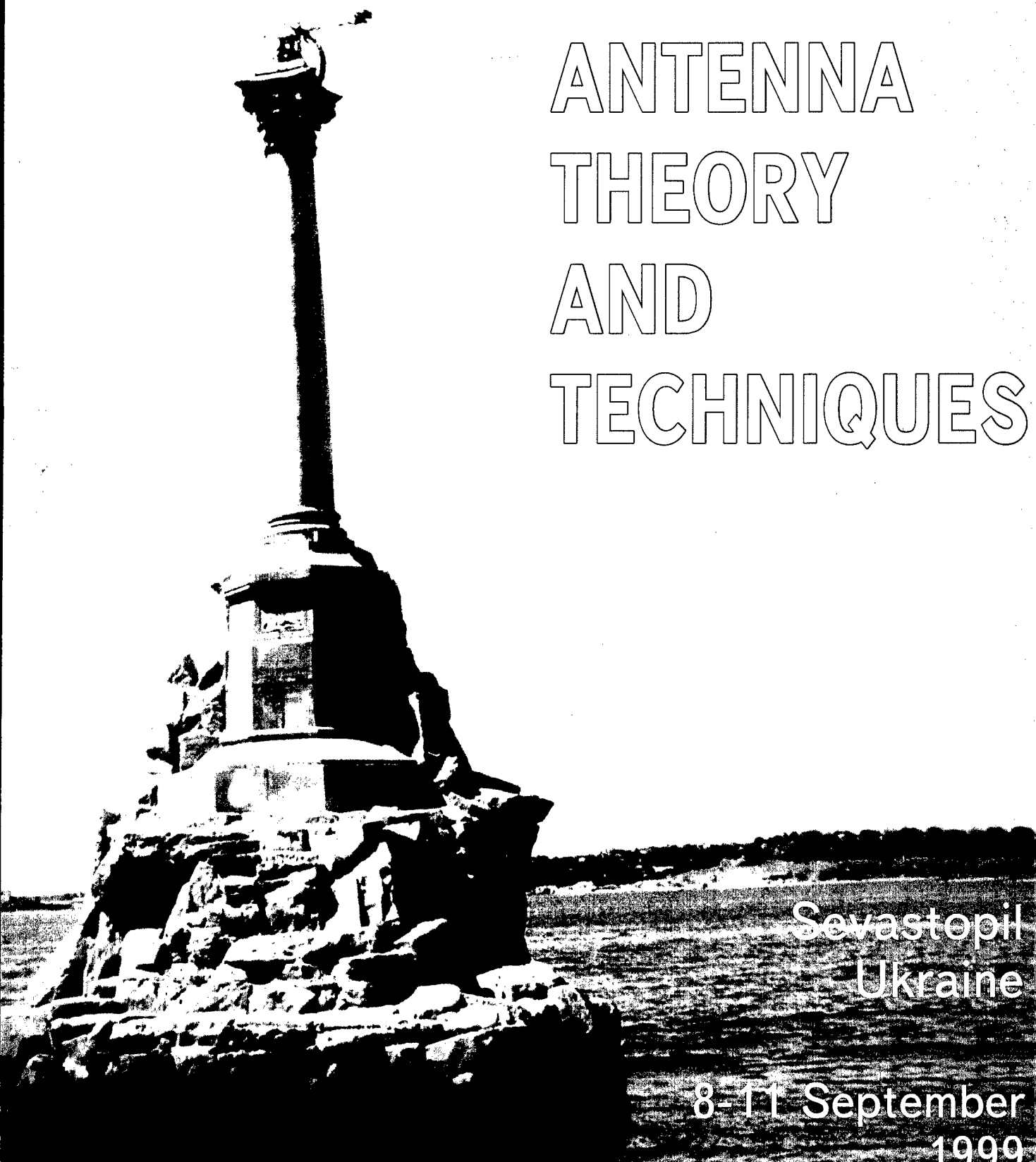




Proceedings of 11th International Conference

ANTENNA THEORY AND TECHNIQUES



Sevastopol
Ukraine

8-11 September
1999

Third International Conference on

Antenna Theory and Techniques

8-11 September 1999

Organizers

National Antenna Association of Ukraine

National Technical University of Ukraine "Kyiv Polytechnic Institute"

