

цедур по сравнению с аналогичными независимыми, несвязанными процедурами. Из этих графиков также следует, что с увеличением коэффициентов взаимных связей α_{ij} апостериорная дисперсия возрастает, однако более быстрый рост дисперсии происходит при увеличении α_{ii} . Очевидно, что с увеличением шаговых постоянных, наряду со снижением точности оценки сокращается время сходимости к установившемуся состоянию.

Существенным остается вопрос о поведении фильтра при широком диапазоне изменения диагональных α_{ii} и недиагональных α_{ij} коэффициентов. Ответ на этот вопрос может дать рис. 3. На нем изображена зависимость минимума апостериорной дисперсии от α_{ij} и α_{ii} , для размера выборки 10000 и 1000. На рис. 3 четко видно, что чем больше выборка, тем точнее оценка, так как апостериорная дисперсия выше при размере выборки 1000.

Выводы

1). Качество оценки статистически связанных процессов с помощью двумерного рекурсивного фильтра в широком диапазоне изменений α_{ij} оказывается выше по сравнению с оценками, получаемыми при независимых процессах x_i . Полученные результаты подтверждают предположение о большей эффективности двумерных оценок. Поскольку четко видно, что на определенном интервале значений недиагональных элементов оценка становится выше почти в два раза.

2). Точность оценки возрастает при меньшей величине шага дискретизации. Наилучшая оценка (минимум апостериорной дисперсии ошибки оценки) получена при значениях $\alpha_{ij} = 0.001$ и $\alpha_{ii} = 0.0017$ и $\min(V(a(i,j))) = 0.00598$.

Литература

1. Поповский В.В. Математические основы управления и адаптации в телекоммуникационных системах. [Текст]/ В.В. Поповский, В.Ф. Олейник // Х. СМИТ, 2011- 362с.
2. Невельсон М.Б. Стохастическая аппроксимация и рекуррентное оценивание. [Текст]/ М.Б. Невельсон., Р.З. Хасьминский // М., 1972-268с.
3. Теплицкая С.Н. Анализ качества оценки случайных величин. [Текст]/ С.Н. Теплицкая, Е.О. Поповская, Я.Т. Хуссейн // «Радиотехника». – Харьков: ХНУРЭ, 2010–199с.
4. Поповский В.В. Синтез цифровой модели двумерного случайного процесса. [Текст]/ В.В. Поповский, Б.С. Тур // «Радиотехника». – Харьков: ХНУРЭ, 2010. – 115с.

У роботі розглядаються питання адаптивної модуляції у каналах MIMO, яка забезпечує покращення показників якості WiMAX за рахунок більш повного врахування відмінностей характеристик просторових субканалів багатопроменевого каналу зв'язку

Ключові слова: MIMO, Аламоуті кодування, фільтр Калмана

В работе рассматриваются вопросы адаптивной модуляции в каналах MIMO, обеспечивающей улучшение показателей качества WiMAX за счет более полного учета различий характеристик пространственных субканалов многолучевого канала связи

Ключевые слова: MIMO, Аламоути кодирование, фильтр Калмана

The paper deals with adaptive modulation in MIMO channels, which provides better quality WiMAX due to more complete account the characteristics of spatial subchannels multibeam communication channel

Keywords: MIMO, Alamouti coding, Kalman filter

УДК 621.382

METHODS OF INCREASING THE QUALITY OF WIMAX BY USING MIMO

V. Loshakov

Doctor of Technical Sciences, Prof*

Telephone: 096-237-03-64

E-mail: ut31l.v@gmail.com

Z. Wadea*

*Department of Telecommunication Systems

Telephone: 093-198-81-25

E-mail: ziyadt@yahoo.com

Kharkiv National University of Radio Electronics

Lenina 14, Kharkov, Ukraine

1. Introduction

In this paper the different methods of transmit and receive diversity used with MIMO system for WiMAX

technology are presented. Also the mathematical model for controlling the adaptive modulation in MIMO channels was analyzed.

