List of Errata to

Massive MIMO Networks: Spectral, Energy, and Hardware Efficiency

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This documents lists typos detected in the published manuscript of:

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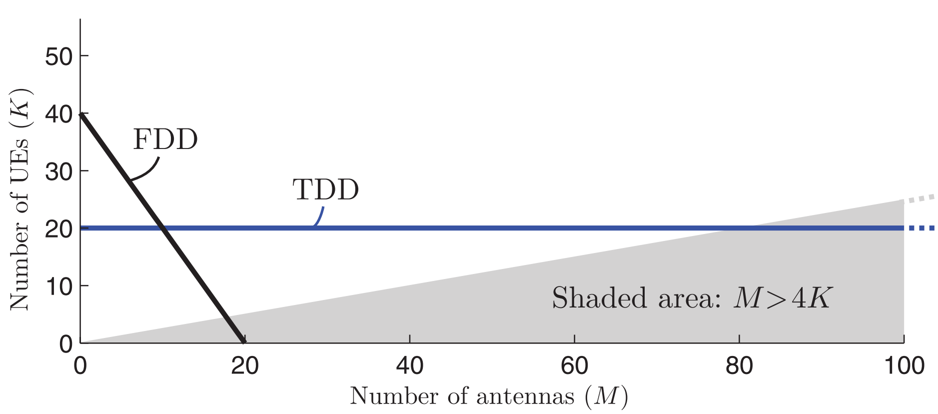
List of Errata

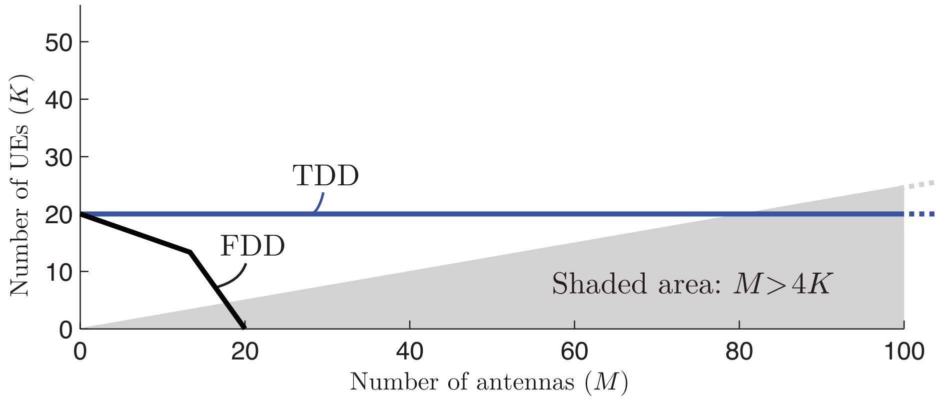
1. In the paragraph before Eq. (1.23), "horizontal ULA with antenna spacing d_{H}" should be "horizontal ULA with antenna spacing $d_{\mathrm{H}} \in (0, 0.5]$".

2. In Section 1.3.5, the statement "the same as that of sending M additional UL pilot signals" is only true if $M \geq K$. To make it more accurate, the statement should instead be "the same as that of sending $\max(M, K)$ additional UL pilot signals" and the following sentence should be added to the footnote on the same page: "More precisely, with the multiplexing gain $\min(M, K)$ of SDMA, we need $\max(M, K)$ symbol transmissions to feed back the MK channel coefficients."

   Consequently, the average pilot overhead of the FDD protocol is $\frac{M+K+\max(M,K)}{2}$ and not $M + \frac{K}{2}$ (which is only correct for $M \geq K$). This error is found at several places in this section. Moreover, Figure 1.22 is shown as

