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Analysis of multiport broadband amplifiers with antenna arrays

***Abstract**: New structures of original multiple broadband amplifiers for radiocommunication systems are proposed in the work. These amplifiers consist of several amplify blocks and special multiple phase commutators. Base properties, characteristics and results of computer simulation of the multiple amplifiers with antenna and antenna arrays are presented. These devices may be used for reduction of electromagnetic disturbances in different radio systems.*

***Streszczenie.** Proponowano struktury oryginalnych szerokopasmowych wielowrotnikowych wzmacniaczy dla systemów radiowych. Wzmacniacze zawierają bloki wzmacniające oraz specjalne komutatory fazowe. Przedstawiono właściwości, charakterystyki i wyniki symulacji komputerowej wzmacniaczy razem z anteną i układem antenowym. (**Analiza szerokopasmowych wzmacniaczy wielowrotnikowych z układem antenowym**).*

Keywords: Electromagnetic disturbances, multiport amplifiers, phase commutators, antenna arrays, CAD.
Słowa kluczowe: Zakłócenia elektromagnetyczne, wzmacniacze wielowrotnikowe, komutatory fazowe, układy antenowe, CAD.

Introduction

The paper presents EMD modeling, structures and frequency characteristics of multiport broadband amplifiers with phase channel for different radio system [1-7].

The basis of the study multiport amplifiers with computer designing broadcasting devices and multiplexers are described in books [1,2]. Structures and computer software to designing new multiport power amplifiers in [3,4]. The use of new proposed multiport structures to the study of broadband antenna arrays with phase, frequency and spatial multiplexing are described in [5,7], to the synthesis of uncoupling networks for multiport complex loads - in [6].

Main topic of the paper is a computer analysis of power parameters of these amplifiers based on two-channel structures (hybrids) with antenna and antenna array at given frequency band.

These structures provide a destruction of undesirable signals without of some filter mechanical commutations.

Structures of the multiports for phase and frequency channel multiplexing

Main blocks of multiport broadband amplifiers are multiport frequency and phase commutators. Whole structures of the multiports for phase and frequency channel multiplexing are shown in Fig. 1.

Determinations of the main blocks are:

Phase commutator - double side multiport that provides a given **phase distribution** of output signals with excitation of separate inputs of the network (Fig. 1,a). Inversely, phase commutator provides sum signal of all excitation generators in some one output only for different phase distribution of the generators. With change of generator's phase's sum of the signals are in the some output of the device.

The phase commutator can be used as broadband antenna uncoupler assuring on certain conditions diagonal matrices (**Z**, **Y**, **S**), after connecting this structure to the multiport load (antenna array) with specific symmetry [6].

These commutators may be synthesized with use of special two-channel phase blocks - *hybrids* [1,3,4].

Frequency commutator - double side multiport is providing given **distributions of frequency bands** on outputs with different excitation of inputs of the network (Fig. 1,b). Synthesis of the frequency commutators is made by use of special blocks: diplexers and multiplexers [2,5].

Represented frequency and phase broadband commutators provide necessary frequency and phase signal distributions on all amplify block in whole multiport amplifier in given frequency band [3,4].

Structure and parameters of hybrid and phase commutators

As written above a main block for design of broadband phase commutators is balun (hybrid) two-channel device [1,3,4]. Structures of scattering matrix and its non-diagonal blocks of ideal hybrid is:

$$\mathbf{S}_N = \begin{bmatrix} \mathbf{0} & \mathbf{T}_t \\ \mathbf{T} & \mathbf{0} \end{bmatrix}, \qquad \mathbf{T}_2 = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \tag{1}$$

These matrices show that ideal hybrid has zero diagonal blocks and constant non-diagonal blocks. The multiport that has the zero diagonal blocks of the scattering matrix is called the **uncoupled-matched network** [6]. It's mean that the inputs of this network are theoretically ideally matched and uncoupled in the work with matched loads (Fig. 1,b).

This network realizes equal and opposite phases of the output signals with excitations of some inputs. Principle of the hybrid operation is shown in Fig. 2. Structure of the ideal hybrid is shown in Fig.3.

The hybrid is a base element for design of four-channel phase commutator (Fig. 4). This commutator consist of four hybrids and provides four combinations of phase distributions (0^0 and 180^0) or: (+1) and (-1) – of output signals with excitations of different one input. This commutator is one of base multiport for design of four-channel amplifier [1,3,4].

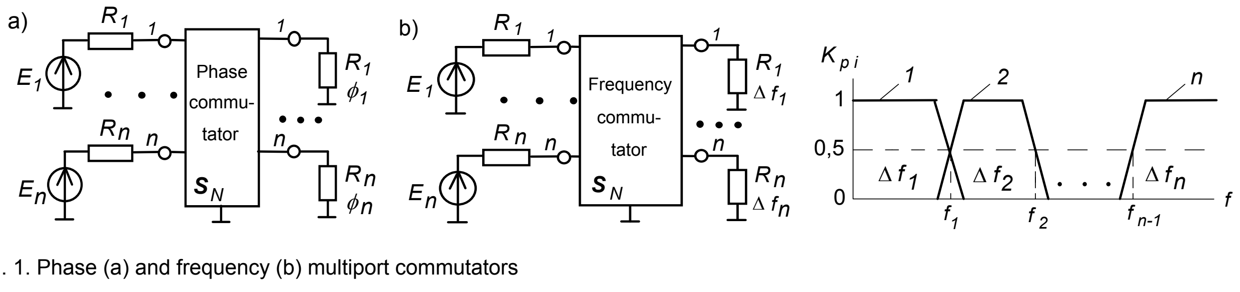


Fig. 1. Phase (a) and frequency (b) multiport commutators

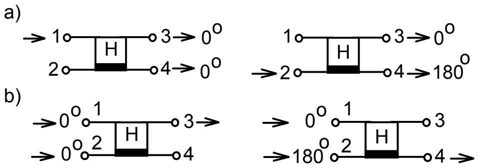


Fig. 2. Principle of the hybrid operation: a) division of power, b) summing of power