2. Analyzing the performance quality for different MIMO schemes

An analyze is held for all main the reasons of degradation of transmit quality in WiMAX technology, especially for the frequencies above 2GHz where the WiMAX work. Also the different types of solutions for the reasons of performance degradation are analyzed. In the analysis we introduce the overall channel model for simulating the large and small scale trends that affect this model. The overall model we use for describing the channel in discrete time is a simple tap delay line:

$$h[k, t] = h_0\delta[k, t] + h_1\delta[k - 1, t] + \dots + h_v\delta[k - v, t], \quad (1)$$

Here, the discrete-time channel is time varying, so it changes with respect to t and has non-negligible values over a span of v+1 channel taps. Generally, we assume that the channel is sampled at a frequency $f_s = 1/T$, where T is the symbol period, and hence, the duration of the channel in this case is about vT. Assuming that the channel is static over a period of seconds, we can then describe the output of the channel as

$$y[k, t] = \sum_{j=-\infty}^{\infty} h[j, t]x[k - j] = h[j, t]^* x[k], \quad (2)$$

where x[k] is an input sequence of data symbols with rate 1/T,

* - denotes convolution. Although this tapped-delay-line model is general and accurate, it is difficult to design a communication system for the channel without knowing some of the key attributes about h[t]. For this purpose it is used Clark's model to generate, also the change in h[t] depends on the mobility speed of the channel.

Through our research we found that three effects cause the varying in received power. The first over long distances with path loss, the second for medium distances with shadowing, and with short distances with fading. Although solving the problem of path loss and shadowing is important but for WiMAX technology fading represents the biggest problem because for very short distance the signal can suffer fading.

The fading in wireless communication is divided in two types. The first is flat fading which happens in time domain, and the second is frequency selective fading which happens in frequency domain. In general two types of solutions are used for each of the fading types. The first solution is MIMO antenna system, which is divided in to several types depending on the number of antennas used and the the type of coding used. The orthogonal frequency division multiplexing OFDM is a modulation method used in solving the problem of frequency selective fading in wireless channels.

The first type which is selective receiving depends on selecting the antenna with the highest received signal to noise ratio and the selection depends on a specified threshold and it is considered a SIMO technology, the error probability for this method as follows [5,6]:

$$P_{out} = P[\gamma_1 < \gamma_0, \gamma_2 < \gamma_0, \dots, \gamma_{N_r} < \gamma_0], \quad (4)$$

$$P_{out} = P[\gamma_1 < \gamma_0]P[\gamma_2 < \gamma_0] \dots P[\gamma_{N_r} < \gamma_0] = P^{N_r},$$

Where γ_0 - represents the signal to noise ratio threshold. The average received signal to noise ratio is:

$$\gamma_{sc} = \gamma \sum_{i=1}^{N_r} \frac{1}{i} = \gamma \left(1 + \frac{1}{2} + \frac{1}{3} + \dots + \frac{1}{N_r}\right), \quad (5)$$

where N_r - is the number of received antennas.

The selective transmit is very similar to selective receiving except it chooses the best antenna to transmit and it is considered a MISO technology, where the average received signal to noise ratio is [9]:

$$\gamma_{Lsd} = \gamma \sum_{i=1}^{N_t} \frac{1}{i}, \quad (6)$$

where N_t - the number of transmit antennas.

The most used is method is maximal ratio combining it depends on summing the power from all the receiving antennas and it is considered a SIMO technology, the average received signal to noise ratio is [1]:

$$\gamma_{\Sigma} = \frac{\sum_{i=1}^{N_r} |h_i|^2 \epsilon_x}{\sigma^2}. \quad (7)$$

The method that uses Alamouti coding shown below it is called open loop MIMO with space time coding:

Antenna	1	2
Time 0	s_1	s_2
1	s_2^*	s_1^*

where s_1 and s_2 are successive transmitted symbols.

The transmit and receiving equations for Alamouti 2x1 are as follows [1,2]:

$$r(0) = h_1s_1 + h_2s_2 + n(0); \quad (8)$$

$$r(T) = -h_1s_2^* + h_2s_1^* + n(T);$$

$$y_1 = h_1^*r(0) + h_2^*r(T); \quad (9)$$

$$y_2 = h_2^*r(0) - h_1^*r(T).$$

The combining equations and the average received signal to noise ratio are as follows:

$$y_1 = (|h_1|^2 + |h_2|^2)s_1 + h_1^*n(0) + h_2n^*(0); \quad (10)$$

$$y_2 = (|h_1|^2 + |h_2|^2)s_2 + h_2^*n(0) - h_1n^*(0);$$

$$\gamma_{\Sigma} = \frac{\sum_{i=1}^2 |h_i|^2 \epsilon_x}{\sigma^2} \frac{\epsilon_x}{2}, \quad (11)$$

where ϵ_x - transmitted power, $|h_i|^2$ - channel gain, σ^2 - noise variance.