IEEE AP/MTT/AES/ED/LEO/GRS-SS East Ukraine Joint Chapter

Sevastopol State Technical University

Venue

20000113 105

Sevastopol State Technical University

Sevastopol, Ukraine

CO-ORGANIZERS AND CO-SPONSORS

STATE COMMITTEE OF UKRAINE ON SCIENCE AND INTELLECTUAL PROPERTY

KHARKIV TECHNICAL UNIVERSITY OF RADIO ELECTRONICS

TERA LTD. (KYIV)

COMPANY "VEBER" (SEVASTOPIL)

ROMSAT LTD. (KYIV)

TERNOPIL STATE DESIGN BUREAU "PROMIN" (TERNOPIL)

*We wish to thank the following for their contribution
to the success of this Conference:*

IEEE REGION 8 OFFICE

US AIR FORCE EUROPEAN OFFICE OF AEROSPACE R&D

OFFICE OF NAVAL RESEARCH INTERNATIONAL FIELD OFFICE

Proceedings of the Third International Conference on Antenna Theory and Techniques
ISBN 966-622-012-1

This material is based upon work supported by the European Office of Aerospace Research and Development,
Airforce Office of Scientific Research, Airforce Research Laboratory under Contract No. F 61775-99-WF071.

This work relates to Department of the Navy Grant N 00014-99-1-1033 issued by the Office of Naval Research
International Field Office. The United States has a royalty-free license throughout the world in all
copyrightable material contained herein.

ANTENNA ARRAYS

- 204 **Underground phased antenna arrays as alternative to mast aerials of receiving radio**
S. M. Alekseev, A. V. Makaseev, A. G. Poshkov, B. V. Sosunov, N. G. Fitenko (St. Petersburg, Russia)
- 206 **The analytical approach to the computing of resonance effects for the diffraction at well reflecting gratings**
N. A. Balakhonova, A. V. Kats, I. S. Spevak (Kharkiv, Ukraine)
- 209 **Two-dimensional image retrieval**
K. P. Gaikovich, A. V. Zhilin (Nizhny Novgorod, Russia)
- 212 **Active phased antenna arrays radiating LFM pulse packet**
V. L. Gostuykhin, V. N. Trusov, A. V. Gostuykhin (Moscow, Russia)
- 214 **Limiting resolution of Capon method for correlated sources**
A. A. Kirillov, G. V. Serebryakov (Nizhny Novgorod, Russia)
- 217 **The accuracy of joint estimation of signal parameters of the antenna arrays in the case of non-gaussian interference**
Y. P. Kunchenko, V. A. Danyk, T. V. Prokopenko (Cherkassy, Ukraine)
- 219 **Apodization functions for antenna arrays with constructive-technological restrictions**
V. V. Lukin, A. V. Kabanov, N. N. Ponomarenko (Kharkiv, Ukraine)
- 222 **Coherence-reduced signal processing in large arrays**
A. Malekhanov (Nizhny Novgorod, Russia)
- 225 **Power optimization of the beam shared-forming monopulse arrays**
B. D. Manuilov, P. N. Bashly (Rostov-on-Don, Russia)
- 228 **Diagnostics of receiving hydroacoustic antenna arrays**
D. A. Orlov And V. I. Turchin (Nizhny Novgorod, Russia)
- 230 **Simulation of antenna array characteristics impact on objects image restoration**
I. Prudyus, L. Lazko, T. Holotyak (Lviv, Ukraine)
- 233 **Simulation of spatial-time signal processing in imaging systems with synthetic aperture**
I. N. Prudyus, A. T. Synyavskyy, V. P. Ostap (Lviv, Ukraine)
- 237 **Optically or electronically steerable mm-wave phased antennas array based on semiconductor structure**
V. Ya. Rogov, A. Yu. Grinev, A. E. Zaikin (Moscow, Russia)
- 239 **Pattern synthesis of antenna array with digital phase shifters**
N. V. Shcherbakov, I. V. Norinchuk (Kharkiv, Ukraine)
- 241 **The matrix models of digital antenna arrays with nonidentical channels**
V. I. Slyusar (Kyiv, Ukraine)
- 244 **A way of correction of DAA receiving channels characteristics using the heterodyne signal**
V. I. Slyusar (Kyiv, Ukraine)
- 246 **Analysis of the effect of geometric parameters of nonequidistant antenna array with unequal amplitude distribution on its working frequencies range**
S. I. Starchenko, A. Yu. Milovanov, I. V. Pleshivtsev (Tambov, Russia)