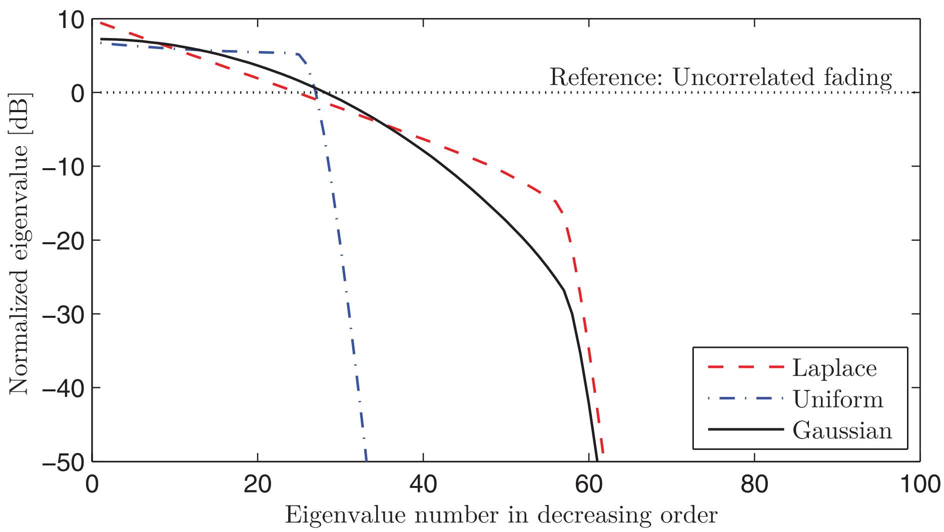


   but should be

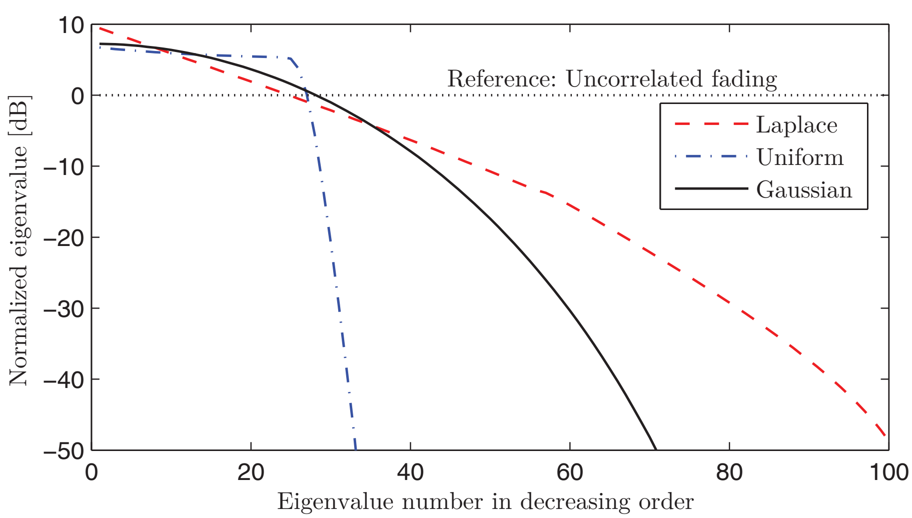


3. In Eq. (2.17), the final expression $\frac{\mathrm{tr}\left((\mathbf{R}_{jk}^{j})^2\right)}{(M_j \beta_{lk}^{j})^2}$ should be $\frac{\mathrm{tr}\left((\mathbf{R}_{jk}^{j})^2\right)}{(M_j \beta_{jk}^{j})^2}$.

4. Figure 2.6 is shown as



but should be



This error was a consequence of insufficient accuracy in the computation of the covariance matrices. The related sentence

"In fact, a uniform angular distribution makes 66% of the eigenvalues 50 dB smaller than in the reference case, while this happens for around 40% of the eigenvalues with Gaussian and Laplace distributions."

should read as

"In fact, a uniform angular distribution makes 68% of the eigenvalues 30 dB smaller than in the reference case, while this happens for 40% of the eigenvalues with Gaussian distribution and 19% with Laplace distribution."

5. In the first paragraph of Section 3.3.3, $\mathbf{h}_{li}^{j} \sim \mathcal{N}_{\mathbb{C}}(\mathbf{0}_M, \mathbf{R}_{li}^{j})$ should be $\mathbf{h}_{li}^{j} \sim \mathcal{N}_{\mathbb{C}}(\mathbf{0}_{M_j}, \mathbf{R}_{li}^{j})$.