The closed loop MIMO uses pre coding method that depends on the singular value decomposition of the channel matrix as follows [1,3]:

$$d = U^*y;$$

$$d = U^* (Hx + n)$$

$$d = U^* (U \Sigma V^* V b + n);$$

$$d = U^* U \Sigma V^* V b + U^* n;$$

$$d = \Sigma b + U^* n. \quad (12)$$

3. Using Kalman filtering in controlling adaptive modulation

An analysis is held for all the types of MIMO schemes by using mathematical simulation. The main conclusion of the mathematical simulation showed that including the channel gain effect in the process of simulation will lower the performance of bit error rate for MIMO, which means that the adaptive modulation system in WiMAX needs to be modified according to the type and number of antennas used [7]. As it can see in fig. 1 the effect of channel gain on the adaptive modulation for 2x2 MIMO.

The system functional scheme model which uses adaptive modulation in MIMO channels for closed and open loop 2x2 MIMO are shown in fig. 2. The model for open loop MIMO uses Alamouti space time code, while for closed loop MIMO the model uses singular value decomposition channel precoding.

The scheme in fig. 2 uses Kalman filter for in order to control the adaptive modulation through different MIMO channels. The main Kalman filter equations are as follows:

$$\hat{h}_{nm}(n) = \hat{h}_{nm}(n-1) + k(n)[y_{nm}(n) - a \hat{h}_{nm}(n-1)]; \quad (17)$$

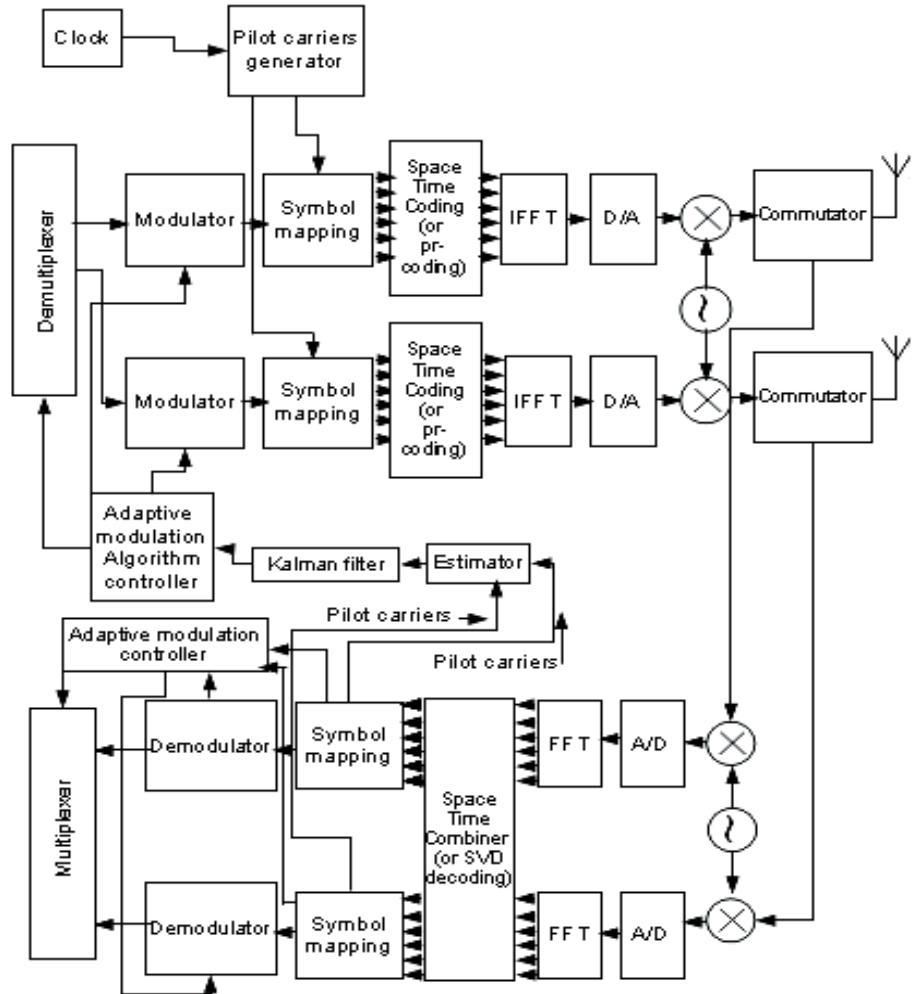


Fig. 2. Functional scheme 2x2 MIMO model

$$k(n) = \frac{c[a^2 p(n-1) \sigma_g^2]}{\sigma_v^2 + c^2 \sigma_g^2 + c^2 a^2 p(n-1)}; \quad (18)$$

