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COMPARATIVE ANALYSIS OF USING TRANSMISSION AND RECEIVING DIVERSITY METHODS IN WiMAX TECHNOLOGY

Introduction

WiMAX of 802.16e standard is a very promising wireless technology which can support transmission rate about 45Mbit/sec. By adding the fast mobility with the high bit rate WiMAX 802.16e is considered the future of wireless networks. Because mobile WiMAX is not line of sight technology it makes the multifading channels interference a very severe problem which challenges the WiMAX performance ability. To solve the multifading problem a multi antennas system are used between the base station and the subscriber like SIMO, MISO and MIMO which can eliminate or decrease the influence of multifading and so it decreases the BER value and increases the WiMAX transmission reliability. The multi antennas system makes use two techniques transmission diversity and receiving diversity. The main advantage of using transmission diversity and receiving diversity is that no additional bandwidth or power is needed in order to take advantage of spatial diversity. Purpose of the paper is comparative analysis of using main types of receiving and transmission diversity in WiMAX systems.

Mathematical model and main equations

In order to investigate the different diversity types it is necessary to build a simulation model and to relate each diversity type performance to the system reliability by measuring the bit error rate (BER). Block diagram of such simulation model is shown in Fig.1.

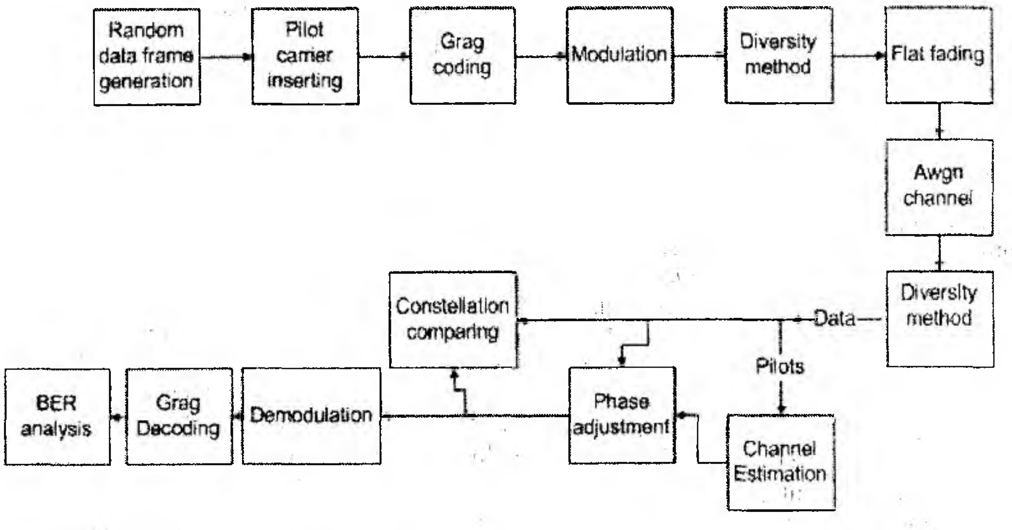

Fig. 1

The simulation model includes different modulation and demodulation types like DPSK, QPSK4, QAM16 and QAM64, Grag coding and decoding, the diversity methods on the transmitter side include space time coding (Alamouti coding). This coding is used in the case of MIMO and MISO while SIMO or SISO do not include transmission multiplexing.

