Indonesian Journal of Electrical Engineering and Computer Science
Vol. 29, No. 3, March 2023, pp. 1520~1528
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v29.i3.pp1520-1528

Linear precoder optimization of spectral efficiency of time division duplex hyper MIMO system with pilot contamination

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Article Info

Article history:

Received Mar 23, 2022
Revised Oct 13, 2022
Accepted Oct 24, 2022

Keywords:

Channel estimation
Contaminated pilot
Hyper MIMO multi-user
Minimum mean square error
Spectral efficiency

ABSTRACT

Our work is developed in context of studing Massive MIMO in a 5G context. The aim is to optimize spectral efficiency of several users hyper MIMO system during Uplink communication in a multi-cell contaminated pilot environment, using a new type of precoders called single cell-minimum mean square eroor (S-MMSE) and multicell-minimum mean square eroor (M-MMSE). Indeed, we address two key and well-known issues of massive multi-user MIMO (MU-MIMO) environments in a test-driven development (TDD) operation scheme, namely acquisition of uplink channel state information (UL) and optimisation of the bit stream per unit frequency, the spectral efficiency (SE). From a practical point of view, these two notions are inclusively linked. Indeed, a very good channel estimation leads to a better spectral efficiency. In our approcah, we derive from the minimum mean square error estimator (MMSE) to two new types of precoders that can operate in a multicell environment with a contaminated pilot sequence, namely the S-MMSE and the M-MMSE. A comparative study performance of these classical precoders such as regulated zero forcing (RZF), ZF (Zero Forcing) and MR (Minimum Ratio) encountered in multi-antenna processing shows an improvement of nearly 51% in terms of system gain and spectral efficiency.

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1. INTRODUCTION

Massive MIMO systems or high integration scale antenna systems or multi-user Massive MIMO represent a new research direction in microwave data transmission [1]. In terms of maximising spectral and energy efficiency, hyper MIMO has become the technological way forward. Due to the coherent operation of the different radiating elements that make up multi-user massive MIMO, there is both a considerable gain in diversity and or multiplexing. The high number of radiating elements that make up massive MIMO gives it the ability to significantly increase throughput also, independent blocks of information can be transmitted and coverage of a much larger number of users can be achieved. With this technique, any one user can be allocated the entire available bandwidth. Depending on the choice of the type of information multiplexing, hyper MIMO can improve capacity performance of a radio communication system by 12 or more. State that instead of the expensive 50 W amplifiers, whose linearity is required in conventional system design, hyper MIMO can be realised not only with cheap components, but also with thousands of amplifiers with reduced power consumption of the order of 10^{-3} W [2]. Thus described, one perceives an alleviation of constraints related not only to the radio frequency gain of the amplifiers used, but also those related to the linearity and accuracy of the whole system. Address the subject of multi-user hyper MIMO from point of view improving energy efficiency [3]. Here, an optimal use of the radiated energy by a massive MIMO system is presented, which has the ability to direct this energy in a specific direction. One advantage, and not the least in this case, is the limitation of inter-channel interference. Interested in the optimisation of jitter in the access network of cellular systems using massive MIMO [4]. Indeed, they start from the considerations of some probabilistic lemmas and other directional beamforming mechanisms used in systems with a lot radiating elements to minimize path losses. Here, the access network interface is lightened, even though it is heavily used for multi-order access. In fact, the channel is crystallised in such a way that it is as close as possible to scheduling in the frequency domain and each user can equally receive the full bandwidth, hence the duplication of the signalling of the access network interface. The wide spectrum of use offered by hyper MIMO, gives it the ability to effectively combat intentional interference.

