Feature Article

Using of Joint Management of Transmission and Receiving of Signals by Parallel Channels

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Abstract:
The paper is devoted consideration of organisation mechanisms of "own" channels (the MIMO method). The results of modeling processes of signals transmission through the Raleigh fading channel at a double diversity for various methods of management on the transferring side and combination on the reception side are illustrated.

Modern communication systems use widely transmitting of signals by parallel channels, so a noise level and distortions reduce and quality of transmitted information improves. There are different methods of performing of parallel channels. One of them is the space diversity [1,2].

In the communication systems with space-diversity signals are often transmitted in both directions. This allows to manage of diversity signal transmission by redistributing the transmitter power between diversed channels and change relative signal phase shift in different antennas. Each transmitted space-diversity signal is supplied by own label. These labels give opportunity to define magnitude of complex transfer coefficients k_{ij} from transmitter number i to receiver number j [3].

The transfer rate can be increased by means of using of "own" channels (the MIMO method - «many input, many output»). The method is based on orthogonal eigenvectors properties of a matrix **K** composed by coefficients k_{ij}. Let the matrix size **K** is equal $N \times N$. In a case nondegeneracy of matrix **K** (that is practically observed in overwhelming percent of a system work time) it has N various eigenvalues λ_i and corresponding to them N eigenvectors $\mathbf{a}_i$. Whole stream of the information that is transmitted through communication system, breaks on N independent substreams. These substreams are transmitted simultaneously through all diversity antennas.

Mutual phase relationships for each of substreams are defined by one of matrix K eigenvectors. These vectors are different for everyone substreams. In the receiver N independent channels are formed. Received diversity signals are combined according to various eigenvectors of a matrix **K** in each of them. Because eigenvectors are mutually orthogonal then after a similar combination in each reception channel only one substream is allocated. Components of the other substreams are mutually compensated. Thus, in one of transfer information system N simultaneously using independent "own" channels are formed. This allows to increase whole volume of the transferred information.

However a noise immunity of these "own" channels differs strongly. Let us form the matrix **A**, their columns will be eigenvectors $\mathbf{a}_i$ and let us form the diagonal matrix $\mathbf{\Lambda}$, their principal diagonal elements will be $\Lambda_{ii} = \lambda_{ii}$. We shall consider that all eigenvectors are orthonormal. In this case it is possible to present the matrix **K** as $\mathbf{K}=\mathbf{A\Lambda A}^+$ (the sign «+» denotes operation of Hermitian conjugation).

We will consider the set of space-diversity channels as the common channel with number j. It is possible to consider the transmission coefficient of such common channel to be equal to $\mathbf{b}_j\mathbf{K}\mathbf{b}_j = \mathbf{b}_j^+\mathbf{A\Lambda A}^+\mathbf{b}_j = \lambda_j$. The sum of components of all substreams with their coefficients is transmitted from each antenna. The coefficients are defined by elements of their eigenvectors with number, equal to antenna number.

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A noise immunity on each "own" channel is defined by its eigenvalue. Properties of channels differ, so equal distribution of the general resource of power between them is not favorable. In "bad" channels with small λ_i it is used for nothing in many respects. In works [7,8] it is suggested to distribute general power P_0 between "own" channels in that way so the maximum rate of transmission of total data will be provided:

$$I_0 = \sum_{i=1}^{N} I_i = \sum_{i=1}^{N} \log_2 (1 + \frac{\lambda_i^2 P_i}{P_n}),$$

with complexity $P_0 = \sum_{i=1}^{N} P_i$, (1)

In this formula P_i is the part of the general power P_0, which is given to i "own" channel; P_n – a noise power in the diversity channels of the receiver (We consider that equal in all channels). This requirement is carried out by means of principle «water pouring». According this principle power of transmitted signal through channel number i is determined by::

$$P_i = \alpha - \frac{P_n}{\lambda_i^2},$$

where the coefficient α is defined by general normalisation. At its account the power given to channel number i is will be defined according to the equation:

$$P_i = \frac{P_0}{N} + P_n (\frac{1}{N} \sum_{i=1}^{N} \frac{1}{\lambda_i^2} - \frac{1}{\lambda 2_i}) \quad (2)$$

Data rate in digital systems is defined in practice not only by signal/noise ratio (SNR) but also other factors (permissible error probability, applied coding method etc.) Therefore dependence of data rate is more complicated function.

Let's generalize the Shannon principle that defines powers distribution to "own" channels. Let data rate in real conditions is defined by some equation:

$I_0 = \sum_{i=1}^{N} f(k_i P_i)$, where $k_i = \lambda_i^2$. According method of the Lagrange multipliers the power normalisation will be used as a constraint equation. Thus, the Lagrange equation is:

$$\Phi = \sum_{i=1}^{N} f(k_i P_i) + \lambda_0 \sum_{i=1}^{N} P_i,$$

where λ_0 is uncertain Lagrange multiplier. Taking derivatives from a Lagrangian function on all P_i and considering the constraint equation, we shall get the system of N+1 equations with N+1 unknown variables:

$$\begin{cases} \dfrac{\partial \Phi}{\partial P_1} = k_1 f'(k_1 P_1) + \lambda_0 = 0 \\ \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\ \dfrac{\partial \Phi}{\partial P_N} = k_N f'(k_N P_N) + \lambda_0 = 0 \\ \sum_{i=1}^{N} P_i = P_0 \end{cases}$$

