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Evaluation of massive multiple-input multiple-output communication performance under a proposed improved minimum mean squared error precoding

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ABSTRACT

The fundamental of a downlink massive multiple-input multiple-output (MIMO) energy-issue efficiency strategy is known as minimum mean squared error (MMSE) implementation degrades the performance of a downlink massive MIMO energy-efficiency scheme, so some improvements are adding for this precoding scheme to improve its workthat is called our proposal solution as a proposed improved MMSE precoder (PIMP). The energy efficiency (EE) study has also taken into mind drastically lowering radiated power while maintaining high throughput and minimizing interference issues. We further find the tradeoff between spectral efficiency (SE) and EE although they coincide at the beginning but later their interests become conflicting and divergent then leading EE to decrease so gradually while SE continues increasing logarithmically. The results achieved that for a single-cellular massive MU-MIMO downlink model, our PIMP scheme is the appropriate scenario to achieve higher precoding performance system. Furthermore, both maximum ratio transmission (MRT) and PIMP are suitable for performance improvement in massive MIMO results of EE and SE. So, the main contribution comes with this work that highest EE and SE are belong to use a PIMP which performs better appreciably than MRT at bigger ratio of number of antennas to the number of the users.

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1. INTRODUCTION

Nowadays regarding to our society problem of global warming now has become an important concerned for entire world. It is claiming to reduce consumption energy of industries and information and communication technology (ICT) while the needs of data traffic for 5G wireless networks are growing which are related to power consumption growing [1]–[4]. Hence, massive multiple-input multiple-output (MIMO) is suitable for such scenarios to provide friendly network or green communication system [5], [6]. Massive MIMO should improve system performance in terms of energy efficiency without requiring the deployment of many base stations in the network. By using simple linear precoding schemes, massive MIMO can significantly reduce radiated power while also providing high throughput and minimizing interference issues [7]–[10]. Because interference is a major roadblock to improving wireless system performance, large MIMO is one contender to address/overcome this limitation [11], [12].

The previous standards of conventional systems did not pay much attention to energy-efficiency issues, and the capacity of those conventional systems is limited primarily due to bandwidth scarcity, as shown in [13]. With aggressive degrees of freedom, power reduction as well as network performance improvement is possible. Therefore, by deploying massive MIMO, the traditional systems with 50Watts amplifiers consumption will be replaced by multi-low-power devices in order of milliwatts consumptions that will reduce significantly the power emitted [14], [15]. It is widely known that massive MIMO uses very large base station (BS) M-antenna to improve system performance. This is principal reason why circuit consumption power should not really be neglected because of each BS antenna required some dedicated circuit elements. This factor is been ignored as widely assumed in literature that total consumption power equals to addition of emitted power and the fixed power (accounts for circuit consumption power) [16]. Even though this model is used widely, but this scheme seems to be a misleading assumption because it can result energy efficiency (EE) unbounded as M-antenna goes to very large. This can be understood because there are no considerations of analog-circuits radio frequency (RF) and the processing of digital signal that increase with K-user and M-antenna. However, this work is motivated to evaluate also compare energy-efficiency precoding performance driven by the analog-circuits consumption power model with the channel station information (CSI) imperfect in realistic way as well practical interest.

In order to reap advantages from massive MIMO system, then we will deploy a simple linear processing signal scheme to achieve the precoding performance. There always exists the tradeoff phenomenon between performance achievement and complexity of system. Regarding regular MIMO, both schemes linear precoding as well nonlinear precoding can then be used [17]–[19]. However, with increasing number of BS M-antenna, linear precoder methods, such as minimum mean squared error (MMSE) and matched filtering (MF) are indicated to be closer or near-optimal [20]–[23]. Hence, this concept seems to be more practical in implementation with small complexity scheme of linear pre-coding in massive MIMO technologies. For this basic reason, our study will be mainly conducted on linear precoding method. Stimulate a great interest of our work in linear precoding scheme and particularly on the simple linear precoder MMSE for EE precoding performance evaluation, then we called this technique as proposed improved MMSE precoding (PIMP) scheme.

For our proposed PIMP scheme, we give a novel consumption-power and evaluate massive MIMO EE using our recommended model of consumption-power in a single-cellular network. After taking into account reducing radiated power while maintaining high throughput and limiting interference issues, the EE is unlikely to be steadily increased in tandem with the BS M-antenna. Our model is further built on the long-term evolution (LTE) Base-station transmission-power situation with huge array-elements for this goal. In our studied model, loss factors and scale factors are employed.

