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IMPROVING THROUGHPUT NETWORK USING MIMO-BEAMFORMING

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Abstract. *The performance of transmission Multi Input Multi Output (MIMO) beamforming for the multi subscriber in large cell with effective channel throughput has been investigated. The work procedure was based on singular value decomposition (SVD) using Single User (SU) in 3GPP Long Term Evolution (LTE). In LTE Single User – Multiple Input Multiple Output (SU-MIMO) operation mode, the data of a single user is transmitted simultaneously on several parallel data streams, using the available transmission resources, both in time and frequency dimensions. The simulation comparisons with beamforming and without beamforming have been studied for transmission in MIMO modulations. Despite the protection of information in LTE networks have their* *vulnerabilities. Planned for a more comprehensive analysis of statistical data and based on them to accurately determine the feasibility of using various protective mechanisms 4G networks for different user groups.*

Key words: *LTE, MIMO, SU-MIMO, MU-MIMO, beamforming, throughput, Adaptive antenna.*

Introduction

The main goal for wireless communication technology system is to design a radio access network with a high quality capacity and a wide coverage area [Release 10], in the last few years, a huge development had occurred to radio access for multiple antennas among the energy efficiency.

The model of multiple antennas was studied by Agilent technology [1]. The performance of adaptive antenna system for coverage and capacity channel was studied by Yasin, Liton [2], and the advantage technology and enhancement were studied by Seymour from Alcatel-Lucent [3] to understand the release 10 & 11 for LTE technology. For a MIMO beamforming, the white paper from Spirent, 2012 [4] gave the principles of the adaptive antenna.

The first LTE release 8, had covered up to 4 antennas, and the LTE-Advanced reached 8 antennas. In this paper we used SU multiple antennas to improve increase throughput transmission rate with beamforming.

1. Adaptive Antenna Basics

1.1. Antenna System Architecture

The System Architecture Evaluation (SAE) increases the data broadband efficiency and minimizes the number of node station, such as Radio Network Control (RNC), Support Node, and Gateway Serving. The change of these items is due to the SAE Gateway (GW) [1]. Figure 1 shows the architecture of LTE Radio Access Network (RAN) [1].

The evolved Node B (eNB) is a base station and the interface between it to direct the throughput data with RNC, interference S1, MME mobility management entity (MME) and serving gateway SGW is X2.

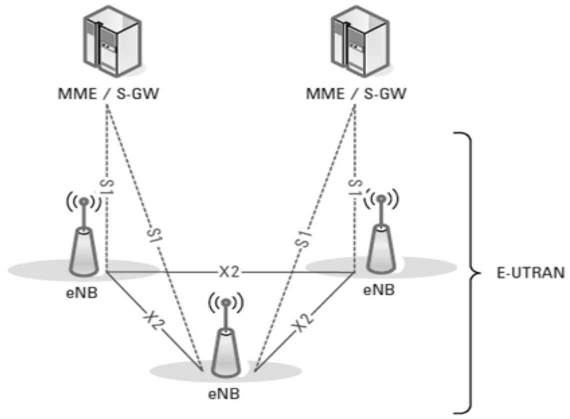

Fig. 1. LTE architecture with E-UTRAN [1]

1.2. The Adaptive Antenna System (AAS)

The adaptive antenna transmutes and receives energy between the device and the receiver. The technology of AAS is a “beamforming”. This technology considers the angle and focuses the direction with the antenna Radiation pattern for the multiple antenna base station (BS).

Every BS will be used for multiple subscribers with higher throughput to receive and transmit at the same time over the sub-channels [2]. To increase data rate transmission, the multi BS must be used for every subscribe as shown in figure 2. The adaptive antenna focuses the coverage area, capacity and direction with higher data rate for LTE technology.

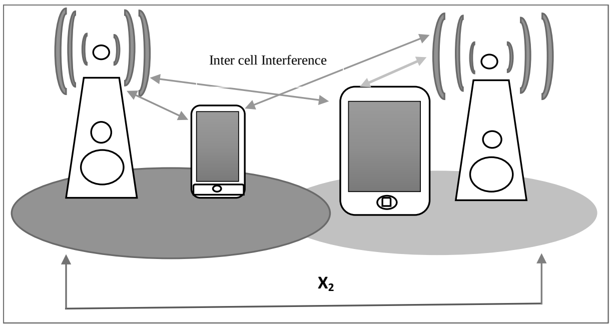

Fig.2. Multi-antenna with subscriber

2. MIMO Beamforming

Beamforming is the closed-loop transmit diversity solution adopted for LTE downlink. It is based on code-book precoding and beam forming is considered as a particular case of spatial multiplexing with only one code word and one layer. Thus, the layer mapping stage is transparent.