$$p(n) = \frac{1}{c} \sigma_v^2 k(n). \quad (19)$$

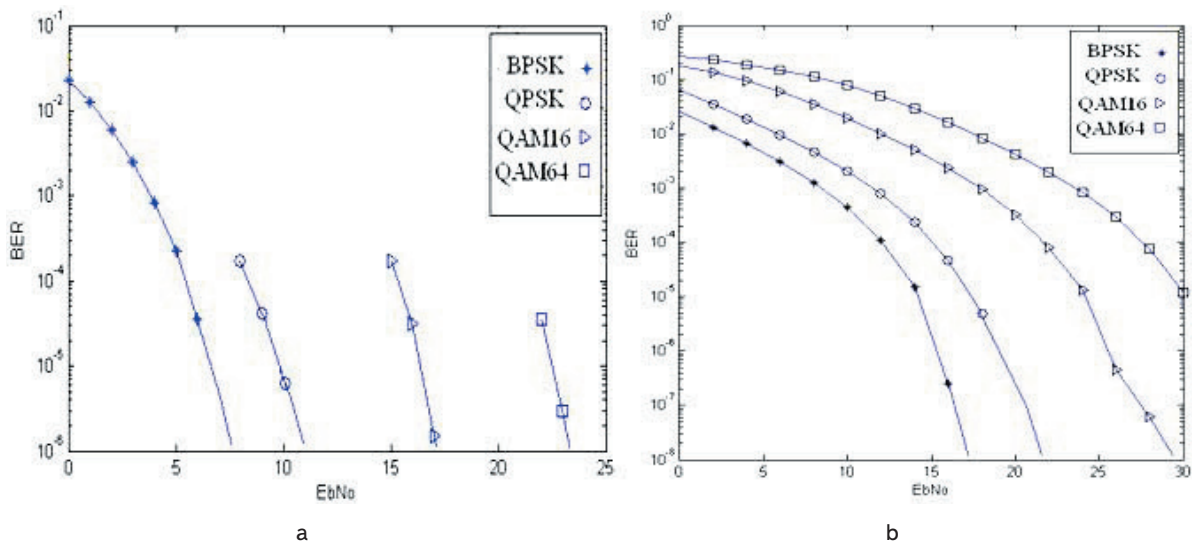


Fig. 1. (a) Adaptive modulation in WiMAX with MIMO, (b) Adaptive modulation for 2x2 MIMO with channel gain effect