2. METHOD

By assuming the time-division duplexing (TDD) operating mode, a single-cellular massive MIMO downlink at BS with transmitter M-antenna supports K user terminals with only a single-antenna that share the same resource. The downlink CSI is acquired by the BS through uplink pilot training in this TDD mode. The obtained CSI will subsequently be used to create MMSE precoding vectors for downlink (forward-link) spatial multiplexing. As shown in Figure 1, BS is supposed to apply this linear precoding strategy to handle signals before delivering them to all K user terminals in this scenario. The assumptions are based on the fact that service station has a big number of M-antennas as compared to the number of K users provided simultaneously under the management of CSI with incomplete knowledge.

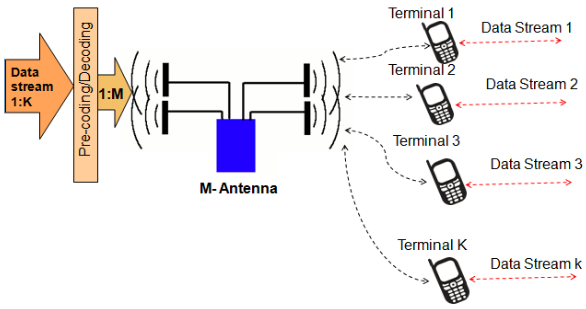

Figure 1. Downlink operation mode with massive MIMO technology

The perfect CSI of the complex gain H channel matrix is allowed in order to retrieve the broadcast data stream at the destination. However, in fact, incorrect CSI estimates can be found in a wide range of wireless systems. In the case of incomplete CSI, the BS uses channel reciprocity to estimate the appropriate channel and construct the downlink pre-coding matrix. [24], [25] They discussed a channel imperfection system in which BS only has a rudimentary awareness of CSI but uses it. The following relationship should be met by this channel estimation,

$$\mathrm{H} = \sigma\widehat{H} + \sqrt{(1\text{-}\sigma^2)}E_{\mathrm{est}} \tag{1}$$

where E_{est} refers as the channel matrix of estimation error vector, and $i.i.d.CN(\text{zero}, \text{one})$ signifies the elements (zero, one). σ determines the CSI precision or, high accurately, the availability of the accurate channel with a higher number signifying greater CSI. With MMSE estimator channel utilization, $\widehat{H}$ and E are independent.

With this single-cellular Massive MIMO downlink system, the BS is equipped with so M antennas that transmit to $K<<M$ single-antenna user terminals concurrently. Both the the number of antennas and users are large, with a constant $\alpha=M/K$ ratio. With BS CSI imperfection, we anticipate small-scale case fading. The BS computed CSI is used to produce the precoded signals vector, which is subsequently broadcast simultaneously to user terminals. Moreover, BS antennas broadcast $M\times 1$ vectors to each antenna, resulting in K user terminals receiving $K\times 1$ signal vectors designated by the symbol y and supplied,

$$\mathrm{y} = \sqrt{\rho_{\mathrm{d}}}\mathrm{H}^{\mathrm{T}}\mathrm{s} + \mathrm{n} \tag{2}$$

where ρ_d denotes downlink transmit power, the superscript $(.)^{\mathrm{T}}$ denotes matrix transpose, s means the precoded version of data symbols q, and n denotes the $K\times 1$ noise vector with $i.i.d.CN(0,1)$ elements, and n denotes the precoded version of data symbols q.

The transmission power is normalized as $\{\|s\|^2\} = 1$, which means that each antenna broadcasts at a power of ρ_d/M, while the word H stands for the $M\times K$ channel matrix, which corresponds to small-scale MIMO channel rayleigh fading, and $i.i.d.CN(0,1)$ entries are assumed. To measure precoding performance in a realistic manner in practice, an estimated channel is assumed rather than a precise channel assumption.

The implementation of MMSE precoding technique considers as the best and preferable solution to be used at the MU-MIMO downlink model. This technique is implemented and gained originally using the approach of MSE calculation. Since the average power is used for each possible transmit antenna, so the Lagrangian method is used for derivation to get the optimal solution for our PIMP.