LTE technology went to higher levels of communication transmission. The Beamforming is incorporation of two types of different multiple antenna technology, which enable increasing data rate by spectral bandwidth. The beamforming supports the increase of coverage system, in other way Multi user MIMO (MU-MIMO) shares high data rate between multiple subscribers which increases the network efficiency as illustrated in figure 3.

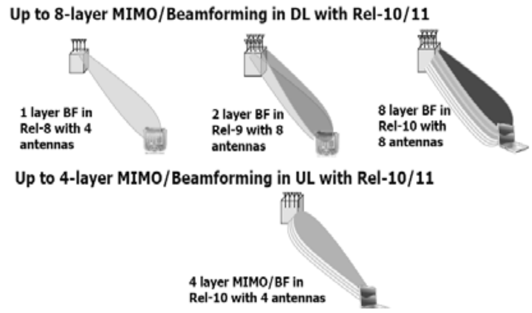

Fig.3. MIMO/Beamforming in Rel-10/11 [3]

2.1. Single MIMO Beamforming System

In MIMO, the system delivers a correlation channel between the transmitter and the receiver of a width of more than a half of the signal wave length [4, 5]. Figure 4 shows coordination MIMO beamforming. The interference channel in beamforming including spatial domain cooperation, beamforming design among cells for a predefined set of scheduled subscriber and control allocated power in each cell on frequency/ time resource of subscriber with energy flow.

In the LTE MIMO system, the increase of data rate and of capacity throughput is our target which can create beamforming with physically separating antenna elements.

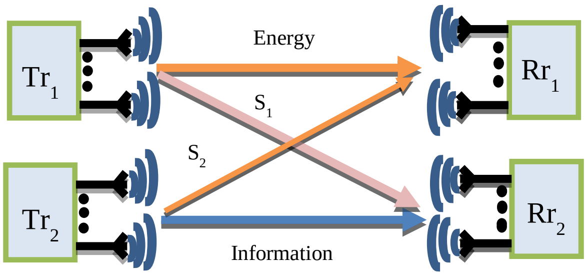

Fig.4. Interference and energy flow in beamforming

The beamforming process combines the signal from each antenna element multiplied by a complex weight vector ω. The output of a narrowband beamformer is obtained by summing up the antenna outputs

$$y(t)=\sum_{p=1}^{M_r}\omega_p^* y_i(n)=w^H y(n). \quad (1)$$

Where y(n) is receive signal vector, P is receive antenna index.

Therefore, the beamformer response, or array factor, results as

$$F(\text{и})=\sum_{p=1}^{M_r}\omega_p^* e^{[-j\frac{2\pi}{\lambda}(p-1)d\ sin\theta]}. \quad (2)$$

The complex weights ($|w|$) are computed by an optimization algorithm that maximizes a certain cost function, not necessarily the direction of the signal. A beamforming that directs the beam toward the signal needs to estimate the Direction of Arrival (DoA) by applying the weights

$$w_p=|w|e^{[-j(p-1)\frac{2\pi}{\lambda}d\ sin\theta]}. \quad (3)$$

There exist beamformers that optimize other cost functions, such as the maximum SNR proposed in [9] the MMSE, or the Least-Square (LS). These are referred to as optimal beamforming. Instead of trying to solve directly the equation for the optimal solution, iterative approaches have been proposed, referred to as adaptive algorithms.

These techniques are especially suited when the mobile environment is time-variable, and the weight vector (w^H) needs to be updated periodically. Considering the problem of minimizing the MSE between the received and transmitted signals, the cost function is

$$J(w)=E[|w^H y(n)-z(n)|^2]. \quad (4)$$

Where E is error estimation.

The optimal weights for MMSE are expressed as

$$w_{opt}=R_{yy}^{-1}r_{yd}. \quad (5)$$

Where R_{yy} is the correlation matrix [$M_r \times M_r$] of the received signal, and r_{yd} is the cross correlation vector between the transmitted data and the received signal.