Rajmane and Sdha [5] demonstrate that almost all of the benefits of hyper MIMO can be achieved by the simple application of digital signal processing (DSP) principles. According to [6], once multipath errors and propagation losses are eliminated, pilot sequence violation remains the only challenge for hyper MIMO. According to [2], [7], 5G has already found its flagship technology and must be implemented. The answer to the exponential demand for user connection rates is to guarantee a considerable connection capacity per area of geographical concentration (bit/m^2). This can be achieved by either optimising the processing methods of the access network interface by boosting the number of information bits transmitted per time-frequency resource (spectral efficiency), or by increasing the cluster size in a given area. In this work, we will focus on optimising the number of information bits transmitted per time-frequency resource or per coherence interval. Our simulation examines in detail the impact of channel estimators, the number of radiating elements of the transmitter, the frequency reuse factor and as well as the pilots, active divice per area coverage, on the spectral efficiency. Our analysis focus on deriving minimum mean square error precoding techniques single cell-minimum mean square eroor (S-MMSE) and multicell-minimum mean square eroor (M-MMSE) to counteract interference due to the action of contaminated pilots. The results obtained are compared to classical linear methods used in large antenna systems such as MR precoder, ZF precoder and regulated zero forcing (RZF).

Boccardi *et al.* [8], Larsson *et al.* [9] address the subject of hyper MIMO by making a comparative study from a security point of view with other multi-antenna transmit and receive systems encountered in wireless communications. It is clear that hyper MIMO will be the obvious candidate for 5G systems due to the many exploitable advantages it brings. Further, [10], [11] focus on the realisation and/or design of systems with a lot of elements radiating. As for [12], [13], it is demonstrated, according to certain hypotheses, that an optimal allocation of time, frequency and power resources can efficiently overcome co-channel jammers. Two types of deployment are most often encountered: centralised MIMO and distributed MIMO. In the case of distributed MIMO, the massive base stations are physically placed at different locations and connected to each other by broadband optical fibres. In the first case, however, all the radiating elements of the wireless communication system are confined to a single geographical area. Centralized deployment is much more flexible and offers greater design flexibility. Distributed deployment, on the other hand, is subject to several propagation phenomena that make it more difficult to study. Moreover, distributed deployment does not only have disadvantages. Indeed, once these difficulties are put aside [14], [15] focus on the achievements of distributed deployment. Here we learn that this type of deployment not only increases the number of bits transmitted in a radio channel per time-frequency resource, but also alleviates the cell splitting mechanisms. A battery of tests is carried out with both distributed and centralised joint deployments considering the real propagation variables of a radio channel and the results obtained are reported in [16].

Zhang *et al.* [17], Ding and Lian [18] use the properties of a clustered delay line (CDL) channel to demonstrate the significant contributions of A/D conversions on quantity information transmitted on radio channel on one time-frequency resource in a highly integrated antenna system. They also demonstrate that, a lot of radiating elements of MBS and the resolution of the A/D converter positively affect the spectral efficiency of the uplink.

Bjornson *et al.* [19], Arshad *et al.* [20] we focus on a comparative study of the contributions and limitations of feature driven development (FDD) and test-driven development (TDD), systems in the process of acquiring channel state information in wireless communications using Massive MIMO. In the first system, if radiating elements of the MBS improve, important quantity of pilot frequencies will be required for the acquisition sequence; consequently, there is a spontaneous increase in the processing rate due to this overabundance of pilots. This forces this system to have an asymptotic bound that limits its contribution to the improvement of hyper MIMO capacities; on second approach, the learning signals capture this channel state information during the uplink by using only one time-frequency resource at a time. This is an advantage as it eliminates the need for the overflow of frequency required for channel state information (CSI) acquisition. At the same time, the beamforming mechanisms here are much more adaptive and directional and the number of main lobes will increase with quantity active device on the cluster [21]. Ease of acquiring CSI during uplink phase and coverage of TDD system in massive MIMO motivated our choice and explains its adoption in this work [22], [23]. The two linear precoders zero forcing and conjugate beamforming are the focus of much interest and have been the object of several other publications [24], [25]. It is shown here that considering Rayleigh propagation fading in a simplified single cell scenario, this combination brings an improvement in net spectral efficiency at the expense of energy efficiency when acquiring channel state information and data transfer are performed during a brief moment of coherence [26].