Ogorodnijchuk L. D.	461, 464	Samokhvalov A.	145
Omarov M. A.	547	Santachiara V.	46
Onufrienko V. M.	131, 160	Savchenko A. N.	350
Orlenko A. A.	133	Savelyev A. N.	290
Orlov D. A.	228	Savenko P.	135, 187
Orlova L. V.	324	Savochkin A. A.	198
Ostap V. P.	233	Sazonov D. M.	69, 480
Ovsyanikov V. V.	341, 541	Schekaturin A. A.	435
Panchenko A. Y.	496	Sedelnikov I. E.	550
Panteleev A. V.	374	Sedelnikov Y. E.	553
Parkhomenko M. P.	520	Sedyshev P. Y.	293
Pasnak L.	135	Sedyshev Y. N.	72, 293
Peretyatko T. V.	108	Seleznyov A. V.	348
Perfilov O. Ju.	423	Semenikhina D. V.	526
Perov A. O.	395	Serebryakov G. V.	214
Petrov B. M.	432	Sestroretsky B. V.	350, 528
Petrusenko I. V.	539, 541	Sevsky S. V.	562
Phomushkin S. P.	176	Shatrov A. D.	122
Pivnenko S. N.	119, 387	Shatskiy V. V.	162, 358
Plahov Y. M.	127, 129	Shcherbakov A. S.	534
Platonov S. Y.	95	Shcherbakov N. V.	239
Pleshivtsev I. V.	246	Shehalev M. A.	85
Pochanin G. P.	392	Shifrin Y. S.	148, 297, 468
Podlevskiy B.	187	Shigesawa H.	80
Poedinchuk A. Ye.	368	Shishkova A. V.	324
Poldin O. V.	284	Shmat'ko A. A.	498
Polyakov S. Y.	282	Shokalo V. M.	148, 559, 562
Polyarus A. V.	138	Shostko I. S.	565
Ponomarenko N. N.	219	Shostko O. S.	565
Ponomarev L. I.	140	Shostko S. N.	565
Popovsky V. V.	276	Shrenk A. E.	400
Porshnev S. V.	465	Shumljansky I. I.	304, 326
Poshkov A. G.	204	Shvelidze R. R.	363
Posniy O. A.	335	Sibruk L. V.	453, 573
Potapova O. V.	553	Silaev A. M.	284
Prokopenko T. V.	217	Sirenko Yu. K.	395
Protsenko M. B.	335, 344, 346	Sivov A. N.	122
Prudyus I. N.	230, 233	Slyozkin V. G.	331
Pynylo V. S.	201	Slyusar V. I.	241, 244
Radtzig Yu. Yu.	143, 311, 413	Smirnov S. A.	104
Razdorkin D. Y.	190	Smirnov Yu. G.	150
Rensh Y. A.	397	Sokolov A.	299, 301, 410
Repa F. M.	568	Sosunov B. V.	204
Robert B.	46	Spevak I. S.	206
Rodyushkin K. V.	269	Starchenko S. I.	246
Rogov V. Ya.	237	Stepanenko P. Ya.	492
Romanenko M. V.	190	Stepanov A. S.	173
Rosa A.	46	Stepanov L. N.	353
Rozvadovsky A. F.	337	Sukharevsky I. V.	408
Rud' L. A.	499, 502, 522	Sukharevsky O. I.	152
Rudakov V. I.	192, 195, 556	Synepoop A. V.	248
Russo P.	46	Synyavskyy A. T.	233
Ryabuha V. P.	266	Syrotyuk V. H.	201
Ryabukhin A. A.	496	Talalaevskii V. M.	515
Rybalko A. M.	248, 562	Tankov I. V.	346
Sadekov T. A.	3, 482, 487	Tarasov V. B.	1
Saltykov D. Yu.	312, 571	Tarshin V. A.	266
		Terent'ev J. M.	155
		Tereshchenko V. M.	382