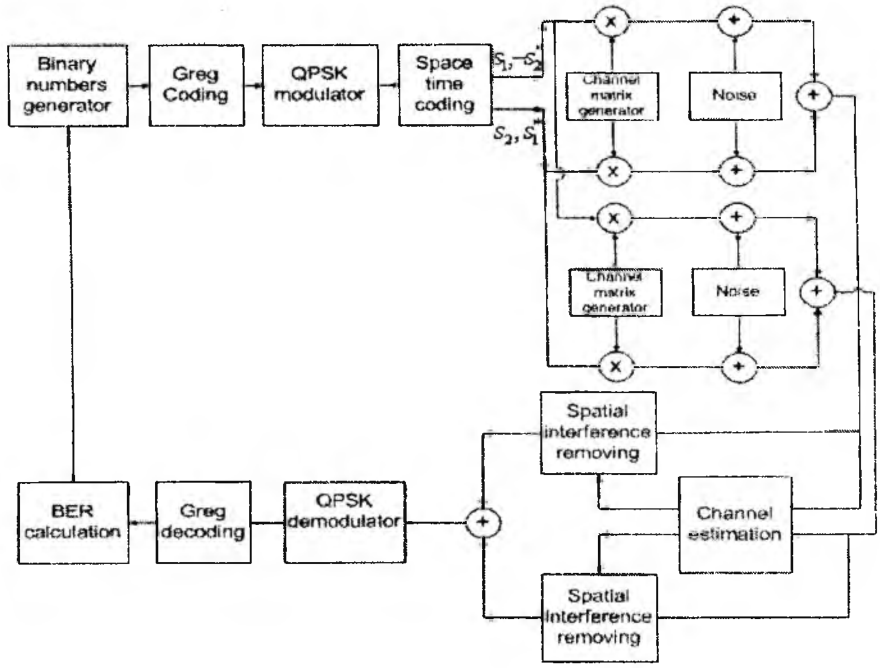

Fig. 2

The mathematical model for simulation is shown in Fig.2. The channel matrix generator is generating the fading channel coefficients for the channel model by using Rayleigh fading with Clarke's Model (see Fig. 3). The coefficients of Clarke's model can be found by using equations:

$$S_0(t) = T_c(t)\cos 2\pi f_c t - T_s(t)\sin 2\pi f_c t\,; \qquad (1)$$

$$T_c(t) = \sum_{n=1}^{N} C_n \cos(2\pi f_n t + \theta_n)\,; \qquad (2)$$

$$T_s(t) = \sum_{n=1}^{N} C_n \sin(2\pi f_n t + \theta_n)\,, \qquad (3)$$

The simulation model program which is written in matlab starts the simulation process by generating random data frame and then it adds pilot carriers for channel estimation. The number of symbols sent through the channel with each iteration equals t_c/t_s , where $t_c=9/(16\pi f_d)$ – time of coherence, $f_d=vf_c/c$ – Doppler frequency, v – velocity of mobile terminal, f_c – carrier frequency, t_s=1/bandwidth – symbol duration.

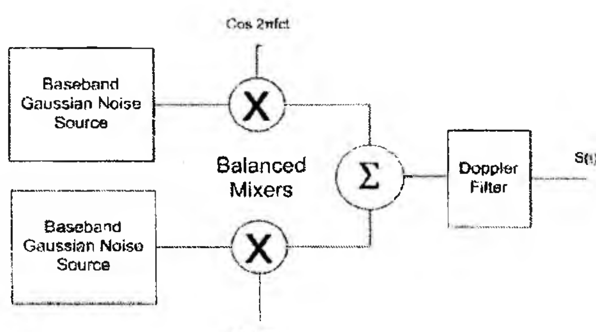

Fig. 3

The result of this simulation is the dependences BER values from signal to noise ratio. By changing the program parameters we can see and analyze the influence changing velocity, carrier frequency or pilot carrier percent with each coherence time.

The first was considered the receiving diversity, it is a simple technique and it does not need any coding from the transmitter side or any knowledge from the receiver. In this case it can use two most important techniques receiving diversity – selective combining and maximal ratio combining. The diversity gain from using selection combining can be confirmed quite quickly by considering the outage probability, defined as the probability that the received SNR drops below some required threshold, $P_{out}=P[\gamma<\gamma_0]=p$, where γ_0 is threshold value of SNR. Assuming N_r uncorrelated receptions of the signal [2],

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

then

$$P_{out} = P[\gamma_1 < \gamma_0]P[\gamma_2 < \gamma_0]...P[\gamma_{N_r} < \gamma_0] = p^{N_r} \ . \tag{1}$$