We are interested in a semi-blind estimation of informations of channel in [27] during uplink phase to reduce degrading effects of its performance indicators due to driver contamination. This method is interesting since it does not require any cooperation between cells let alone statistical information about the channels [28]. We focus on maximising the number of useful bits can be transmited per second and per hertz of multi-user hyper MIMO. Starting from consideration of the empirical principles of large-scale fading channels, we characterize evolution of spectral efficiency when maximum transmission precoder is used by MBS to effectively combat the effects of Co-cell jammers [29].

Another very interesting performance indicator of hyper MIMO several users is energy efficiency. [30], the maximisation of energy efficiency in each coverage area is investigated by considering a multi-user hyper MIMO in joint UL and DL phases. Establishment of perfect relationship between power emitted by the Massive base station, active device in a coverage area and optimal quantity elements radiating on a coherence interval is shown to be the cornerstone of this energy maximisation [31]. By considering different processing schemes (ZF, MRC, and MRT) of the massive base station [32] derives a realistic model of energy consumption and demonstrates by simulation how these different processing schemes influence the energy efficiency. A single cellular scenario is adopted and optimal expressions for the energy efficiency of each of the three parameters mentioned above are derived [33]. To do so, the authors proceed by iterations by fixing two parameters which are either the transmission power, active devices, or quantity of radiating elements, for a pre-fixed processing scheme of the massive base station. It appears that, contrary to empirical beliefs that predicted a decrease MBS transmited power with increasing quantity of radiating element, this power increases. Based on this observation and on the analysis of the results obtained, the authors of [34] continued their work and concluded that the energy savings achieved by multi-user MIMO systems make this technology a perfect candidate for optimal operation in a high SIR environment. Starting from a symmetrical multi-user Massive MIMO postulate in a multi-cellular environment, they have sufficiently demonstrated that the optimum energy efficiency is achieved by using a ZF precoding scheme on the Massive base station side.

Here, the starting hypothesis is a hyper MIMO multi-cell environment with several users. Starting from the general knowledge of linear precoders and in particular MSE precoders, we derive two new types of precoders S-MMSE and M-MMSE. We then study the impact of these channel estimators, the increasing number of radiating elements of the massive base station, the reuse factor and active device per cluster on the spectral efficiency during the uplink phase (UL) of a TDD communication with pilot contamination. A comparative study of the classical precoders used in multi-antenna processing such as RZF, ZF, MR and S-MMSE, M-MMSE is then discussed to show the different contributions on the spectral efficiency of each of the estimators and consequently the above average performance of S-MMSE, M-MMSE.

2. METHOD

Problem formulation and system modeling base of our study is Figure 1. There are multi cluster hyper MIMO sheme with several users on uplink phase. This system operates in TDD mode. L are cells and K are users. At the center of each cell is a massive base station (MBS) consisting of M radiating elements each. The system is designed as M ≫K. Each UE transmits to the MBSs a pilot sequence consisting of τ_p samples. Thus, the signal resulting from the uplink noted Y_j^p received at the j^{th} MBSj is none other than the set of τ_p samples received such that $Y_j^p \in \mathbb{C}^{\tau_p \times M_j}$ and admits for expression:

$$Y_j^p = \sum_{k=1}^{K_j} \sqrt{p_{jk}}\, h_{jk}^j \phi_{jk}^T + \sum_{\substack{l=1 \\ l \neq j}}^{L} \sum_{i=1}^{k_l} \sqrt{p_{li}} h_{li}^j \phi_{li}^T + N_j^p \tag{1}$$

where $h_{li}^j \in \mathbb{C}^{M_j \times l}$ is the signal from the user UE k of cell l received at the j^{th} massive base station (MBS j); $\phi_{li} \in \mathbb{C}^{\tau_p}$ the pilot sequence of the k^{th} UE of cell j; p_{li} the power with which the pilot sequence ϕ_{li} was transmitted. From left to right, first expression represents desired pilot sequence, second one represents inter-cell pilot sequence (jammer), and last one $N_j^p \in \mathbb{C}^{\tau_p \times M_j}$ additive noise distributed as $N_{\mathbb{C}}(0, \sigma_{UL}^2)$. In practice, $(l, i) \in P_{jk}$ since all UEs in an operator's network use the same pilot sequence. Moreover $h_{jk}^j \sim \mathcal{N}_{\mathbb{C}}\left(0_{M_j}, \sigma_{UL}^2 \tau_P I_{M_j}\right)$ since the pilot sequences are deterministic. This therefore implies that the signal