THE MATRIX MODELS OF DIGITAL ANTENNA ARRAYS WITH NONIDENTICAL CHANNELS

V. I. Slyusar

Central Research and Development Institute of Armament and Military Engineering
Kiev, Andruschenko Street, 4, e-mail: swadim@777.com.ua

The modern technology of radar and mobile communications systems is adaptive digital beam forming. When considering the multicoordinate digital beam forming in radar and communication systems with nonidentical channels of antenna arrays there is a problem of compact matrix record of the receiving channels responses. To solve the given problem it is proposed to operate with a special type of the matrices product, named by the author as "penetrated" and "generalized face-splitting" products.

According to the definition [1], for $p \times g$ -matrix A and $p \times gn$ -matrix B with $p \times g$ -blocks ($B = [B_n]$) their penetrated face-splitting product $A \boxtimes B$ is the $p \times gn$ -block-matrix $[A \circ B_n]$, where " \circ " - a symbol of Adamar splitting, B_n — is a $p \times g$ -block of matrix B :

$$A \boxtimes B = [A \circ B_1 | A \circ B_2 | \dots | A \circ B_n | \dots] \text{ or } A \boxtimes B = \begin{bmatrix} A \circ B_1 \\ A \circ B_2 \\ \vdots \\ A \circ B_n \\ \vdots \end{bmatrix}$$

The example:

$$A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \\ a_{31} & a_{32} \end{bmatrix}, \quad B = \begin{bmatrix} B_1 \\ B_2 \\ B_3 \end{bmatrix} =$$

$$= \begin{bmatrix} b_{111} & b_{121} \\ b_{211} & b_{221} \\ b_{311} & b_{321} \\ b_{112} & b_{122} \\ b_{212} & b_{222} \\ b_{312} & b_{322} \\ b_{113} & b_{123} \\ b_{213} & b_{223} \\ b_{313} & b_{323} \end{bmatrix}, \quad A \boxtimes B = \begin{bmatrix} a_{11} \cdot b_{111} & a_{12} \cdot b_{121} \\ a_{21} \cdot b_{211} & a_{22} \cdot b_{221} \\ a_{31} \cdot b_{311} & a_{32} \cdot b_{321} \\ a_{11} \cdot b_{112} & a_{12} \cdot b_{122} \\ a_{21} \cdot b_{212} & a_{22} \cdot b_{222} \\ a_{31} \cdot b_{312} & a_{32} \cdot b_{322} \\ a_{11} \cdot b_{113} & a_{12} \cdot b_{123} \\ a_{21} \cdot b_{213} & a_{22} \cdot b_{223} \\ a_{31} \cdot b_{313} & a_{32} \cdot b_{323} \end{bmatrix}$$

As an example, the response of three-coordinate flat digital antenna array of $R \times R$ elements can be written down through penetrated face-splitting product of matrices as (without noise):

$$U = \dot{a} \cdot (Q \boxtimes F) = \dot{a} \cdot [Q \circ F_1 | Q \circ F_2 | \dots | Q \circ F_r | \dots],$$

where \dot{a} — is a complex signal amplitude,

$$Q = \begin{bmatrix} \dot{Q}_{11}(x, y) & \dot{Q}_{12}(x, y) & \dots & \dot{Q}_{1R}(x, y) \\ \dot{Q}_{21}(x, y) & \dot{Q}_{22}(x, y) & \dots & \dot{Q}_{2R}(x, y) \\ \vdots & \vdots & \ddots & \vdots \\ \dot{Q}_{R1}(x, y) & \dot{Q}_{R2}(x, y) & \dots & \dot{Q}_{RR}(x, y) \end{bmatrix}$$