2.2. Radio Frequency (RF) in MIMO Beamforming

The Beamforming is transmitted by the interference patterns that's mean the signal wave is transmitted from two and more than spatial separated points, and vice versa for the receiver side in the beamforming technology. The RF wave signal comes from the best directional antenna to enable the transmit ion by other antenna separated from the first element. The separation is half the RF carrier wavelength. Both antenna elements carry signal data to be transmitted and the signal power transmission will have the direction pattern from 0 to +/-90 degree, figure 5.

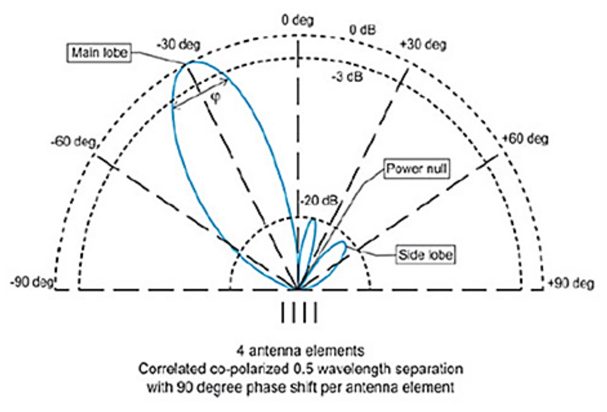

Fig.5. Radio Frequency in Beamforming [6]

2.3 Time Domain (TD) of Beamforming MIMO

Just MIMO beamforming has a spatial domain to create multiple data stream, the time domain performs duplexing, time division duplexing (TDD) it offers several advantage over frequency division duplex (FDD) system more than that is necessary.

For the single frequency band (Uplink "UL", Downlink "DL") the time slot in each directive have a seven frames structure (for the TDD fixed in resource allocation and time division "TD") as represented in [4].

Once upon a time FDD implementation beamforming is a feedback loop from the terminal to the transmitter of the DL channel.

The RF channel is a function of time, frequency and space. For the DL/UL channel, they have the same frequency dependent by space with time, and there is no different between channel states from one time to the next slot, this considered as channel estimation of DL/UL characteristics.

The array of antenna elements is weighted in order to shape the radiation diagram of the antenna pattern. In beamforming, the choice of weights depends on the algorithm used to optimize the radiation pattern which explain in section 2.1. Here, the Minimum Mean Square Error (MMSE) criterion it's used to compute the weights of the beamformer. The computation of weights in beamforming requires the knowledge of the channel coefficients. In slowly time-variant fading, the channel of a downlink Time Division Duplex (TDD) system is estimated in the uplink frame without loss of performance. On the other hand, FDD systems require a feedback channel to obtain the channel estimate at the transmitter side, since the array response is frequency dependent.

3. System Model & Simulation

A multi-user Beamforming system is shown in figure 6. It shows the downlink Single User (SU) and Multi-User (MU) environment between base station (BS) and Subscriber (K), the transmission antenna (N) and each subscriber will connected with multi-antenna.

$$x(t) = \sum_{i=1}^{K} w_i s_i(t). \tag{6}$$

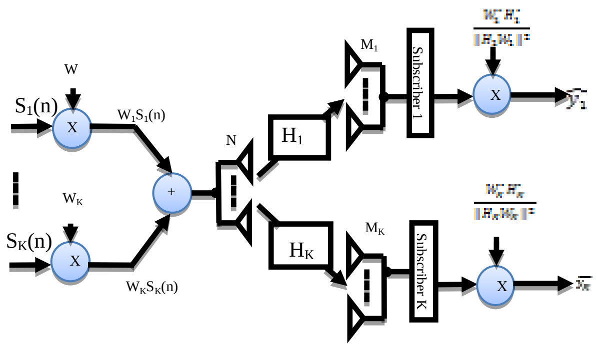

Fig.6. Block diagram of the multi-user beamforming system [8]

Where

M_i Is number of receiver antenna for the ith subscriber.

S_i Is transmitted data from Subscriber at time (t).

W_i Is Beamforming vector before transmission over channel.