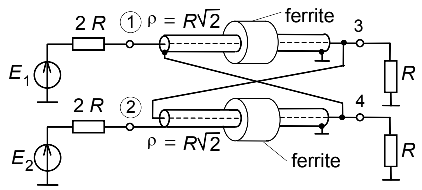
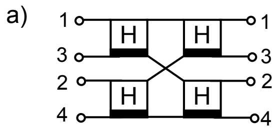


Fig. 3. Structure of the ideal cable hybrid (balun)

a)



b)

$$\mathbf{T}_4 = \frac{1}{2}\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & 1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix}$$

Fig. 4. Structure (a) and transmission matrix (b) of 4-port phase commutator

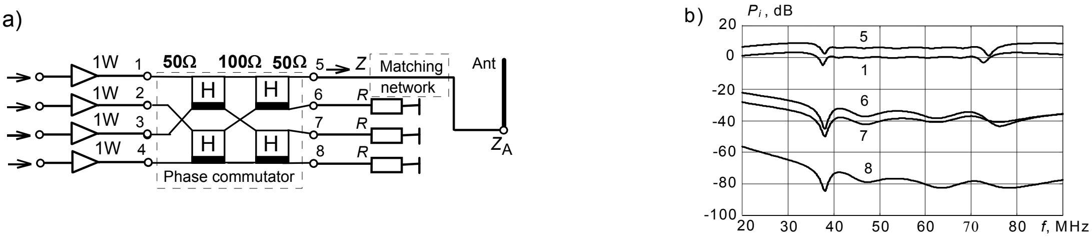


Fig. 5. Structure of excitations and characteristics of the four-channel phase commutator with single antenna

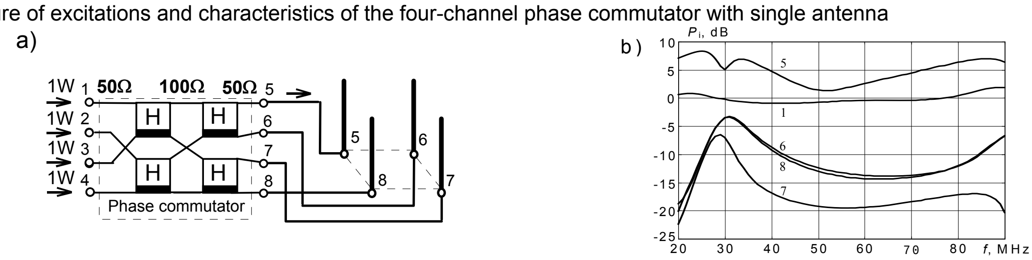


Fig. 6. Structure (a) and characteristics (b) of the four-channel phase commutator with antenna array

Computer simulation of the phase commutators

The results of the computer simulations of the four-channel phase commutator with unmatched loads were presented in this chapter.

For the computer simulations it was used hybrid (Fig. 3) with loads R = 50Ω, then the characteristic impedance of cables ρ = 75Ω $\cong 50\sqrt{2}$Ω; other parameters: the lengths of cables 6.7cm, the electrical permeability of isolation ε = 2.2, the inductance of the cable shield, with ferrite core, that was used for reduction shunt effect of the inductance of transmission line shield on small frequencies, L = 10μH. The resistance of generators 2R = 100Ω. For the analysis $E_1 = E_2$ = 20V, for assuring the power of generators P_{max} = 1W. Structure of the excitation of the four-channel phase commutator when this one provides sum signals of all input powers in one output with single wire antenna (the length 2.3m) are shown in Fig. 5,a. Corresponding characteristics are shown in Fig. 5,b; values of signals on uncoupled outputs (6,7,8) of the commutator are small: 30-80dB.

Structure of the excitation and the characteristics of the output power of the four-channel phase commutator with sum signals of all input powers in one output (5) with antenna array are shown on Fig. 6. The values of undesirable signals in the uncoupled outputs are a lot of larger because of couplings among the antennas of the antenna array.

We should remember this to design antenna arrays of radio systems MIMO.

The results of the computer simulations introduced in this work show that the worked out structures of excitation on the basis of the phase commutators can be have application in the work with multiport antenna array, in this in the systems MIMO for radiation of different signals the various elements of the antenna array.

Conclusions

Theoretical bases, structures and the results of the computer simulations of the broadband circuits of excitation of the antennas with the multiports amplifiers on the basis of phase commutators are presented in the article. The special case of the work with unmatched loads is described.

Proposed devices may be used to design of new radio-communication systems with antenna spatial multiplexing (SDMA) and in this also MIMO.

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