is the matrix of the directivity characteristics of primary channels in azimuth and elevation angle planes (can not be factorized),

$$F = \begin{bmatrix} \dot{F}_{111}(\omega) & \dots & \dot{F}_{1R1}(\omega) & \vdots & \dot{F}_{11G}(\omega) & \dots & \dot{F}_{1RG}(\omega) \\ \vdots & \dots & \vdots & \ddots & \vdots & \dots & \vdots \\ \dot{F}_{R11}(\omega) & \dots & \dot{F}_{RR1}(\omega) & \vdots & \dot{F}_{R1G}(\omega) & \dots & \dot{F}_{RRG}(\omega) \end{bmatrix}$$

is the block-matrix of amplitude-frequency characteristics meanings $\dot{F}_{nmG}(\omega)$ of G filters for $R \times R$ nonidentical receiving channels ($\dot{F}_{11G}(\omega) \neq \dot{F}_{rG}(\omega)$);

$$Q \circ F_g = \begin{bmatrix} \dot{Q}_{11}(x, y) \dot{F}_{11g}(\omega) & \dots & \dot{Q}_{1R}(x, y) \dot{F}_{1Rg}(\omega) \\ \dot{Q}_{21}(x, y) \dot{F}_{21g}(\omega) & \dots & \dot{Q}_{2R}(x, y) \dot{F}_{2Rg}(\omega) \\ \vdots & \vdots & \vdots \\ \dot{Q}_{R1}(x, y) \dot{F}_{R1g}(\omega) & \dots & \dot{Q}_{RR}(x, y) \dot{F}_{RRg}(\omega) \end{bmatrix}$$

U — block-matrix of voltages of the channels responses.

To select a single source on four coordinates (azimuth, elevation angle, frequency and range) the response of digital antenna array can be written down through generalized face-splitting product or generalized transposed face-splitting product (the theory of face-splitting products is presented in [1-4]). According to the definition, for block-matrices $A = [A_{ij}]$ and $B = [B_{ig}]$ with $p \times g$ - blocks their generalized face-splitting product $A \boxtimes B$ is the block-matrix

$$[A_{ij} \boxtimes [B_{i1} \ B_{i2} \ \dots \ B_{ig} \ \dots]]$$

The example:

$$A \boxtimes B = \begin{bmatrix} A_{11} & A_{12} & \dots & A_{1T} \\ A_{21} & A_{22} & \dots & A_{2T} \\ \vdots & \vdots & \ddots & \vdots \\ A_{P1} & A_{P2} & \dots & A_{PT} \end{bmatrix} \boxtimes \begin{bmatrix} B_{11} & B_{12} & \dots & B_{1G} \\ B_{21} & B_{22} & \dots & B_{2G} \\ \vdots & \vdots & \ddots & \vdots \\ B_{P1} & B_{P2} & \dots & B_{PG} \end{bmatrix} =$$

$$= \begin{bmatrix} A_{11} \boxtimes [B_{11} \ \dots \ B_{1G}] & \vdots & A_{1T} \boxtimes [B_{11} \ \dots \ B_{1G}] \\ A_{21} \boxtimes [B_{21} \ \dots \ B_{2G}] & \vdots & A_{2T} \boxtimes [B_{21} \ \dots \ B_{2G}] \\ \vdots & \ddots & \vdots \\ A_{P1} \boxtimes [B_{P1} \ \dots \ B_{PG}] & \vdots & A_{PT} \boxtimes [B_{P1} \ \dots \ B_{PG}] \end{bmatrix}$$

The alternative to the above considered is a generalized transposed face-splitting block-matrices product:

$$A \tilde{\square} B = \begin{bmatrix} A_{ij} \square & \begin{bmatrix} B_{1j} \\ B_{2j} \\ \vdots \\ B_{Gj} \end{bmatrix} \end{bmatrix}$$