For a Rayleigh fading channel

$$p = 1 - e^{-\gamma_0 \sqrt{\gamma}}. \tag{2}$$

Thus selection combining dramatically decreases the outage probability [2]

$$P_{out} = (1 - e^{-\gamma_0 \sqrt{\gamma}})^{N_r} \ . \tag{3}$$

and average received SNR for N_r branch Spatial Combining in case of Rayleigh fading is

$$\bar{\gamma}_{sc} = \bar{\gamma}(1 + \frac{1}{2} + \frac{1}{3} + ... + \frac{1}{N_r}). \tag{4}$$

Maximal Ratio Combining (MRC) combines the information from all the received branches in order to maximize the ratio of signal-to-noise power [1,2] . MRC works by weighting each branch with a complex factor $q_i = |q_i| \, e^{j\Phi_i}$ and then adding up the N_r branches. The received signal in each branch can be written as $x(t)\ h_i$, assuming that the fading is flat with a complex value of $h_i = |h_i| \, e^{j\Phi_i}$ in the i-th branch

$$y(t) = x(t)\sum_{i=1}^{N_r} |q_i| \, |h_i| \exp\{j(\hat{O}_i - \theta_i)\}. \tag{5}$$

If it let the phase of the combining coefficient $\Phi_i = -\Phi_i$ for all the branches, the signal to noise ratio can be written as [2]

$$\gamma_\Sigma = \frac{\sum_{j=1}^{2} \sum_{i-1}^{2} |h_{ij}|^2 \, \varepsilon_x}{\sigma^2}. \tag{6}$$

The second diversity type of our analyze is transmission diversity which depends on sending signal copies from different antennas. The most popular channel coding in case of using transmission diversity technique is Alamouti coding which is an orthogonal space time coding. Its popularity is due to its simple implementation and because it achieves full code rate. The received signal $r(t)$ for Alamouti coding can be written as

$$r(0) = h_1 s_1 + h_2 s_2 + n(o), \tag{7}$$

$$r(T) = - h_1 s_2^* + h_2 s_1^* + n(T), \tag{7a}$$

where n(.) is a sample of white Gaussian noise. The following diversity-combining scheme can be used, assuming that the channel is known at the receiver:

$$y_1 = h_1^* r(0) + h_2 r^*(T); \quad (8)$$

$$y_2 = h_2^* r(0) - h_1 r^*(T). \quad (9)$$

The resulting SNR for MISO 2x1 and MIMO 2x2 with Alamouti coding are [2]:

$$\gamma_\Sigma = \frac{\sum_{i=1}^{2} |h_i|^2}{\sigma^2} \frac{\varepsilon_x}{2}; \quad (10)$$

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

These equations are used in our simulation model to evaluate the performance of transmission ıd receiving diversity.

Results of simulation

The results of simulation for different types of receiving and transmission diversity for velocity 0 *km/h*, bandwidth 5MHZ and pilot carriers percent 8 % for each coherent time are shown in ig.4, 5, 6 and 7. Comparison the reliability have been making for the maximum acceptable BER alue for WiMAX standard 10^{-4}.