The Beamforming is a mix between antenna technology and digital technology, the transmission $N \times 1$ for $x(n)$ broadcast over the channel, and the receiver vector $M_i \times 1$ at the ith subscriber is calculated from the following equation:

$$y(t) = H_i \sum_{k=1}^{K} w_k s_k(t) + z_i(t). \tag{7}$$

And the channel matrix H_i is;

$$H_i = \begin{bmatrix} h_i(1,1) & \cdots & h_i(1,N) \\ \vdots & \ddots & \vdots \\ h_i(M_i,1) & \cdots & h_i(M_i,N) \end{bmatrix}.$$

The complex Gaussian for H_i will be set of variables with base station independent for i and unit-variances [8]. There is an additive noise (z). The signal to noise ratio (SNR) for each user can be defined as $= 1/\sigma_i^2$ for the channel estimation in TDD or FDD where y is the standard deviation.

For a Single User Beamforming with a multi-receiver antenna, we can write the following equation by using equation (4):

$$y(t) = H_i x + Z_i, \quad (\mathrm{i} = 1, 2, \ldots K). \tag{8}$$

Where the time is absent in equation (5). Using the singular value decomposition (SVD) for channel matrix, Equation (5) gives:

$$H_k = U_k \mathrm{Y}_k V_k. \tag{9}$$

Where $U_k \in C^{r*r}, V_k \in C^{n*n}$, $U_k^* U_k = I$, $V_k^* V_k = I$.

And Z is noise, C is the Channel, I is the identity matrix and Y_k is $r*n$ matrix.

And for Random beamforming (RBF), equation (8) and equation (9) will be:

$$y_k = U_k \mathrm{Y}_k V_k^* V_b. \tag{10}$$

The SU-MIMO RBF will be:

$$\hat{y}_k = U_k^H \mathrm{H}_k V_b P_k s_k + U_k^H Z_k. \tag{11}$$

Where $k \in U$, P_k is the power allocation matrix; V_b is a random unitary matrix generation, and when $H_k = U_k \Lambda_k V_k^H$ the formula will be:

$$\hat{y}_k = \wedge_k \left(V_k^H V_b\right) P_k s_k + Z_k. \tag{12}$$

Where $\wedge_k$ is a diagonal matrix with SVD, and V_b is a random unitary matrix generation.

To modify V_k to V_b, the receiver must reject the interferences in the transmitter weight vector. The transmit antenna will affect the effective RBF control channel and the supplementary precoder which are included in the SU-MIMO BF, so that equations (8, 9) can be written as

$$\tilde{y}_k = \tilde{U}_k^H \left(\mathrm{H}_k W_k\right) V_b P_k s_k + \tilde{U}_k^H Z_k. \tag{13}$$

Where W_k is supplementary precoder matrix, which can be written

$$W_k = \begin{bmatrix} W_{k,1} & 0 \\ 0 & W_{k,2} \end{bmatrix}.$$

When the effective channel matrix $\tilde{H}_k$ equals the $\mathrm{H}_k W_k$ and equal the value of $\tilde{U}_k \Lambda_k V_k^H$, then the formula will be

$$\tilde{y}_k = \tilde{U}_k^H \mathrm{H}_k V_b P_k s_k + U_k^H Z_k = \tilde{\wedge}_k \left(\tilde{V}_k^H V_b\right) P_k s_k + \tilde{Z}_k. \tag{14}$$

The transmission and receive signal can be calculate from the subscriber with beamforming MIMO. The capacities of channels can be calculate according to the power and SNR values. Interferences will be calculating more perfectly between the transmitted weight vectors.

4. Results

The of accomplishment MIMO beamforming has been analyzing by using Matlab program depending on Effective Code Rates equal to 1/3 with SU-MIMO beamforming. To calculate throughput BF or no-BF, the simulations were shown using a QPSK modulation and 16-QAM modulation.

Figures (7, 8) confirmations a compression between throughput and SNR for with and without beamforming in two types of modulation. In figure 7 modulations QPSK was used, and in figure 8 modulations 16QAM was used, for two types of modulation the throughput transmission with beamforming was found to be better than without beamforming. With using QPSK, a throughput was bring into being when the SNR was zero. For 16QAM the throughput with BF was found to be higher than without BF.

