У роботі розглядаються головні аспекти використання в технології LTE систем MIMO та методів ортогональної частотної модуляції. Аналізуються можливості більш повного використання просторового і частотного ресурсів за рахунок адаптивного управління параметрами сигналів у часовій та частотній площинах у залежності від реальних параметрів багатопроменевого каналу зв'язку LTE

Ключові слова: LTE, MIMO, OFDMA, SC-FDMA, PAPR, SU-MIMO, MU-MIMO

В работе рассматриваются различные аспекты использования в технологии LTE систем MIMO и методов ортогональной частотной модуляции. Анализируются возможности более полного использования пространственного и частотного ресурсов за счет адаптивного управления параметрами сигналов во временной и частотной областях в зависимости от реальных параметров многолучевого канала связи LTE

Ключевые слова: LTE, MIMO, OFDMA, SC-FDMA, PAPR, SU-MIMO, MU-MIMO

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ADAPTIVE MODULATION IN LTE TECHNOLOGY BY USING OFDMA AND SC-FDMA WITH MIMO

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1. Introduction

LTE is the brand name for an emerging and fast developing technology that is considered a 4G technology and a big development compared to the existing 3G technologies. Aim for this paper is considering ability of increasing the LTE performance by using MIMO systems and frequency diversity methods like as OFDMA and SC-FDMA.

The LTE technology depends on the use of adaptive modulation in time and frequency domains, where the used adaptive modulation system in LTE ignores the different fading in different MIMO channels and different frequencies.

2. LTE Multiple Access Techniques

The OFDMA nature is well suited for MIMO operation. As the successful MIMO operation requires reasonably high SNR, with an OFDMA system it can benefit from the locally (in the frequency/time domain) high SNR that is achievable.

The basic principle of MIMO is shown in Fig. 1, where the different data streams are fed to the pre-coding operation and then onwards to signal mapping and OFDMA signal generation [1].

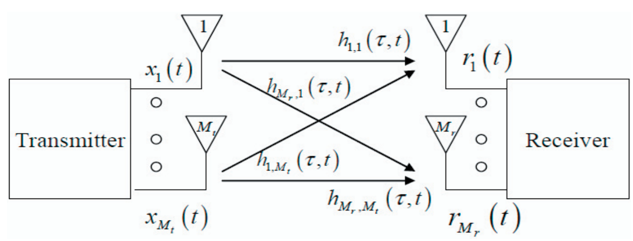


Fig. 1. MIMO principle with 2 x 2 antennas

The received signal at the M_r-th receive antenna is given by

$$r_{M_r}(t) = x_1(t) * h_{M_r,1}(\tau,t) + \ldots + x_{M_t}(t) * h_{M_r,M_t}(\tau,t) . \qquad (1)$$

The general input-output relation for a MIMO system in matrix-vector notation is given by [5]

$$r(t) = H(\tau,t) * X(t) . \qquad (2)$$

Where $x(t)$ is the M_tx1 transmission vector, $r(t)$ is the received signal, and $H(\tau,t)$ is the M_rxM_t channel matrix given by

$$H(\tau,t)=\begin{bmatrix} h_{1,1}(\tau,t) & h_{1,2}(\tau,t) & \cdots & h_{1,M_t}(\tau,t) \\ h_{2,1}(\tau,t) & h_{2,2}(\tau,t) & \cdots & h_{2,M_t}(\tau,t) \\ \vdots & \vdots & \ddots & \vdots \\ h_{M_r,1}(\tau,t) & h_{M_r,2}(\tau,t) & \cdots & h_{M_r,M_t}(\tau,t) \end{bmatrix}. \quad (3)$$

The spatial multiplexing is sending signals from two or more different antennas with different data streams and by signal processing means in the receiver separating the data streams, to increasing the peak data rates. In LTE, MIMO technologies have been widely used to improve downlink peak rate, cell coverage, as well as average cell throughput. To achieve this diverse set of objectives, LTE adopted various MIMO technologies including transmit diversity, single user (SU)-MIMO, multiuser (MU)-MIMO, closed-loop, open-loop, and dedicated beamforming (Fig. 2). The SU-MIMO scheme is specified for the configuration with two or four transmit antennas in the downlink, which supports transmission of multiple spatial layers with up to four layers to a given User Equipment (UE). The closed-loop scheme is used to improve data coverage utilizing SU-MIMO technology based on the cell-specific common reference signal while introducing a control signal message that has lower overhead [9].