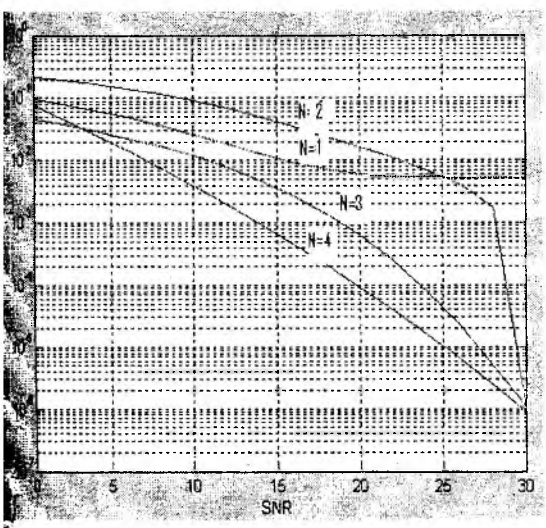

Fig. 4

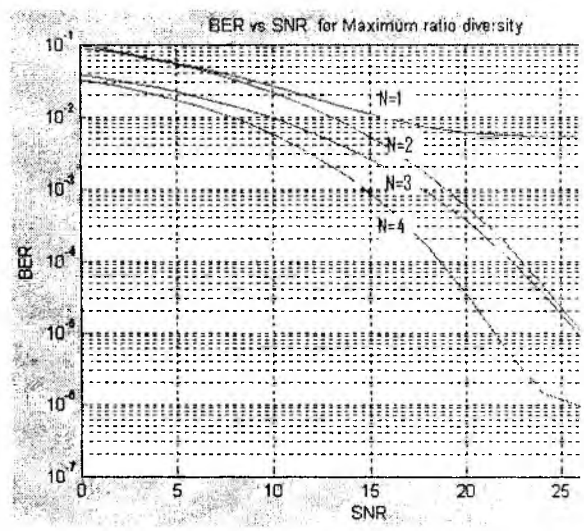

Fig. 5

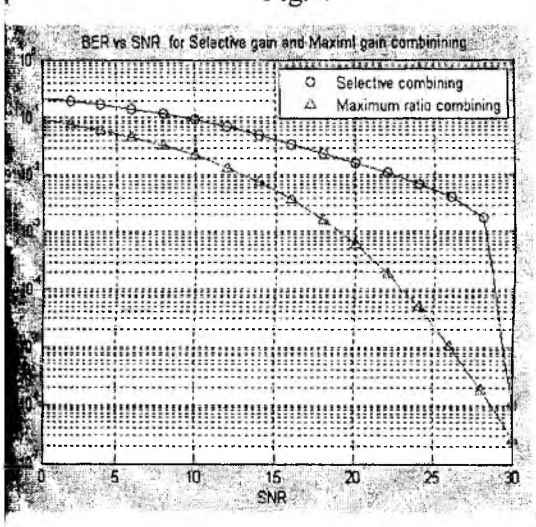

Fig. 6

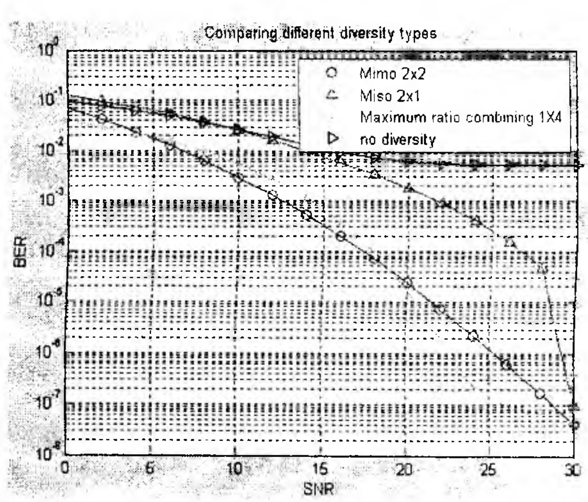

Fig. 7

The simulation results for selective combining for SIMO system with different antenna number n the receiver side are shown in Fig.4. It can be seen that the BER performance for 1x4 system is approximately 20 *db,* 1x3 system is 24*db*, 1x2 is system 28 *db*. For 1x1 SISO system the performance did not improve to reach the 10^{-4} intended BER value.

Maximal ratio combining with the same SIMO system gets better result (see Fig. 5), where 1x4 system has 18*db* performance, 1x3 22 *db* and 1x2 23 *db*. For 1x2 SIMO the maximal ratio combining has a 7*db* advantage over selective combining (Fig.6). The BER performance for SIMO 1x4, MIMO 2x2, MISO 2x1 and SISO are shown in Fig.7. SIMO 1x4 and MIMO 2x2 have the same performance of 17 *db* while MISO 2x1 has 27*db* performance.