Y_j^p received at the (MBSj) is a sufficient statistic to estimate h_{li}^j. We assume totality pilot sequences aligned. This hypothesis widely used on scheme with a lot radiataing element and makes the problem formulation and solution easier [15]. Let us evaluate the gain of the channel estimators S-MMSE and M-MMSE from the pilot sequence received at the MBS and their impact on SE, EE and cell throughput when quantity of radiating elements M, users k, and power consumption (PC) varies.

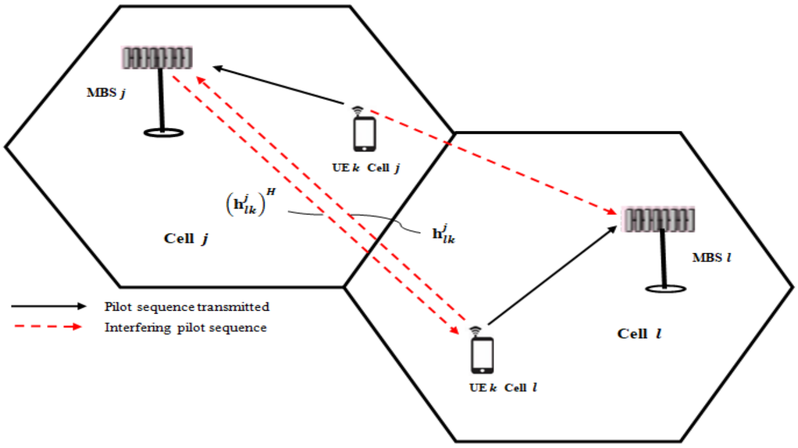


Figure 1. Multi cluster hyper MIMO sheme with multiple users on uplink phase

2.1. Uplink channel state information acquisition

On following lines, we seek to derive an estimator of the channel response h_{li}^j using a mean square error (MMSE) based estimator from the resulting uplink signal Y_j^p. Using a mutually orthogonal pilot sequence, MMSE estimator of channel h_{li}^j based on uplink received signal Y_j^p :

$$\mathbb{E}\left\{\left\| h_{li}^j - \widehat{h_{li}^j} \right\|^2\right\} \tag{2}$$

$$\widehat{h_{li}^j} = \sqrt{p_{li}} R_{li}^j \Psi_{li}^j Y_{jli}^p \tag{3}$$

Where Y_{jli}^p is the signal obtained by correlating Y_j^p and pilot sequence ϕ_{li} transmitted by device i located on Cluster l and received at MBSj. p_{li} the power with which the pilot sequence ϕ_{li} was transmitted. R_{li}^j represent spatial correlation matrix channel to be estimated and Ψ_{li}^j represente inverse of normalized correlation matrix of the received uplink signal:

$$\Psi_{li}^j = \left(\sum_{(l,i)\in P_{jk}} p_{l'i'} \tau_p R_{l'i'}^j + \sigma_{UL}^2 I_{M_j}\right)^{-1} \tag{4}$$

Thus presented, it can be seen that this estimator allows channel estimation of any UE in the network from the MBS j. A good estimation obtained with a small MSE as you can see:

$$\mathbb{E}\left\{\left\| h_{li}^j - \widehat{h_{li}^j} \right\|^2\right\} = tr\left(C_{li}^j \right) \tag{5}$$

$$\text{With: } C_{li}^j = R_{li}^j - p_{li}\tau_p R_{li}^j \Psi_{li}^j R_{li}^j \tag{6}$$