Initially, we begin to obtain the MSE of the signal. The MSE (ε) can be written as [12],

$$\varepsilon = \mathbb{E}[\|\delta y - x\|^2] \tag{3}$$

where δ is a scalar of Wiener filter. And let O defines as a linear precoding matrix and then, O and δ are determined to have a minimum the value of MSE subject to a power constraint. So, we have,

$$\begin{gathered}[\hat{O}, \hat{\delta}] = arg \min_{O,\delta} \varepsilon \\ s.t. \mathbb{E}[\|s\|^2] = P_{tr}\end{gathered} \tag{4}$$

to solve this optimization problem, the Lagrangian method is used for this purpose. Then,

$$\mathcal{L}(O, \delta, \lambda) = \mathbb{E}[\|\delta y - x\|^2] - \lambda tr(s^H s - P_{tr}) \tag{5}$$

where $\lambda \in \mathbb{R}$ is the Lagrangian parameter. Now, to determine O, δ, and $\boldsymbol{\lambda}$ so as minimizing the value of MSE, deriving it with respect to O, and δ. Consequently, O_{MMSE} can be given by,

$$O_{MMSE} = \frac{1}{\delta} H^* (H^T H^* + \frac{K}{P_{tr}} I_K)^{-1} \tag{6}$$

where,

$$\delta = \sqrt{\frac{tr(vv^H)}{P_{tr}}} \tag{7}$$

and,

$$\upsilon = H^* \left(H^T H^* + \frac{K}{P_{tr}} I_K\right)^{-1} \tag{8}$$

we can show our proposed improvement in working of MMSE precoding (PIMP) by presenting the details of derivations (6) and (7), this derivative is following as [26]. From (4), we have,

$$\varepsilon = \mathbb{E}[\|\delta y - x\|^2] \tag{9}$$

where *y* is a received signal vector, *x* is a transmitted signal vector, *O* is a precoding matrix and δ is a scalar of Wiener filter. We find the precoding matrix *O* and δ to minimize the MSE under the average power constrain P_{tr} described an objective function in expression (5).

To solve the optimization problem (4), we use the Lagrangian method. We define the Lagrangian function,

$$\mathcal{L}(O, \delta, \lambda) = \epsilon - \lambda(tr(O^H O) - P_{tr}) \tag{10}$$

where $\lambda \, \epsilon \, \mathbb{R}$ is the Lagrangian factor. Then, we will derive with respect to *O*. We have,

$$\frac{\partial \mathcal{L}(O,\delta,\lambda)}{\partial O} = 2\delta^2 H^* H^T O - 2\lambda O - 2\delta H^* = 0 \tag{11}$$

therefore, we have,

$$O(\mu) = \frac{1}{\delta} H^* (H^T H^* + \mu I_K)^{-1} \tag{12}$$

here, we replace $-\frac{\lambda}{\delta^2}$ by $\mu \in \mathbb{R}$. Owing to the power constraint in expression (4), δ can be represented as a function of μ. More precisely,

$$\delta(\mu) = \sqrt{\frac{\mathrm{tr}\left(\mathrm{H^T H^*}\left(\mathrm{H^T H^*} + \mu \mathrm{I_K}\right)^{-2}\right)}{\mathrm{P_{tr}}}} \tag{13}$$

in this situation, we will need to transfer (or reduce) the constrained optimization case into unconstrained optimization case, i.e., constraints is changed from *O* and δ into only μ. In detailed description, it can express as,

$$\hat{\mu} = arg \min_{\mu} \epsilon \, (O(\mu), \delta(\mu)) \tag{14}$$

we take a derivative with respect to μ equal to zero and we can obtain,

$$\hat{\mu} = \frac{tr(I_K)}{P_{tr}} = \frac{K}{P_{tr}} \tag{15}$$

substituting (15) into (13) and (14), the optimal MMSE precoding $\hat{O}$ is given by,

$$\hat{O} = \frac{1}{\hat{\delta}} H^* \left(H^T H^* + \frac{K}{P_{tr}} I_K\right)^{-1} \tag{16}$$

where,

$$\hat{\delta} = \sqrt{\frac{tr\left(H^T H^* \left(H^T H^* + \frac{K}{P_{tr}} P_{tr} I_K\right)^{-2}\right)}{P_{tr}}} \tag{17}$$

2.1. Achieveable rate with PIMP scheme

To evaluate energy efficiency network performance, then we need to know achievable rate which follows the famous Shannon capacity as reference. It describes how maximum rate that can transmit through channel. $Ergodic$ channel is basically assumed and all the parameters are Gaussian random. In massive

MIMO scheme $ergodic\ R_{sum}$ (sum rate) be chosen to describe its effectiveness. Due to simplicity analysis reason of spectral efficiency network we consider single-cellular where all user terminals share a constant transmit power equally in the downlink system.