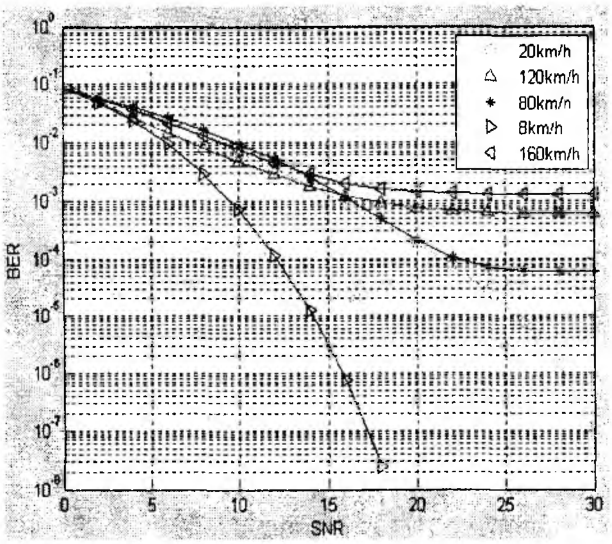

Fig. 8

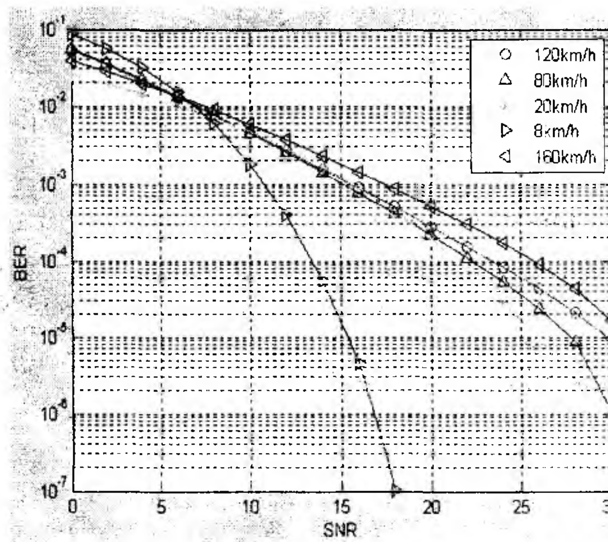

Fig. 9

Results of simulation for cases of moving terminal and using MIMO 2x2 system are shown in Fig. 8. Velocity of moving terminals were: 8 *km/h*; 20 *km/h*; 80 *km/h*; 120 *km/h*; 160 *km/h*. It can be seen that for MIMO 2x2 system values of performance is 12 *db* for 8 *km/h*, 22 *db* for 20 *km/h*, 23 *db* for 80 *km/h* while for 120 *km/h* and 160 *km/h* the performance didn't reach the 10^{-4} value.

The results of simulations for cases of moving terminal and using SIMO 1x4 system with maximal ratio combining are shown in Fig. 9. There are the performance 13 *db* with 8 *km/h*, 22 *db* with 20 *km/h*, 23*db* with 80 *km/h*, 24db with 120 *km/h* and 26 *db* with 160 *km/h*. It can see that with low velocity values the MIMO and SIMO systems have relatively the same performance, but with high velocity values SIMO system has much better performance. It means that with high velocity MIMO system has the worst performance seemingly because of spatial interference.

References: 1.*Volker Kuhn*. Wireless Communications over MIMO Channels. Applications to CDMA and Multiple Antenna Systems. University Rostock. Germany. 2006. 363 p. 2. *Jeffrey G.Andrews, Arunabha Ghosh, Rias Muhamed.* Fundamentals of WiMAX Understanding Broadband Wireless Networking, Prentice Hall 2007. 3. *Alamouti S.M.* A Simple Transmit Diversity for Wireless Commu-nications // IEEE Journal on Select Areas in Communications. Oct.1998. Vol.16. №8. p.1451-1458.

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