However, in (1) shows us that the signal received at MBS j is a composite signal. The second term of this equation shows us that each MBS in the network also receives interfering pilot sequences; this contaminates the pilot sequences of the other users who want to transmit. This pilot sequence contamination can be intracellular or extracellular. If MBS j estimates only the UE channels of cell j, we speak of S-MMSE defined by:

$$V_j^{S-MMSE} = \hat{H}_j^j P_j \left(\hat{H}_j^j\right)^H + \left(\sum_{i=1}^{K_j} p_{ji} C_{ji}^j + \sum_{\substack{l=1 \\ l\neq j}}^{L} \sum_{i=1}^{K_l} p_{li} R_{li}^j + \sigma_{UL}^2 I_{M_j}\right)^{-1} \hat{H}_j^j P_j \tag{7}$$

In practice, due to a multi-cell deployment with reuse of carrier frequencies in adjacent cells and thus pilot sequences, the MBS j finds itself estimating not only the channels of the UEs of cell j but also those of cell l. In this case, we speak of M-MMSE defined by:

$$V_j^{\text{M-MMSE}} = \left(\sum_{l=1}^{L} \hat{H}_l^j P_l \left(\hat{H}_l^j\right)^H + \sum_{l=1}^{L} \sum_{i=1}^{K_l} p_{li} C_{li}^j + \sigma_{UL}^2 I_{M_j}\right)^{-1} \hat{H}_j^j P_j \quad (8)$$

where σ_{UL} represents deviation standard angular multipath components needed on the spatial model correlation matrix; $M_j \times K_l$ all path estimation matrix of UEs on cluster l seen by MBS j and

$$\hat{H}_l^j = \left[\hat{H}_{l1}^j \dots \hat{H}_{lK_l}^j\right] \quad (9)$$

our channel estimators being drifted, we will now observe their impact on the spectral efficiency (SE), when quantity of radiating elements M, users k, and PC varies.

2.2. Spectral efficiency

In our scenario case, each MBS detects signals desired using linear receiver combination. Moreover, the k^{th} UE on cluster j transmits a random signal data such that $s_{jk} \sim \mathcal{N}_{\mathbb{C}}(0, p_{jk})$ for $j = 1, \dots, L$ and $k = 1, \dots, K_j$. When using mean square error channel estimation, the spectral efficiency (SE_{jk}) of uplink of k^{th} UE on cluster j is:

$$\text{SE}_{jk} = \frac{\tau_u}{\tau_c} \mathbb{E}\left\{log_2\left(1 + \text{SINR}_{jk}\right)\right\} \quad (10)$$

where τ_u / τ_c represents the fraction used for useful data per coherence block sample. Neglecting all correlation matrices in (7), we obtain a RZF estimator and whose equation is governed by (11).

$$V_j^{\text{RZF}} = \hat{H}_j^j \left(\left(\hat{H}_j^j\right)^{\text{H}} \hat{H}_j^j + \sigma_{UL}^2 P_j^{-1}\right)^{-1} \quad (11)$$

The regulation terminology refers to what (12) is pseudo-inverse of estimated matrix channel $\hat{H}_j^j$ in which inverted matrix is regulated diagonal matrix $\sigma_{UL}^2 P_j^{-1}$. Regulation is classical methode of signal processing that enhances stability of inverse. Here, we use it to provide a weighting between interference suppression and maximization of desired signals on useful direction. Often, when SNR is high, $\sigma_{UL}^2 P_j^{-1}$ tends toward 0I_{K_j}. Sarting from the, when moreover system has a lot antennas, approximation $\left(\hat{H}_j^j\right)^{\text{H}} \hat{H}_j^j + \sigma_{UL}^2 P_j^{-1} \approx \left(\hat{H}_j^j\right)^{\text{H}} \hat{H}_j^j$ can be made since the diagonal $\left(\hat{H}_j^j\right)^H \hat{H}_j^j$ enhances with M_j while control expression remains constant. Either case, we can minimize regulation term and obtain combination matrix of zero-forcing estimator defined by (12).

$$V_j^{\text{ZF}} = \hat{H}_j^j \left(\left(\hat{H}_j^j\right)^{\text{H}} \hat{H}_j^j\right)^{-1} \quad (12)$$