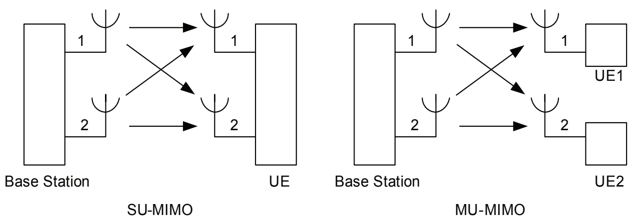


Fig. 2. SU-MIMO and MU-MIMO

Although the use of MIMO system with LTE technology increased the performance of the physical layer, our simulation showed that the channels diversity in MIMO is not fully used, and that is because the modulation system in LTE uses the same modulation in different MIMO channels. The MIMO model that uses adaptive modulation in different channels is shown in Fig. 3 [2, 6].

3. Transmission Model of OFDMA and SC-FDMA

One of the key elements of increasing the performance of LTE technology with MIMO is the use of OFDMA and SC-FDMA. In view of its advantages, the use of OFDM and the associated access technologies, OFDMA and SC-FDMA are natural choices for the new LTE cellular standard to decrease frequency selective fading while the MIMO decreases the time selective fading.

OFDMA uses OFDM it is the scheduling and assignment of resources that makes OFDMA distinctive. The OFDM diagram in Fig. 4 below shows that the entire bandwidth belongs to a single user for a period. In the OFDMA diagram, multiple users are sharing the bandwidth at each point in time [10].

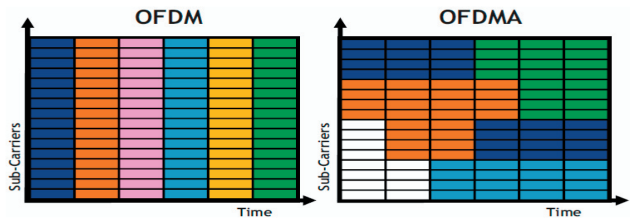


Fig. 4. OFDM vs. OFDMA

In the uplink, LTE uses a pre-coded version of OFDM called SC-FDMA. SC-FDMA has a lower PAPR (Peak-to-Average Power Ratio) than OFDM. This lower PAPR reduces battery power consumption, requires a simpler amplifier design and improves uplink coverage and cell-edge performance [8]. In SCFDMA, data spreads across multiple subcarriers, unlike OFDMA where each subcarrier transports unique data. The need for a complex receiver makes SC-FDMA unacceptable for the downlink.