For example, it can be written down:

$$A \tilde{\square} B = \begin{bmatrix} A_{11} & A_{12} & \dots & A_{1T} \\ A_{21} & A_{22} & \dots & A_{2T} \\ \vdots & \vdots & \dots & \vdots \\ A_{P1} & A_{P2} & \dots & A_{PT} \end{bmatrix} \tilde{\square} \begin{bmatrix} B_{11} & B_{12} & \dots & B_{1G} \\ B_{21} & B_{22} & \dots & B_{2G} \\ \vdots & \vdots & \dots & \vdots \\ B_{P1} & B_{P2} & \dots & B_{PG} \end{bmatrix} =$$

$$= \begin{bmatrix} \begin{bmatrix} A_{11} \square & \begin{bmatrix} B_{11} \\ B_{21} \\ \vdots \\ B_{P1} \end{bmatrix} \end{bmatrix} & \begin{bmatrix} A_{12} \square & \begin{bmatrix} B_{12} \\ B_{22} \\ \vdots \\ B_{P2} \end{bmatrix} \end{bmatrix} & \dots & \begin{bmatrix} A_{1T} \square & \begin{bmatrix} B_{1G} \\ B_{2G} \\ \vdots \\ B_{PG} \end{bmatrix} \end{bmatrix} \\ \vdots & \vdots & \dots & \vdots \\ \begin{bmatrix} A_{P1} \square & \begin{bmatrix} B_{11} \\ B_{21} \\ \vdots \\ B_{P1} \end{bmatrix} \end{bmatrix} & \begin{bmatrix} A_{P2} \square & \begin{bmatrix} B_{12} \\ B_{22} \\ \vdots \\ B_{P2} \end{bmatrix} \end{bmatrix} & \dots & \begin{bmatrix} A_{PT} \square & \begin{bmatrix} B_{1G} \\ B_{2G} \\ \vdots \\ B_{PG} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

The response of four-coordinate flat digital antenna array with R×R nonidentical channels can be present as (without noise):

$$U = (Q \square \{ \tilde{\square} F \}) \cdot \dot{a} = Q \square [S_1 \square F \mid S_2 \square F \mid \dots \mid S_T \square F] \cdot \dot{a},$$

where

$$S = \begin{bmatrix} S_{111}(z) & \dots & S_{1R1}(z) & \mid & S_{11T}(z) & \dots & S_{1RT}(z) \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ S_{R11}(z) & \dots & S_{RR1}(z) & \mid & S_{R1T}(z) & \dots & S_{RRT}(z) \end{bmatrix}$$

is the matrix of the responses of single signal in T range gates (all channels have nonidentical radio impulse curve $S_{11t}(\omega) \neq S_{irt}(\omega)$).

The alternate to considered above variant of analytical model of four-coordinate radar with flat digital antenna array is

$$U = (Q \square \{ \tilde{\square} \tilde{F} \}) \cdot \dot{a} = Q \square \begin{bmatrix} S_1 \square \tilde{F} \\ \vdots \\ S_T \square \tilde{F} \end{bmatrix} \cdot \dot{a},$$

where

$$\tilde{S} = S^R = [S_1 \mid \dots \mid S_T]^R = \begin{bmatrix} S_1 \\ \vdots \\ S_2 \end{bmatrix} = \begin{bmatrix} S_{111}(z) & \dots & S_{1R1}(z) \\ \vdots & \vdots & \vdots \\ S_{R11}(z) & \dots & S_{RR1}(z) \\ \vdots & \vdots & \vdots \\ S_{11T}(z) & \dots & S_{1RT}(z) \\ \vdots & \vdots & \vdots \\ S_{R1T}(z) & \dots & S_{RRT}(z) \end{bmatrix}$$

$$\tilde{F} = F^R = [F_1 \mid \dots \mid F_G]^R = \begin{bmatrix} F_1 \\ \vdots \\ F_2 \end{bmatrix} = \begin{bmatrix} F_{111}(\omega) & \dots & F_{1R1}(\omega) \\ \vdots & \vdots & \vdots \\ F_{R11}(\omega) & \dots & F_{RR1}(\omega) \\ \vdots & \vdots & \vdots \\ F_{11G}(\omega) & \dots & F_{1RG}(\omega) \\ \vdots & \vdots & \vdots \\ F_{R1G}(\omega) & \dots & F_{RRG}(\omega) \end{bmatrix}$$

"R" is the symbol of block-rotation (this new block-matrix operation is proposed by author).