In contrast, when the SNR is low the approximation $\left(\hat{H}_j^j\right)^{\text{H}} \hat{H}_j^j + \sigma_{UL}^2 P_j^{-1} \approx \sigma_{UL}^2 P_j^{-1}$ can be done and the zero regulated forcing matrix in (12) becomes approximately equal to $1/_{\sigma_{UL}^2} \hat{H}_j^j \text{P}_j$. let's remember that normalization of combination vector is uplink instantaneous signal-to-interference ratio [23]. Based on this consideration, if we remove the diagonal matrix $1/_{\sigma_{UL}^2} \text{P}_j$, we obtain the expression for the matrix of a maximum ratio (MR) estimator defined by (13).

$$V_j^{\text{MR}} = \hat{H}_j^j \quad (13)$$

Contamination of the pilot or pilot sequence has two effects on the uplink transmission; it increases the minimum squared error and gives rise to coherent interference similar to the desired signal that is amplified by the network gain. The impact of our channel estimators on this phenomenon can be seen in the following simulation section uplink and SINR_{jk} the signal-to-interference ratio given by (14).

$$\text{SINR}_{jk} = \frac{p_{jk}\left|V_{jk}^{\text{H}} \hat{h}_{jk}^j\right|^2}{\sum_{l=1}^{L} \sum_{\substack{i=1 \\ (l,i) \neq (j,k)}}^{K_l} p_{li}\left|V_{jk}^{\text{H}} \hat{h}_{li}^j\right|^2 + V_{jk}^{\text{H}}\left(\sum_{l=1}^{L} \sum_{i=1}^{K_l} p_{li} C_{li}^j + \sigma_{UL}^2 I_{M_j}\right) V_{jk}} \quad (14)$$

With $V_{jk} \in \mathbb{C}^{M_j}$ the combination vector of the k^{th}UE depending on $\hat{h}_{jk}^{j}$ received by the MBS j ; V_{jk}^{H} the correlated signal received by the MBS j when transmitting the k^{th} UE data.

Since the MMSE-derived channel estimators are the ones used in this paper, the expression for the spectral efficiency SE_{jk} thus defined remains valid for any choice of combination vector. By way of comparison, the classical estimators encountered in the work dealing with uncorrelated multiuser Massive MIMO are motivated by asymptotic arguments [27]; it only applies to fading Rayleigh channels. Among these estimators, we can mention MR, ZF, and RZF estimators; all of them are derived from the basic MMSE estimator and are used when the propagation conditions are favorable, the spurious signals coming from other cells are weak and conditions of propagation are well.

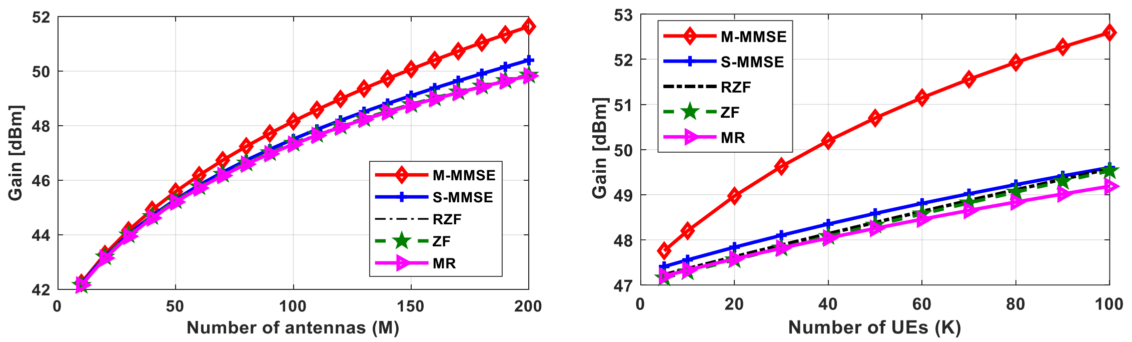
3. RESULTS AND DISCUSSION

We consider for these simulations a cellular network consisting of M antennas of the massive base station, K users, L =16 cells, an area per cell of 0.0625km^2a channel gain per km of $\gamma = -148$ dB a free space attenuation factor of $\alpha = 3.76$, a bandwidth per channel of $B = 20MHz$ a noise power of -72 dBm an uplink power $p_{li} = 20\ dBm$, quantity of samples per block of coherence $\tau_c = 200$, pilot sequence reuse factor is $f = 1{,}2\ et\ 4$ and quantity uplink pilot sequence is $\tau_p = fK$. The simulations were performed in a MATLAB R2020b environment.