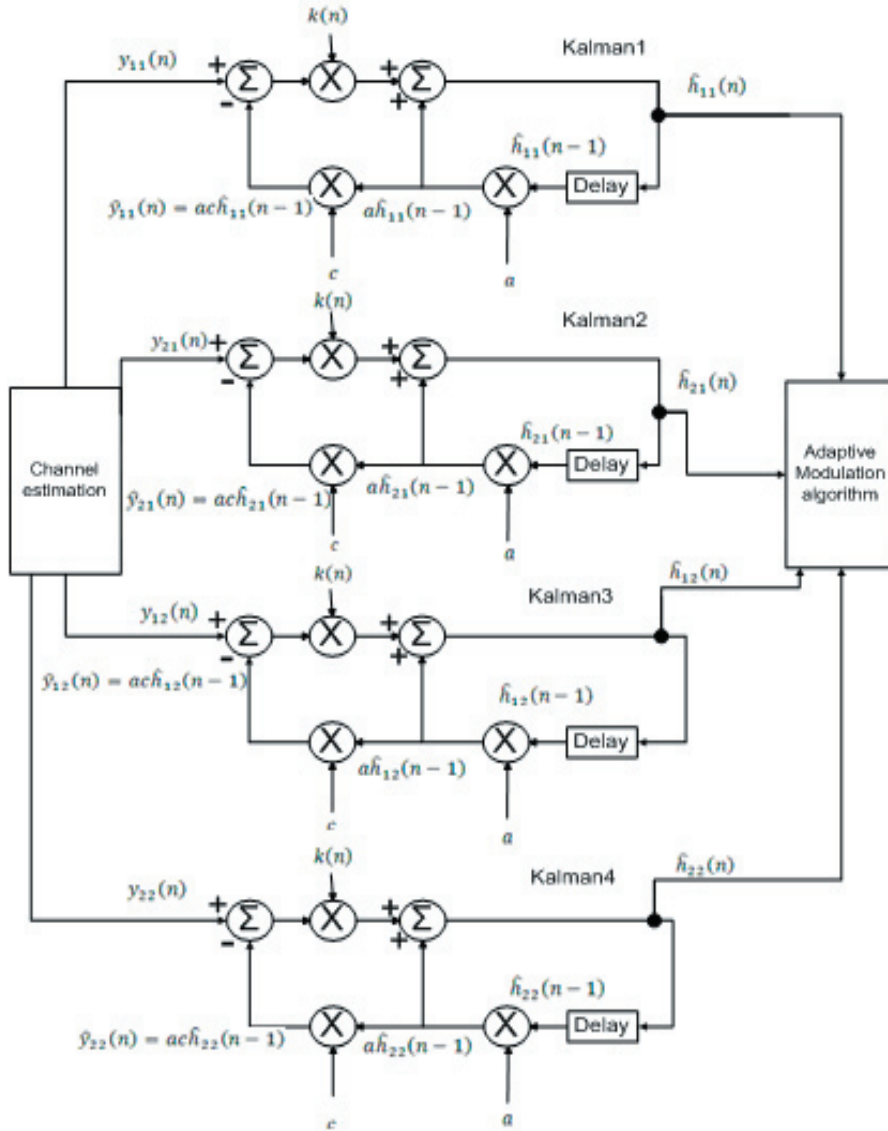


Fig. 3. Mathematical model for the adaptive modulation in MIMO channels

Equation 17 represents the main loop, which estimates the next channel coefficient $\hat{h}_{nm}(n)$, by using the previous value $\hat{h}_{nm}(n-1)$, and the Kalman gain $k(n)$. The next Kalman gain value is estimated by using the previous root mean square error $p(n-1)$, and by estimating the next Kalman gain the next $p(n)$ value can be estimated.

The mathematical model for the adaptive modulation in MIMO channels is shown in fig. 3, the model is for 2x2 MIMO system which means that four channels in the system, so four Kalman filters were used in the model. The Kalman filters read the measured channel coefficients $y_{nm}(n)$ from the channel estimation system, which uses the pilot carriers to estimate the channel matrix, and feed the estimated channel matrix to the adaptive modulation algorithm block.

4. Simulation results

The simulation results for Kalman filtering with adaptive modulation, where we compared the BER for the system with and without using Kalman filter, are shown in fig. 4 and fig. 5. In fig. 4 open loop MIMO was used, where the BER results shows that the ideal system and Kalman filter have very close BER and it is under 10^{-4} . In fig. 5 closed loop MIMO was used, and also the ideal system and Kalman filter have very close BER and it is under 10^{-4} .

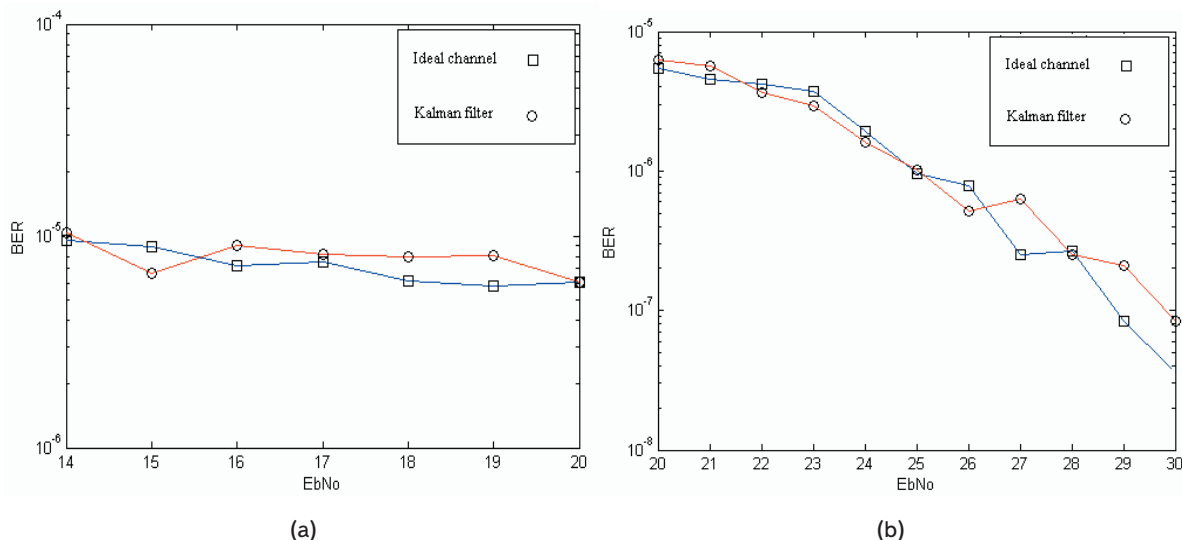


Fig. 4. Simulation results for Kalman filter performance used with open loop MIMO (a) With QAM16 range (b) With QAM64 range