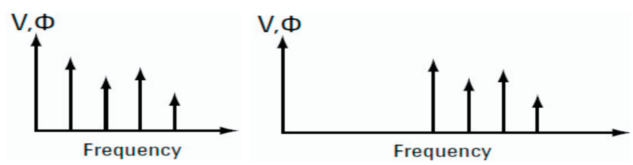


Fig. 5. Baseband and frequency shifted DFT representations of an SC-FDMA symbol

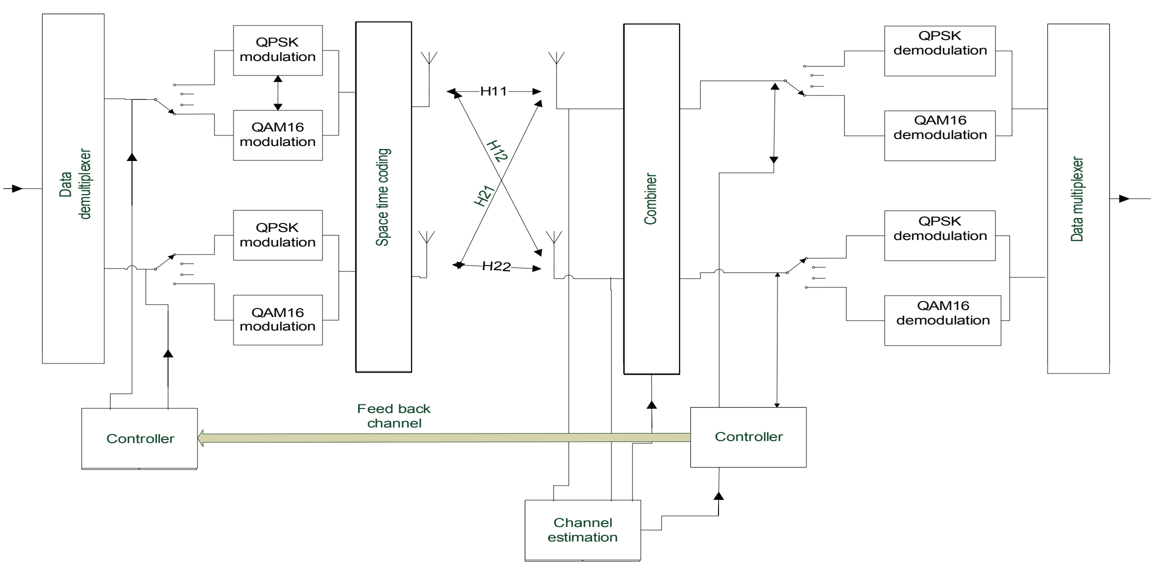


Fig. 3. 2x2 MIMO with adaptive modulation in different channels

A one-to-one correlation always exists between the number of data symbols to be transmitted during one SC-FDMA symbol period and the number of DFT bins created. This in turn becomes the number of occupied subcarriers. When an increasing number of data symbols are transmitted during one SC-FDMA period, the time-domain waveform changes faster, generating a higher bandwidth and hence requiring more DFT bins to fully represent the signal in the frequency domain. Note in Fig. 5 that there is no longer a direct relationship between the amplitude and phase of the individual DFT bins and the original QPSK data symbols. This differs from the OFDMA example in which data symbols directly modulate the subcarriers [3].

The next step of the signal generation process is to shift the baseband DFT representation of the time-domain SC-FDMA symbol to the desired part of the overall channel bandwidth. Because the signal is now represented as a DFT, frequency-shifting is a simple process achieved by copying the M bins into a larger DFT space of N bins. This larger space equals the size of the system channel bandwidth, of which there are six to choose from in LTE spanning 1.4 to 20 MHz.

The signal can be positioned anywhere in the channel bandwidth, thus executing the frequency-division multiple access (FDMA) essential for efficiently sharing the uplink between multiple users.

To complete SC-FDMA signal generation, the process follows the same steps as for OFDMA. Performing an IDFT converts the frequency-shifted signal to the time domain and inserting the CP provides the fundamental robustness of OFDMA against multipath. The relationship between SC-FDMA and OFDMA is illustrated in Fig. 6.

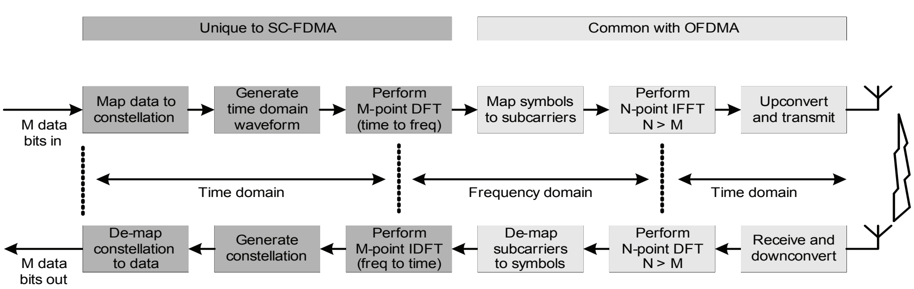


Fig. 6. Simplifi ed model of SC-FDMA and OFDMA signal generation and reception

As mentioned above, SC-FDMA subcarriers can be mapped in one of two ways: localized or distributed as shown in Fig. 7. Also as we proposed the use of adaptive modulation in different MIMO channels where the fading is time selective, we also can use the adaptive modulation in frequency domain by taking advantage of the use of OFDM with LTE [4]. LTE technology doesn't define the adaptive modulation in frequency domain which can increase the BER performance of OFDM as it is shown in [7].