From (2), the received vector with MMSE can be expressed as,

$$y = \frac{1}{\delta} H^T \left[H^* (H^T H^* + \frac{K}{P_{tr}} I_K)^{-1} \right] x + n \tag{18}$$

where,

$$\delta = \sqrt{\frac{tr(H^T H^* (H^T H^* + \frac{K}{P_{tr}} I_K)^{-2})}{P_{tr}}} \tag{19}$$

firstly, we rewrite the precoding expression stated at (6) for MMSE as,

$$O_{MMSE} = \frac{1}{\delta} (H^* H^T + \frac{K}{P_{tr}} I_M)^{-1} H^* \tag{20}$$

substituting expression (20) in (18), then we have,

$$y = \frac{1}{\delta} H^T (H^* H^T + \frac{K}{P_{tr}} I_M)^{-1} H^* x + n \tag{21}$$

the received vector of k^{th} user with MMSE is given by,

$$\mathrm{y_k} = \frac{1}{\delta} \mathrm{h_k^T} (\mathrm{H^* H^T} + \frac{\mathrm{K}}{\mathrm{P_{tr}}} \mathrm{I_M})^{-1} \mathrm{h_k^* x_k} + \frac{1}{\delta} \sum_{\mathrm{i=1, i \neq k}}^{\mathrm{K}} \mathrm{h_k^T} (\mathrm{H^* H^T} + \frac{\mathrm{K}}{\mathrm{P_{tr}}} \mathrm{I_M})^{-1} \mathrm{h_i^* x_i} + \mathrm{n_k} \tag{22}$$

then, the achievable rate of k^{th} user with MMSE is given by,

$$\mathrm{R_k^{MMSE}} = \mathbb{E} \left[\log_2 \left(1 + \frac{\frac{1}{\delta^2} \left| \mathrm{h_k^T} (\mathrm{H^* H^T} + \frac{\mathrm{K}}{\mathrm{P_{tr}}} \mathrm{I_M})^{-1} \mathrm{h_k^*} \right|^2}{1 + \frac{1}{\delta^2} \sum_{\mathrm{i=1, i \neq k}}^{\mathrm{K}} \left| \mathrm{h_k^T} (\mathrm{H^* H^T} + \frac{\mathrm{K}}{\mathrm{P_{tr}}} \mathrm{I_M})^{-1} \mathrm{h_i^*} \right|^2} \right) \right] \tag{23}$$

2.2. Energy efficiency with PIMP scheme

The downlink eEE for our model can be given using (23), and then the achievable sum rate for MMSE is given by,

$$\mathrm{R^{MMSE}} = \sum_{\mathrm{k=1}}^{\mathrm{K}} \mathrm{R_k^{MMSE}} \tag{24}$$

using (23), (24) will be as,

$$\mathrm{R^{MMSE}} = \sum_{\mathrm{k=1}}^{\mathrm{K}} \mathbb{E} \left[\log_2 \left(1 + \frac{\frac{1}{\delta^2} \left| \mathrm{h_k^T} (\mathrm{H^* H^T} + \frac{\mathrm{K}}{\mathrm{P_{tr}}} \mathrm{I_M})^{-1} \mathrm{h_k^*} \right|^2}{1 + \frac{1}{\delta^2} \sum_{\mathrm{i=1, i \neq k}}^{\mathrm{K}} \left| \mathrm{h_k^T} (\mathrm{H^* H^T} + \frac{\mathrm{K}}{\mathrm{P_{tr}}} \mathrm{I_M})^{-1} \mathrm{h_i^*} \right|^2} \right) \right] \tag{25}$$

to solve the inverse formula of $\mathbb{E} \left[\frac{\frac{1}{\delta^2} \left| \mathrm{h_k^T} (\mathrm{H^* H^T} + \frac{\mathrm{K}}{\mathrm{P_{tr}}} \mathrm{I_M})^{-1} \mathrm{h_k^*} \right|^2}{1 + \frac{1}{\delta^2} \sum_{\mathrm{i=1, i \neq k}}^{\mathrm{K}} \left| \mathrm{h_k^T} (\mathrm{H^* H^T} + \frac{\mathrm{K}}{\mathrm{P_{tr}}} \mathrm{I_M})^{-1} \mathrm{h_i^*} \right|^2} \right]$ which is the signal-to-interference-plus-noise ratio of MMSE.