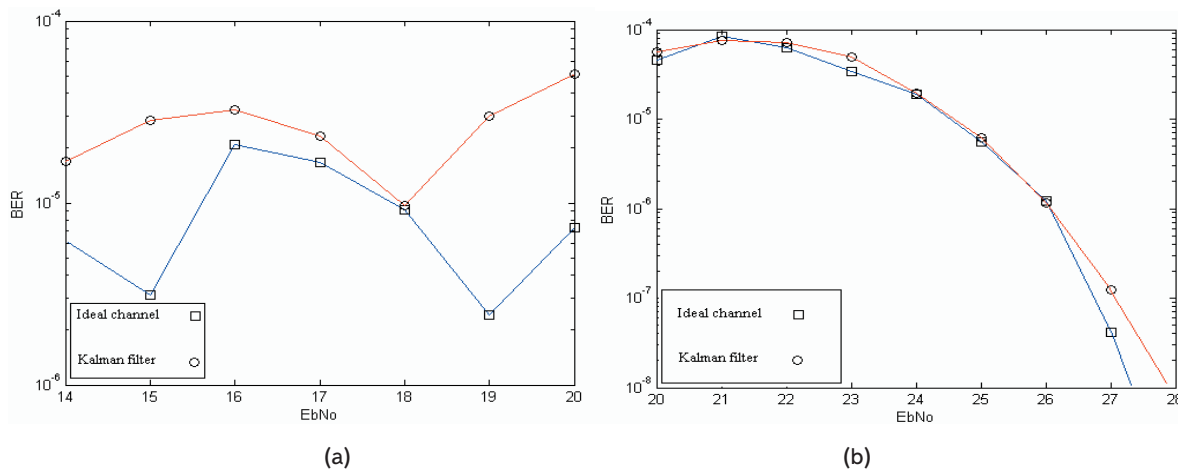


Fig. 5. Simulation results for Kalman filter performance used with closed loop MIMO (a) With QAM16 range (b) With QAM64 range

5. Conclusions

1. The method of adaptive modulation in MIMO channels based selection of higher multiplicity bahatopoztysiyoyi spatial modulation in channels with low levels losses and with less frequency rate modulation in channels with high signal attenuation.

2. To provide high accuracy and speed of performance estimation of individual spatial subkanaliv required to implement adaptive choice of type modulation is proposed to use Kalman filter.

3. Simulation of processes in WiMAX with adaptive modulation in MIMO channels confirmed the possibility of substantial improvement of the quality of communication

References

1. Jeffrey T. S. Rappaport. Wireless Communications: Principles and Practice, 2d ed. // Prentice-Hall, 2002.
2. E. N. Onggosanusi, A. G. Dabak, and T. A. Schmidl. High rate space-time block coded scheme: Performance and improvement in correlated fading channels. In Proceedings. // IEEE Wireless Communications and Networking Conference, 1:194–199, Orlando, FL, March 2002.
3. D. Parsons. The Mobile Radio Propagation Channel.// Wiley, 1992.
4. D. Love, R. Heath, V. Lau, D. Gesbert, B. Rao and M. Andrews. An overview of limited feedback in wireless communication systems. // IEEE Journal on Selected Areas Communications, vol 26, pp. 1341-1365, 2008.
5. R. Chen, J. Andrews, and R. W. Heath. Transmit selection diversity for multiuser spatial multiplexing systems. In Proceedings. // IEEE Globecom, pp. 2625–2629, Dallas, TX, December 2004.
6. R. Chen, R. W. Heath, and J. G. Andrews. Transmit selection diversity for multiuser spatial division multiplexing wireless systems. //IEEE Transactions on Signal Processing, March 2007.
7. Лошаков В.А., Вадиа Зияд. Адаптивная модуляция сигналов в каналах MIMO // Проблеми телекомунікацій. – 2010. – No.1 (1). – с.102–108. – Режим доступу до журн.: http://http://www.nbu.gov.ua/e-journals/prtel/2010_1/10lvaimc.pdf.