With the considered matrices models, on the basis of Neudecker's matrix derivative [3,4] an information Fischer's block-matrix, describing the accuracy of joint estimation of angular coordinates, range and frequency, is obtained:

$$I = \frac{1}{\sigma^2} \cdot \begin{bmatrix} P^T \cdot P & a^* \cdot P^T \cdot \frac{\partial P}{\partial Y} \\ \dot{a} \cdot \left(\frac{\partial P}{\partial Y} \right)^T \cdot P & \left(\dot{a} a^* \cdot I_{RRTG} \right) \frac{\partial P}{\partial Y} \end{bmatrix}$$

where I_{RRTG} — a unit matrix of dimension $R \times R \times T \times G$, $\frac{\partial P}{\partial Y}$ — Neudecker's derivative of matrix P on vector Y formed of unknown estimations of angular coordinates, range and frequency,

$$P = Q \square \{ \tilde{\square} F \} \text{ or } P = Q \square \{ \tilde{\square} \tilde{F} \}$$

To analyse multistatic radar systems the following matrix model (without noise) can be used:

$$U = \left(\begin{bmatrix} Q_1 \\ Q_2 \\ \vdots \\ Q_P \end{bmatrix} \square \begin{bmatrix} S_{11} & \dots & S_{T1} \\ \vdots & \vdots & \vdots \\ S_{1P} & \dots & S_{TP} \end{bmatrix} \square \begin{bmatrix} F_{11} & \dots & F_{G1} \\ \vdots & \vdots & \vdots \\ F_{1P} & \dots & F_{GP} \end{bmatrix} \right) \cdot \dot{a},$$

$$\begin{bmatrix} Q_1 \\ Q_2 \\ \vdots \\ Q_P \end{bmatrix} = \begin{bmatrix} \dot{Q}_{111}(x, y) & \dots & \dot{Q}_{1R1}(x, y) \\ \dot{Q}_{211}(x, y) & \dots & \dot{Q}_{2R1}(x, y) \\ \vdots & \vdots & \vdots \\ \dot{Q}_{R11}(x, y) & \dots & \dot{Q}_{RR1}(x, y) \\ \vdots & \vdots & \vdots \\ \dot{Q}_{11P}(x, y) & \dots & \dot{Q}_{1RP}(x, y) \\ \dot{Q}_{21P}(x, y) & \dots & \dot{Q}_{2RP}(x, y) \\ \vdots & \vdots & \vdots \\ \dot{Q}_{R1P}(x, y) & \dots & \dot{Q}_{RRP}(x, y) \end{bmatrix}$$

$$S_{tp} = \begin{bmatrix} S_{11tp}(z) & \dots & S_{1Rtp}(z) \\ \vdots & \vdots & \vdots \\ S_{R1tp}(z) & \dots & S_{RRtp}(z) \end{bmatrix}$$

$$F_{gp} = \begin{bmatrix} F_{11gp}(\omega) & \dots & F_{1Rgp}(\omega) \\ \vdots & \vdots & \vdots \\ F_{R1gp}(\omega) & \dots & F_{RRgp}(\omega) \end{bmatrix}$$

$$U_{gtp} = (Q_p \circ S_{tp} \circ F_{gp}) \cdot \dot{a},$$

P is a number of radar position.

