Ergodic Capacity of MIMO Channel with and without Channel State Information

Lykhograi Vasil, Vovchenko Victoria, Nooh Taha Nasif

Abstract - **This report contains the results of modeling the ergodic capacity (EC) of the data transmission digital systems (DTDS) in the medium with multiple input - multiple output (MIMO) at presence and absence of information about the channel state information (CSI).**

Keywords - **Ergodic capacity, MIMO, antenna arrays.**

I. Introduction

Increasing the carrying capacity (CC) of the data transmission digital system (DTDS) radio channel in the medium with multipath fading under the conditions of the frequency resource and transmission power limitations is the complex task. One of the ways of increasing the CC of such DTDS is to use technologies with multiple input - multiple output (MIMO), i.e. the simultaneous data transmission via several subchannels using the multicomponent transmitting and receiving antennas [1].

II. Capacity of MIMO Channal

MIMO communication channel (Fig. 1) can be represented by means of the channel matrix **H** with size of N_R x N_T the elements h_{nm} of which are the complex-valued coefficients of transmission from *m*-input (*m*-transmitting antenna) to n-output (n-receiving antenna).

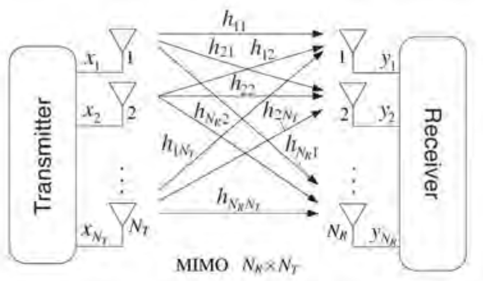

Fig.1 MIMO channel model

Mainly, the literary sources contain consideration of the MIMO deterministic channels, and the CC of such channel has the following form [1]:

$$C = \max_{p(\mathbf{x})}\left\{\log_2 \det\left(\mathbf{I}_{N_R} + \frac{1}{s_N^2}\mathbf{H}\mathbf{R}_{XX}\mathbf{H}^H\right)\right\} \quad (1)$$

where $\mathbf{I}_{NR}$ is the unitary square matrix with size of N_R x N_R; $\mathbf{R}_{XX}$ is the input signal autocorrelation matrix; σ_N^2 is the noise power.

When information about the MIMO channel state (its channel matrix is **H**) is known to transmitter and receiver (CSI), the CC of such channel is determined as the sum of the subchannels' CC - intrinsic modes of the MIMO channels. Maximum CC with accounting the intrinsic modes determined on base of optimization problem solution (water filling) [1]:

$$\max_{h_1 \ldots h_r}\sum_{i=1}^{r}\log_2\left(1 + s_i^2\frac{h_i}{s_N^2}\right), \quad (2)$$

Solution (2) assumes search of optimum level of the power η_i transmitted via the virtual channels for which $\sigma_i^2 >$ 0. Due to existence of only $r = N_{min} = min(N_T, N_R)$ nonzero singular values of **H** matrix, transmission of the power $\eta_i > 0$ via the other $r < i \le N_T$ subshannels is unreasonable. In general. the MIMO channel parameters change in random manner and, consequently, the H matrix elements are the random values. Hence, the MIMO channels CC changes in the random manner, and it shall be determined using the time averaging. Such random channel represents the ergodic process, and the average or EC can be introduced for it:

$$\overline{C} = E\{C(\mathbf{H})\} = E\left\{\max_{p(\mathbf{x})}\left\{\log_2 \det\left(\mathbf{I}_{N_R} + \frac{1}{s_N^2}\mathbf{H}\mathbf{R}_{XX}\mathbf{H}^H\right)\right\}\right\} \quad (3)$$

Taking into account (1-3), there was executed modeling the MIMO channels' EC at the antenna elements different configurations on the transmitting and receiving side. Modeling was carried out in MATLAB. For creating the MIMO random channel it was used "randn" function that allowed to create the H matrix the elements of which are the random values with the zero mathematical expectation and dispersion equal to 1. Fig. 2 shows the EC dependence as function of the signal / noise ratio at presence and absence of information about the MIMO communication channel state.

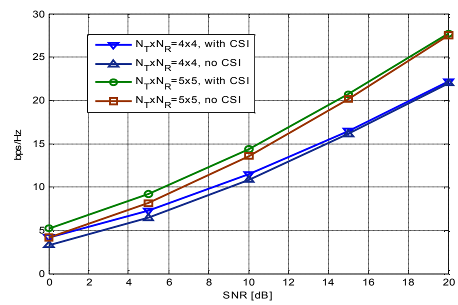

Fig.2 Ergodic capacity of MIMO channel

III. Conclusion

EC increases at increase of the antenna elements number both on transmitting and receiving side. Information about the MIMO channel (CSI) has the winning meaning mainly at small signal/noise ratios (SNR) and slightly improves the EC in case of SNR more than 15 dB (e.g. for MIMO 4 x 4 configuration).

References

[1] G. Levin, "Capacity analysis of asymptotically large MIMO channels," *University of Ottawa, Canada, 2008,* pp. 15-32.

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