Table 1 shows the performance of the uplink (SE) spectral efficiency obtained from the S-MMSE and M-MMSE estimators compared to the classical RZF, ZF, and MR precoders when quantity of radiating element enhances. Table 2 shows capacity improve of uplink SE spectral efficiency obtained from S-MMSE and M-MMSE estimators' function of the pilot sequence reuse factor for M=100. Figures 2 show the network gains obtained from the S-MMSE and M-MMSE estimators compared to the conventional RZF, ZF and MR precoders respectively when M increases Figure 2(a) and K increases Figure 2(b). Figure 3 shows the distribution of the reuse factor of the pilot sequences on the 16 cells. Figures 4 show the spectral efficiency (SE) obtained from the S-MMSE and M-MMSE estimators compared to the classical precoders RZF, ZF and MR respectively for M=100, k=10, f=2 , τ_p= 2K in Figure 4(a) and M=100, k=10, f=4 , τ_p= 4K in Figure 4(b).

Table 1. Shows the performance of the SE spectral efficiency obtained from the S-MMSE and M-MMSE estimators compared to the classical RZF, ZF, and MR precoders

Quantity of radiating element on massive base station (M)	Spectral Efficiency (bit/s/Hz/Cell)				
	M-MMSE	S-MMSE	RZF	ZF	MR
10	12,85	12,13	5,44	12,13	5,44
20	23,05	20,24	19,15	17,94	9,07
30	30,2	25,4	24,3	23,9	11,8
40	35,64	29,01	27,93	27,93	13,91
50	39,88	31,82	30,57	30,57	15,7
60	43,34	34,09	32,83	32,83	17,25
70	46,22	36,006	34,71	34,71	18,6
80	48,69	37,65	36,32	36,32	19,81
90	50,81	39,08	37,75	37,75	20,905
100	52,68	40,36	38,97	38,97	21,903



(a) (b)

Figures 2. Show the network gains obtained from the S-MMSE and M-MMSE estimators compared to the conventional RZF, ZF and MR precoders respectively when (a) M increases and (b) K increases

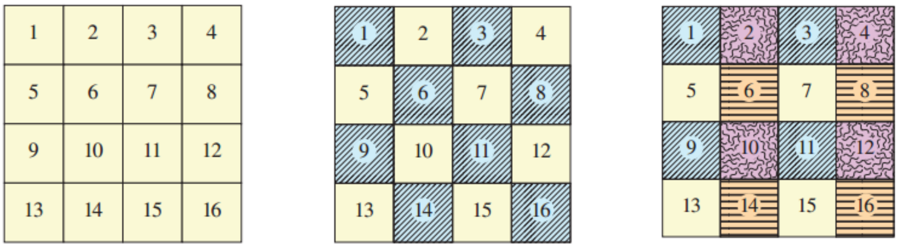
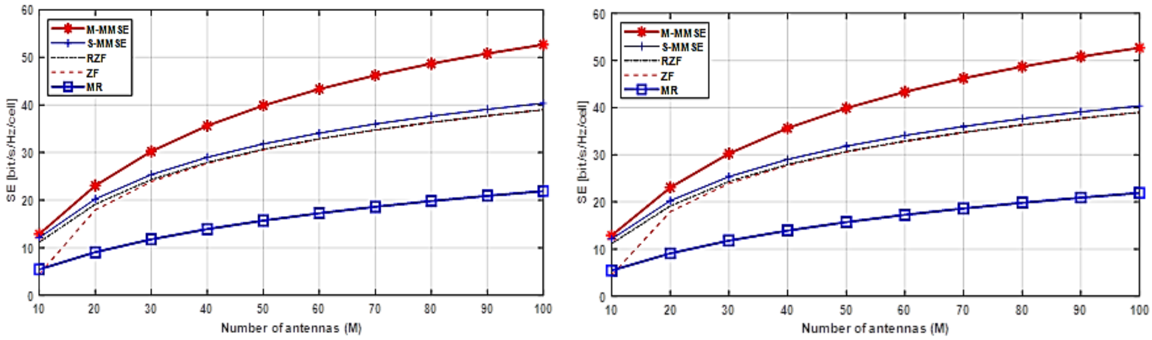