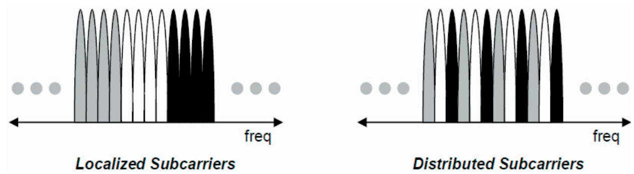
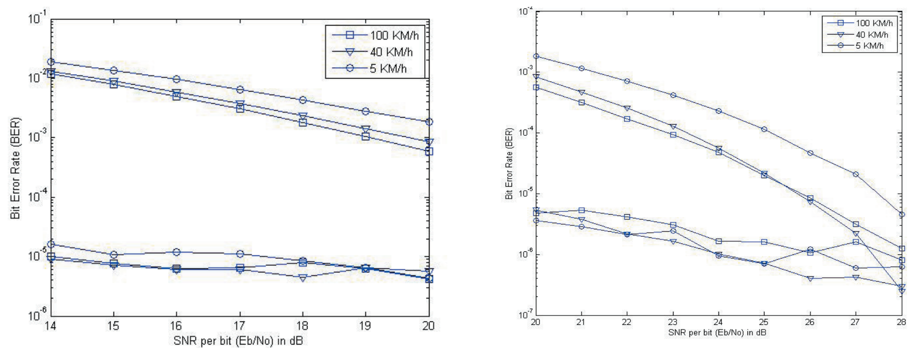


Fig. 7. SC-FDMA Subcarriers Can be Mapped in Either Localized or Distributed Mode

4. Simulation Results

The simulation results for the adaptive modulation for MIMO in open-loop are in Fig. 8.

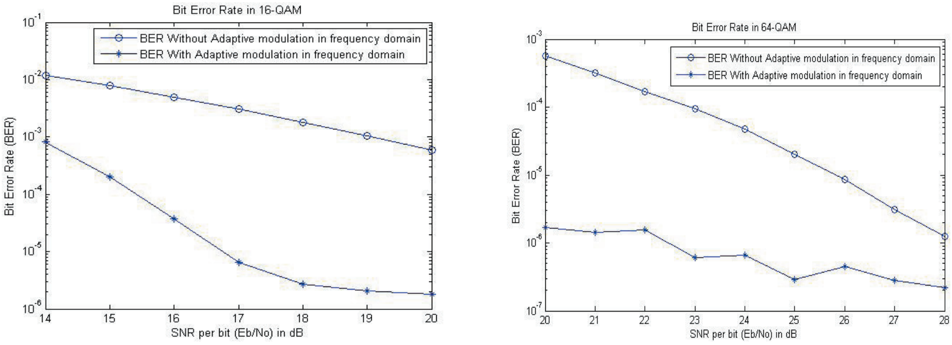


a) b)

Fig. 8. Bit error rate by using adaptive modulation in MIMO channels and without feedback QAM16 modulation a) and QAM64 modulation b)

In Fig. 8a the simulation shows the BER for adaptive modulation in MIMO channels compared to fixed QAM-16 with three speeds which are the upper curves. The BER for the three speeds as follows: 5 km/h - 20 dB, 40 km/h - 19.6 dB and 100 km/h - 19 dB, while The BER for adaptive modulation in MIMO channels is fixed under 10^{-4} for the three speed vales as we see the three lower curves in Fig. 8a. In Fig. 8b we have the same thing but by comparing the adaptive modulation to QAM64, where the three upper curves represent the BER for QAM64 with three speeds, while the lower curves represent adaptive modulation in MIMO channels. The BER results for QAM64 are as follows: 5 km/h - 25 dB, 40 km/h - 24 dB and 100 km/h - 23.8 dB, while the BER for adaptive modulation in MIMO channels is fixed under 10^{-4} for the three speeds.

The results of simulation for the adaptive modulation in frequency domain by using OFDM model are shown in Fig. 9. In Fig. 9a the simulation is made for fixed QAM16 modulation over range from 14dB to 20dB and for an adaptive modulation system in frequency, where the system also uses QAM16 but with ability of adaptive modulation over 20 carriers. In Fig. 9b is the same but QAM64 is used instead with a range from 20dB to 28dB. The results in Fig. 9 showed that by using adaptive modulation in frequency the system is able to avoid fading in frequency domain, which will lower the bit error rate.



a) b)

Fig. 9. Adaptive modulation in frequency domain QAM16 (a) and QAM64 (b)

5. Conclusion

The variety of schemes MIMO in LTE and the possibility of selecting a different schemes in adaptation to the conditions of the radio wave propagation, guarantees the achievement of high spectral efficiency up to 15 (bits / s) / Hz.

The BER increases for high order modulation 16-QAM and 64-QAM in both the multiple access techniques OFDMA and SC-FDMA used in LTE system.

The average power distributed on all frequencies in SC-FDMA is greater than OFDMA.

Therefore the peak transmits power requirements of SC-FDMA is relatively less as compare to OFDMA. Thus SC-FDMA is more power efficient.

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