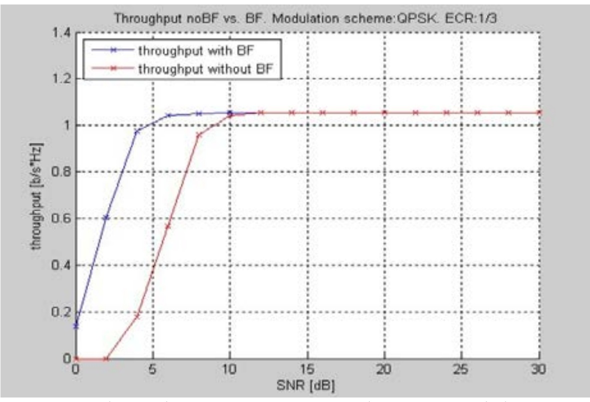

Fig.7. Throughput BF vs. no BF with QPSK modulation

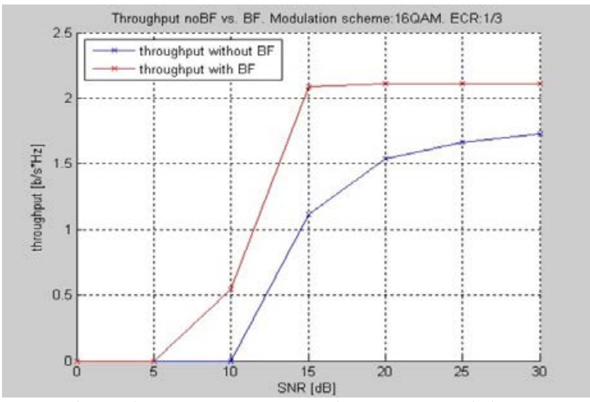

Fig.8. Throughput BF vs. no BF with 16QAM modulation

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Аль-Шурайфі М. Т., Аль-Заяді Х. Х., Рєзніков М.І., Хлапонін Ю.І. Підвищення пропускної спроможності мережі за допомогою MIMO-формування діаграми спрямованості

Анотація. *Була досліджена пропускна спроможність системи з великою кількістю входів та виходів (MIMO) при формування діаграми спрямованості у великій мережі з ефективною пропускною здатністю каналу. Робота була заснована на сингулярному розкладанні (SVD), використовуючи Single User (SU) в 3GPP Long Term Evolution (LTE). У LTE Single User - Multiple Input Multiple Output (SU- MIMO) - режим роботи, при якому дані від одного користувача передаються одночасно кількома паралельними потоками даних, використовуючи доступні ресурси мережі як за часом так і за частотою. Для порівняння пропускної здатності проведено моделювання з формуванням діаграми спрямованості і без нього для двох типів модуляції передачі потоку. Незважаючи на наявні засоби захисту інформації в мережах LTE вони мають свої уразливості. Планується провести більш детальний аналіз статистичних даних і на їх основі точно визначити доцільність використання різних захисних механізмів мереж 4G для різних груп користувачів.*

Ключові слова: *LTE, MIMO, SU-MIMO, MU-MIMO, діаграма спрямованості, пропускна спроможність, адаптивна антена.*

Аль-Шурайфи М. Т., Аль-Заяди Х. Х., Резников М.И, Хлапонин Ю.И. Повышение пропускной способность сети с помощью MIMO-формирования диаграммы направленности

Аннотация. *Была исследована пропускная способность системы с множеством входов и множеством выходов (MIMO) при формировании диаграммы направленности в крупной сети с эффективной пропускной способностью канала. Работа была основана на сингулярном разложения (SVD), используя Single User (SU) в 3GPP Long Term Evolution (LTE). В LTE Single User - Multiple Input Multiple Output (SU-MIMO) - режим работы, при котором данные от одного пользователя передаются одновременно несколькими параллельными потоками данных, используя доступные ресурсы сети как по времени так и по частоте. Для сравнения пропускной способности проведено моделирования с формированием диаграммы направленности и без нее для двух типов модуляции передачи потока. Несмотря на имеющиеся средства защиты информации в сетях LTE они имеют свои уязвимости. Планируется провести более детальный анализ статистических данных и на их основе точно определить целесообразность использования различных защитных механизмов сетей 4G для различных групп пользователей.*

Ключевые слова: *LTE, MIMO, SU-MIMO, MU-MIMO, диаграмма направленности, пропускная способность, адаптивная антенна.*

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