Accordingly, from (22), the desired signal of k^{th} user is given by,

$$\mathrm{Ds} = \frac{1}{\delta} \mathrm{h_k^T} (\mathrm{H^* H^T} + \frac{\mathrm{K}}{\mathrm{P_{tr}}} \mathrm{I_M})^{-1} \mathrm{h_k^* x_k} \tag{26}$$

by using the matrix inverse lemma which it is described at [26] and we can be noting that,

$$(\mathrm{H^* H^T} + \frac{\mathrm{K}}{\mathrm{P_{tr}}} \mathrm{I_M})^{-1} = (\mathrm{H_k^* H_k^T} + \mathrm{h_k^* h_k^T} + \frac{\mathrm{K}}{\mathrm{P_{tr}}} \mathrm{I_M})^{-1} \tag{27}$$

Then,

$$(H^*H^T + \frac{K}{P_{tr}} I_M)^{-1} h_k^* = \frac{(H_k^* H_k^T + \frac{K}{P_{tr}} I_M)^{-1} h_k^*}{1 + h_k^T (H_k^* H_k^T + \frac{K}{P_{tr}} I_M)^{-1} h_k^*} \tag{28}$$

where H_K is the channel matrix with K^{th} vector removed. Using (28), the desired signal power is given by,

$$\mathbb{E}[Ds\ Ds^H] = \frac{1}{\delta} h_k^T \frac{(H_k^* H_k^T + \frac{K}{P_{tr}} I_M)^{-1} h_k^*}{1 + h_k^T (H_k^* H_k^T + \frac{K}{P_{tr}} I_M)^{-1} h_k^*} \tag{29}$$

the interference expression of other users is given by,

$$I_f = \frac{1}{\delta} \sum_{i=1, i\neq k}^{K} h_k^T (H^*H^T + \frac{K}{P_{tr}} I_M)^{-1} h_i^*\ x_i \tag{30}$$

then, the interference power is given by,

$$\mathbb{E}\left[I_f I_f^H\right] = \frac{1}{\delta^2} \sum_{i=1, i\neq k}^{K} \sum_{j\neq k}^{K} h_k^T (H^*H^T + \frac{K}{P_{tr}} I_M)^{-1} h_i^*\ \delta_{i,j} \times h_j^T (H^*H^T + \frac{K}{P_{tr}} I_M)^{-1} h_k^*$$
$$= \frac{1}{\delta^2} h_k^T\ (H^*H^T + \frac{K}{P_{tr}} I_M)^{-1}\ H_k^* H_k^T\ (H^*H^T + \frac{K}{P_{tr}} I_M)^{-1} h_k^* \tag{31}$$

using (28) and defining L_k and U_k as,

$$L_k = h_k^T (H_k^* H_k^T + \frac{K}{P_{tr}} I_M)^{-1} h_k^* \tag{32}$$

$$U_k = h_k^T (H_k^* H_k^T + \frac{K}{P_{tr}} I_M)^{-1} H_k^* H_k^T (H_k^* H_k^T + \frac{K}{P_{tr}} I_M)^{-1} h_k^* \tag{33}$$

then, the SINR becomes,

$$SINR = \frac{\frac{1}{\delta^2} L_k^2}{\frac{1}{\delta^2} U_k + (1 + L_k)^2 \sigma_n^2} \tag{34}$$

where $\sigma_n^2 = 1$ is the noise variance.

Now, in order to have the final expression of SINR, we will simplify (34) as shown in Appendix. Then we have,

$$SINR = \frac{\alpha\ (Z(r,c))^2}{\left[\alpha + (1 + Z(r,c))^2\right]\left[Z(r,c) + c\frac{d}{dc} Z(r,c)\right]} \tag{35}$$

where $\alpha = \frac{P_{tr}}{\sigma_n^2} = P_{tr}$ since $\sigma_n^2 = 1$, $r = \frac{K}{M}$ and $c = \frac{K}{MP_{tr}}$.
then, we substitutes (35) in (25), which it will give,

$$R^{MMSE} = \sum_{k=1}^{K} \log(1 + SINR) = K \log(1 + SINR) \tag{36}$$

Then, we have

$$EE_{MMSE} = \frac{R^{MMSE}}{P_{tr} A + B + MC} \tag{37}$$

Let $r = \frac{K}{M}$ be a fixed ratio between the number of antennas *M* and served users *K*, and let $c = \frac{K}{MP_{tr}}$, so the expression (32) becomes:

$$L_k = \frac{1}{M} h_k^T\ (\frac{1}{M} H_k^* H_k^T + cI_M)^{-1} h_k^* \tag{38}$$