In the general case, for multiple signals the modeling concept, based on using of block generalized face-splitting product (symbol " $\tilde{\otimes}$ ") and block generalized transposed face-splitting product (symbol " $\tilde{\otimes}^T$ ") can be proposed. According to the definition,

$$A \tilde{\otimes} B = [A_{bg} \tilde{\otimes} B_{bk}]_{dn}, \quad A \tilde{\otimes}^T B = [A_{bg} \tilde{\otimes}^T B_{kg}]_{dn}.$$

The example:

$$A = \begin{bmatrix} A_{111} & A_{121} & A_{112} & A_{122} \\ A_{211} & A_{221} & A_{212} & A_{222} \end{bmatrix},$$

$$B = \begin{bmatrix} B_{111} & B_{121} & B_{112} & B_{122} \\ B_{211} & B_{221} & B_{212} & B_{222} \end{bmatrix}, \quad A \tilde{\otimes} B =$$

$$= \begin{bmatrix} [A_{111} & A_{121}] & [B_{111} & B_{121}] \\ [A_{211} & A_{221}] & [B_{211} & B_{221}] \end{bmatrix} \tilde{\otimes} \begin{bmatrix} [A_{112} & A_{122}] & [B_{112} & B_{122}] \\ [A_{212} & A_{222}] & [B_{212} & B_{222}] \end{bmatrix},$$

$$A \tilde{\otimes}^T B =$$

$$= \begin{bmatrix} [A_{111} & A_{121}] & [B_{111} & B_{121}] \\ [A_{211} & A_{221}] & [B_{211} & B_{221}] \end{bmatrix} \tilde{\otimes}^T \begin{bmatrix} [A_{112} & A_{122}] & [B_{112} & B_{122}] \\ [A_{212} & A_{222}] & [B_{212} & B_{222}] \end{bmatrix}.$$

The model of four-coordinate radar with flat digital antenna array in multisignal case can be written as:

$$U = (Q \tilde{\otimes} (S \tilde{\otimes} F))(A \otimes I_R),$$

where A is the vector of complex amplitudes of signals of M sources,

$$Q = [Q_1 \ Q_2 \ \dots \ Q_M], \quad Q_m = \begin{bmatrix} Q_{1R}(x_m, y_m) & \dots & Q_{IR}(x_m, y_m) \\ \vdots & & \vdots \\ Q_{R1}(x_m, y_m) & \dots & Q_{RR}(x_m, y_m) \end{bmatrix}$$

$$S = [S_1 \ S_2 \ \dots \ S_M],$$

$$S_m = \begin{bmatrix} S_{111}(z_m) & \dots & S_{IR1}(z_m) \\ \vdots & & \vdots \\ S_{R11}(z_m) & \dots & S_{RR1}(z_m) \\ \vdots & & \vdots \\ S_{1IT}(z_m) & \dots & S_{IRT}(z_m) \\ \vdots & & \vdots \\ S_{RIT}(z_m) & \dots & S_{RRT}(z_m) \end{bmatrix},$$

$$F = [F_1 \ F_2 \ \dots \ F_M], \quad F_m = \begin{bmatrix} F_{111}(\omega_m) & \dots & F_{IR1}(\omega_m) \\ \vdots & & \vdots \\ F_{R11}(\omega_m) & \dots & F_{RR1}(\omega_m) \\ \vdots & & \vdots \\ F_{1IG}(\omega_m) & \dots & F_{IRG}(\omega_m) \\ \vdots & & \vdots \\ F_{RIG}(\omega_m) & \dots & F_{RRG}(\omega_m) \end{bmatrix},$$

I_R is a unit matrix of dimension R ; \otimes — symbol of Kronecker's- products of matrixes.

REFERENCES

1. Slyusar V. I. The family of the face-splitting matrix products and its characteristics// Kibernetika i sistemny analiz. - 1999. - ' 3. - to be published [in Russian].
2. Slyusar V. I. New operations of matrices product for applications of radars, in Proc. Direct and Inverse Problems of Electromagnetic and Acoustic Wave Theory (DIPED-97), Lviv, September 15-17, 1997, P. 73-74 [in Russian].
3. Slyusar V. I. Accuracy of linear digital antenna array at joint estimation of range and angular coordinate of M sources, in Proc. ICATT—97, Kyiv, May 1997. - P. 110 – 111.
4. Slyusar V. I. The face-splitting matrix products in radar applications.// Radioelectronika. -1998. - ' 3. - P. 71 - 75 [in Russian].