Let denote through $g(x)$ function that is inverse to function $f'(x)$, i.e. $g(x) = [f'(x)]^{-1}$. In this way we get equation for power P_i: $P_i = [g(-\lambda_0/k_i)]/k_i$. After substitutinon it in a constraint equation, we shall obtain:

$$P_0 = \sum_{i=1}^{N} \frac{1}{k_i} g(-\frac{\lambda_0}{k_i}) = G(\lambda_0, k_1, \dots, k_N)$$

It is possible to express connection between P_0 and $G(\lambda_0, k_1, \dots k_N)$ in another way: $\lambda_0 = F(P_0, k_1, \dots k_N)$. Thus, finally:

$$P_i = \frac{1}{k_i} g[-\frac{1}{k_i} F(P_0, k_1, \dots, k_N)] \quad (3)$$

The equation (2) is a special case of the formula (3). Application of "own" channels can give appreciable increase in channel capacity. However the use the method in the systems that work with big power of transferred signals can meet serious objections. Unlike the receiving side that operates with the signals of small level on the transmitting side it is necessary to operate powerful signals. Here possible difficulties of practical implementation can, so values of elements of all its eigenvectors continuously vary. Momentary signals are essentially various in each antenna because they are created by the weighed sums of all "own" channels with different sets of weight coefficients in different antennas. Therefore they cannot be generated by the same transmitter. Each transmitting antenna needs the own transmitter that generates the own signal, so the principle of unequal distribution of power resource between them loses sense. The difficulty of an effective using of transmitter resources of power can essentially outweight the channel capacity increasing.

In such conditions there is more convenient using of one best "own" channel with the greatest λ_i. In this case all diversity antennas radiate the same signal that changes only in amplitude and phase shift only. It is possible to use only one transmitter and optimum distribution of power between antennas get sense again. It becomes possible to pass from optimum management to quasioptimum management for the further simplification of practical implementation. Various methods of quasioptimum management are presented in [1,2]. Management is carried out for accomplishment of the greatest possible SNR after a combination. Among them there are:

-All power resource can be connected to one of antennas (antenna switching - AS).

-All power redistributes between antennas at equal phase shift of signals in antennas (gain adjustment - GA).

- All power ca redistributes between antennas in equal parts but of various relative phase shift between them (phase management - PM).

- A combination of methods AS and PM.

Processes of signals transmission through the fading channel at a double diversity for various methods of management on the transferring side and combination on the reception side were modeled. The Rayleigh model of fading was used. Changes of all four coefficients of a matrix **K** occurred independently. Researches were made for linear addition of received signals (fig. 1) and for optimum addition of received signals (fig. 2). On both figures vertical axis shows the relative level Y_{REL} in dB under relation median level of Rayleigh signal distribution in a single channel (without diversity). On a horizontal axis the percent of time $T\%$ during signal level on an exit of the circuit adding blocks of receiver will be above than Y_{OTH}, is laid.

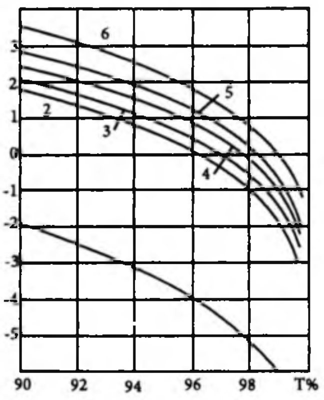

Рис. 1

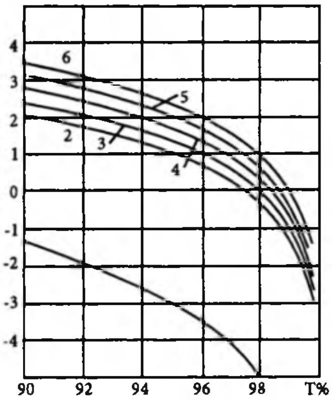

Рис. 2

Management methods of signal transmission were investigated: the diversity transmission without management, when equal signals with equal phase shift (diagrams 1) are transferred; method AS (diagrams 2); method GA (diagrams 3); a method PM (diagrams 4); a combination of methods AS and PM (diagrams 5); optimum management according to the eigenvector corresponding to maximum eigenvalue (diagrams 6).

From the analysis of modeling results it is possible to make such conclusions:

1. For optimum addition and for linear signal addition in the receiver the optimum management slightly scores in comparison with the combined method (accordingly, 0,3 dB and 0,6 dB).

2. The combined method can be replaced by more simple in practice method of phase management with at insignificant loss on noise immunity

Thus, in real working conditions, when rather powerful transferring means are used more favourable can be a failure from use of "own" channels and optimum management in favour of more simple but also effective quasioptimum management of transmission of the space-diversity signals.

Bibliographical list

1. P.A. Polushin Methods of decreasing of interfererences of signals.-LAP LAMBERT Academic Publishing, Saarbrucken, Germany, 2011. – 341 p.
2. P.A. Polushin, A.G. Samoilov Redandance of signals in communications.–Moacow, Radiotechnika, 2007. – 256 p.
3. Love J. David, Heath. W. Robert. Grassman Beamforming for Multi-Input Multi-Output Wireless Systems/IEEE Transactions on Information Theory, vol. 49, No. 10, October, 2003. – pp. 2735-2747.