As *M* and *K* approaches to infinity,

$$L_K \rightarrow Z(r,c) = \int_0^{\infty} \frac{1}{y+c} f_r(y) d_y \tag{39}$$

where,

$$f_r(y) = (1-r)^+ \delta(y) + \frac{\sqrt{(y-i)^+(j-y)^+}}{2\pi y} \tag{40}$$

with,

$$i = \left(1-\sqrt{r}\right)^2 \ and \ j = \left(1+\sqrt{r}\right)^2 \tag{41}$$

And according to [21], expression (38) will be solved as:

$$Z(r,c) = \frac{1}{2}\left[\sqrt{\frac{(1-r)^2}{c^2} + \frac{2(1+r)}{c} + 1} + \frac{1-r}{c} - 1\right] \tag{42}$$

and,

$$Z(r,c) = \frac{1}{2}\left[\sqrt{\frac{\left(1-\frac{K}{M}\right)^2}{\left(\frac{K}{MP_{tr}}\right)^2} + \frac{2\left(1+\frac{K}{M}\right)}{\frac{K}{MP_{tr}}} + 1} + \frac{1-\frac{K}{M}}{\frac{K}{MP_{tr}}} - 1\right]$$

Then,

$$Z(r,c) = \frac{1}{2}\left[\sqrt{\left(\frac{M}{K}-1\right)^2 P_{tr} + 2\left(1+\frac{M}{K}\right)P_{tr} + 1} + \left(\frac{M}{K}-1\right)P_{tr} - 1\right] \tag{43}$$

Similarly for U_k and $\frac{1}{\delta^2}$ as M and K go to infinity

$$U_k \rightarrow Z(r,c) + c\frac{d}{dc}Z(r,c) \tag{44}$$

where,

$$c\frac{d}{dc}Z(r,c) = \frac{1}{2c}\left[\frac{-(1-r)^2 - c(1+r)}{\sqrt{\frac{(1-r)^2}{c} + 2(1+r) + c}} + r - 1\right] \tag{45}$$

$$= \frac{MP_{tr}}{2K}\left[\frac{-\left(1-\frac{K}{M}\right)^2 - \frac{K}{MP_{tr}}\left(1+\frac{K}{M}\right)}{\sqrt{\frac{MP_{tr}}{K}\left(1-\frac{K}{M}\right)^2 + 2\left(1+\frac{K}{M}\right) + \frac{K}{MP_{tr}}}} + \frac{K}{M} - 1\right] \tag{46}$$

In massive MU-MIMO system, $\frac{1}{\delta^2}$ will be converged as:

$$\frac{1}{\delta^2} \rightarrow \frac{P_{tr}}{Z(r,c) + c\frac{d}{dc}Z(r,c)} \tag{47}$$

Now, the SINR under MMSE is given by

$$SINR = \frac{\alpha\left(Z(r,c)\right)^2}{\left[\alpha + \left(1+Z(r,c)\right)^2\right]\left[Z(r,c) + c\frac{d}{dc}Z(r,c)\right]} \tag{48}$$

where $\alpha = \frac{P_{tr}}{\sigma_n^2} = P_{tr}$ since $\sigma_n^2 = 1$.

3. RESULTS AND DISCUSSION

We will analyze the massive MIMO EE in a single-cellular network based on our PIMP method using simulation data. After accounting for the reduction in transmission-antenna radiated power, the EE is unlikely to be steadily raised in tandem with the BS M-antenna. Our model is further built on the LTE Base-station transmission-power situation with huge array-elements for this goal.

Figure 2 plots energy-efficiency versus different BS number of M-antenna at different transmit powers 0dB and 10dB. Additionally, by considering two different scenarios perfect-CSI (σ^2=1) and imperfect-CSI (σ^2=0.50) with same transmission power 0dB. While 10dB transmit power further is driven only with imperfect-CSI analysis. All simulation curves show that EE can increase at first and later decreases after reaching the optimal M-antenna value corresponding to optimal EE value for both schemes. Regarding perfect and imperfect CSIs, PIMP scheme has better performance over maximum ratio transmission (MRT) one within a large range $\alpha=M/K$ after the crossing-point while MRT outperforms PIMP scheme in a small range $\alpha=M/K$ before the active BS M-antenna reaches the crossing-point, these result have been confirmed by the theoretical analysis in previous section.