Figure 3. Shows the distribution of the reuse factor of the pilot sequences on the 16 cells

Table 2. Shows the performance of the uplink SE spectral efficiency obtained using S-MMSE and M-MMSE estimators' function of the pilot sequence reuse factor for M=100

Pilot reuse factor (f)	Spectral efficiency (bit/s/Hz/Cell)				
	M-MMSE	S-MMSE	RZF	ZF	MR
1	46,62	42,16	40,12	40,07	23,96
2	51,36	43,13	41,63	41,6	23,25
4	52,68	40,36	38,97	38,97	21,903



(a) (b)

Figure 4. Show the spectral efficiency (SE) obtained from the S-MMSE and M-MMSE estimators compared to the classical precoders RZF, ZF and MR respectively for (a) M=100, k=10, f=2 , τ_p= 2K and (b) M=100, k=10, f=4 , τ_p= 4K

As we can see, M-MMSE estimator provides best spectral efficiency. It is nearly the same for S-MMSE, RZF and ZF; except ZF is less robust when the number M of antennas is less than about 18. The MR estimator is the one that provides the lowest spectral efficiency. This precoder is the only one that is most often preferred to operate with a fixed hardening bound instead of an estimation bound [8]. For this reason, it is often referred to as an asymptotic precoder, i.e. one that guarantees a better efficiency in a certain range. In several

deployment scenarios tested here it was found that in a multicellular environment with a contaminated pilot, MR only provides a spectral efficiency of about 39 to 51% of the spectral efficiency provided by M-MMSE and about 48 to 62% of the spectral efficiency provided by RZF. Figures 4(a) and (b) show the corresponding spectral efficiency for pilot sequence reuse factor varying between f=2 and f=4. We learn from these results that, M-MMSE offers best performance when $f = 4$; on other hand S-MMSE, RZF and ZF do so for $f = 2$ while MR is for $f = 1$. The synthesized result is presented in Table 2 which shows the spectral efficiency of each channel estimator for M=100. We finally notice that higher spectral efficiency of an estimator scheme, higher its computational complexity. Enhaced spectral efficiency and low computational complexity are two trade-offs that designers should consider when choosing one of these precoders.

4. CONCLUSION

From the above, we can conclude that in hyper MIMO TDD, the precoder M-MMSE is the one that provides the highest spectral efficiency; however, it requires a higher computational complexity. The MR precoder has a much lower computational complexity but provides a much lower spectral efficiency. RZF is the estimator that offers a better compromise between complexity and spectral efficiency. M-MMSE thus appears to be the ideal candidate to use for high complexity channel estimates. The spectral efficiency expression obtained can be used for the numerical calculation of any type of channel. This spectral efficiency shows large variations due to the fact that interference between users arises because of the similarity of their correlation matrix. We can see that thanks to the coherent signal processing, power of signal received on MBS increases linearly with quantity of radiating element, even in case of contamination of the pilot sequence. However, at the massive base station, contaminated pilot sequence gives rise to coherent interference that increases with a number of antennas. We thus have sum of 2 interferences on MBS: one coherent (due to the contaminated pilot sequences) and affected by M and the other conventional or non-coherent. A good association of pilot sequence reuse and M-MMSE estimator brings these two interferences to a negligible level and consequently an increase of the spectral efficiency.

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