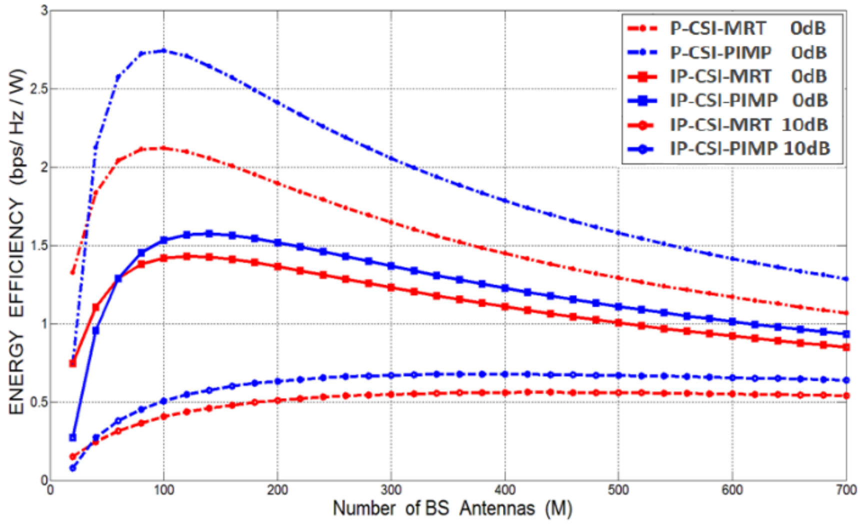

Figure 2. Performance for different precoding schemes of MIMO downlink systems

Figure 3 shows the required transmit power and relative consumption of total power in downlink versus BS number of M-antenna for both precoding techniques, MRT and PIMP. Considering three scenarios here, where our scenario assumes that the required radiated power to achieve more than the 1bps/Hz per user terminal under the given target spectral efficiency SE with 20bps/Hz used to be shared equally among the 15 number of user terminals. We observe that if the no. of antenna increases, then the radiated power required in each scenario and for each pre-coder decreases except only the case where sum-rate is equal to K number of terminals. In addition, by comparing the two-pre-coding performance MRT and PIMP schemes, it shows PIMP scheme requires less emitted power than the MRT scheme for the first scenario while the MRT scheme requires less emitted power than the PIMP scheme for the second scenario, however the gap is too small. Besides, when the sum-rate SE and K user terminals are the same order number then the equal power is required, that is, for the third scenario, in order so to achieve the 1bps/Hz per user terminal where we assume that sum-rate 15bps/Hz is shared equally among all the 15 user terminals, this implies that the two pre-coders require same radiated power further illustrated by Figure 3.

Figure 4 illustrates tradeoff phenomenon between EE/SE in massive MIMO technology with respect to different numbers of BS M-antenna with CSI imperfect. First of all, the Figure 4 illustrates that serving 15 autonomous user terminals with imperfect-CSI, it is remarkable from the curves that results have given reason to massive MIMO, i.e., SE can improve with increasing BS M-antenna number. We observe MRT precoding performance takes advantage whenever the range ratio of $\alpha=M/K$ smaller or whenever number of BS M-antenna smaller compared to K user terminals whereas PIMP precoding performance will be better whenever the range ratio of $\alpha=M/K$ larger compared to number of the K autonomous. We also note as BS antennas M increases the performance gap between the two pre-coders increases in PIMP favor pre-coder that means PIMP scheme works well in a single-cellular massive MIMO scheme. In addition, according to relationship between SE and the total amount power consumed that represents EE. Hence, need of future generation networks is to enhance this SE but this action may be a tradeoff phenomenon which leads to decrease as shown expected EE by Figure 4.

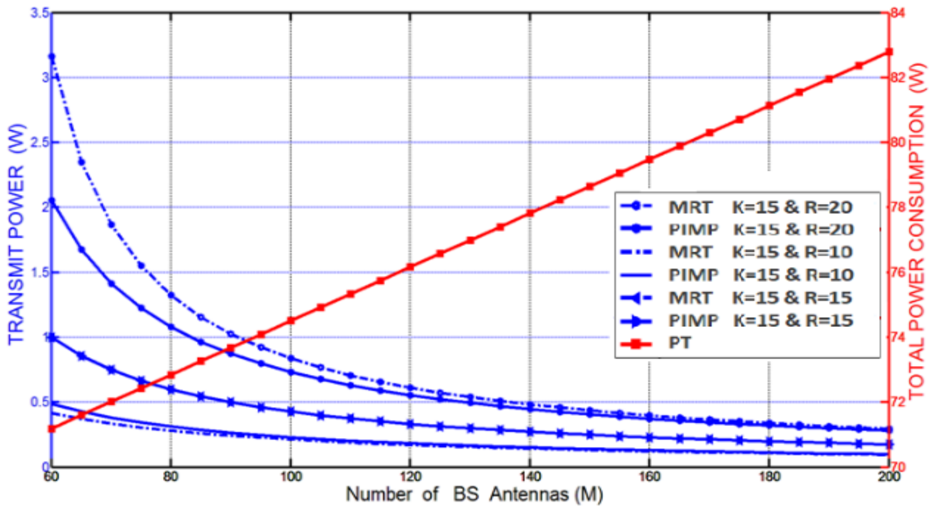

Figure 3. Transmit power vs. no. of BS antennas of MIMO downlink systems

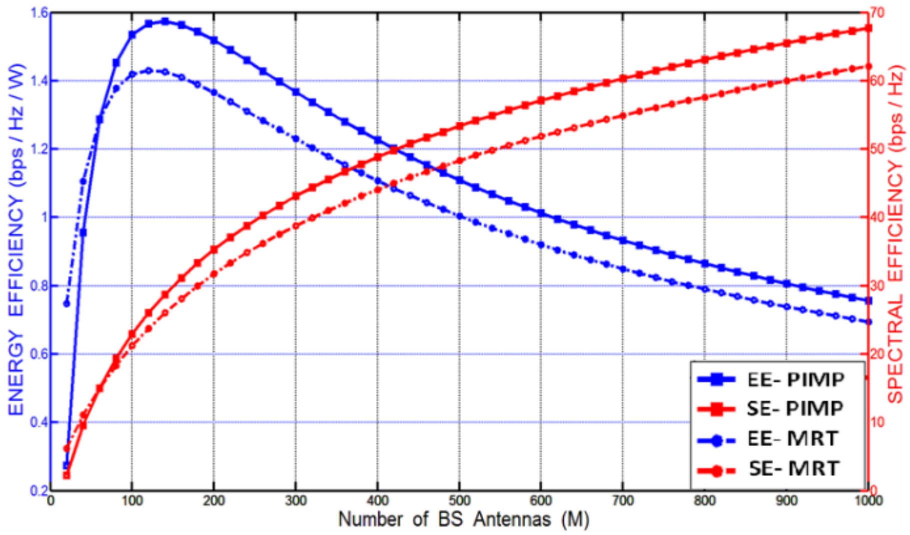

Figure 4. Energy-efficiency & spectral-efficiency tradeoff of MIMO downlink systems

4. CONCLUSION

Simulation results showed that less radiated power is required by the PIMP scheme compared to the MRT scheme in order also to achieve bigger sum-rate, in turn the MRT scheme requires less radiated power compared to PIMP scheme to achieve lower sum-rate in a single-cellular system of massive MIMO. As illustrated there is tradeoff phenomenon when transmit power decreases then inversely power consumption of total system increases, this is the reason why massive MIMO is said to be power-efficient in transmission or radiation. Simulation results submitted another phenomenon of EE-SE tradeoff, firstly, both EE-SE increase, but when EE achieves its maximal value then it starts decreasing while SE is continuously increasing. The cause is that circuit consumption power increases with BS M-antenna. Moreover, the results illustrate that the highest EE of PIMP and MRT are higher compared to so their SEs respectively. While the highest SE of PIMP and MRT are also higher compared to their EEs respectively, this explains the tradeoff phenomenon. Additionally, the EE and the SE of PIMP precoding have better performance at higher ratio $\alpha = M/K$ while the

EE and the SE of MRT precoding are the better choice performance at small ratio α=*M/K*. In which the highest EE and the highest SE belong to PIMP that performs better appreciably than MRT at bigger ratio α=*M/K*. However, when the ratio α=*M/K* is small then MRT would be best choice performance.

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