6. In Eq. (3.36), $\mathbf{I}_M$ should be $\mathbf{I}_{M_j}$. This typo also appears on the row right above Eq. (3.37).

7. In Eq. (3.38), $\frac{1}{p_{li}}\left(\mathbf{\Psi}_{li}^{j}\right)^{-1}$ should be $\frac{1}{p_{li}\tau_p}\left(\mathbf{\Psi}_{li}^{j}\right)^{-1}$.

8. In the paragraph after Theorem 4.6, the statement "reduce the number of samples τ_d used for DL data" should be "reduce the number of samples τ_u used for UL data".

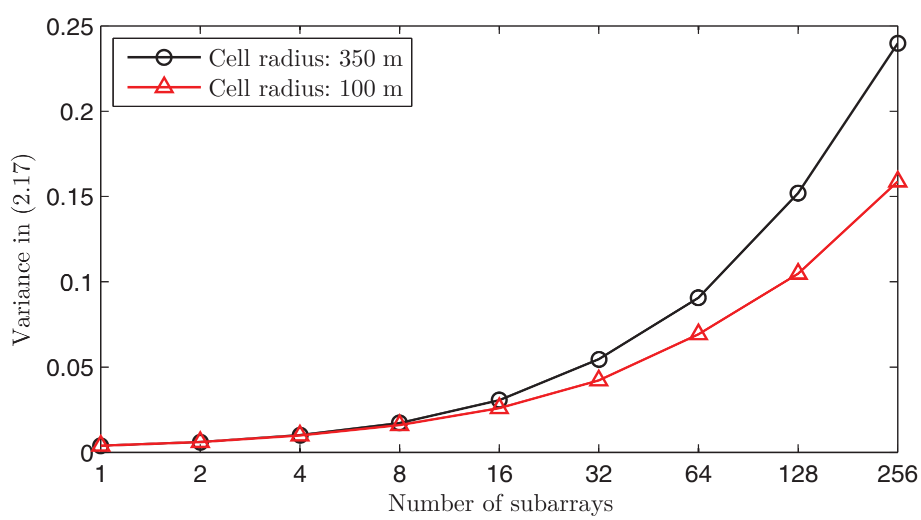
9. In Eq. (4.29), σ^2_{UL} should be σ^2_{DL}.

10. In Section 5.3, the statement "The efficiency of a PA is defined as the ratio of input power to output power" should be "The efficiency of a PA is defined as the ratio of output power to input power".

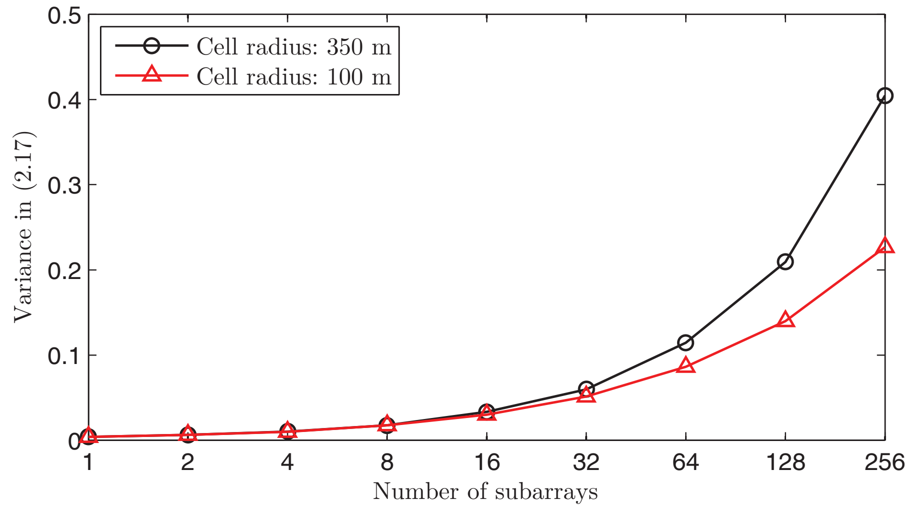
11. In Section 6.1.2, after Eq. (6.7), the statement "LTE only requires $\mathsf{EVM} \leq 0.0175$" should be "LTE only requires $\mathsf{EVM} \leq 0.175$"

12. The subsection title "7.4.1 Physical Array Size and Antenna Spacing" should be "7.4.1 Preliminaries on Physical Array Size".

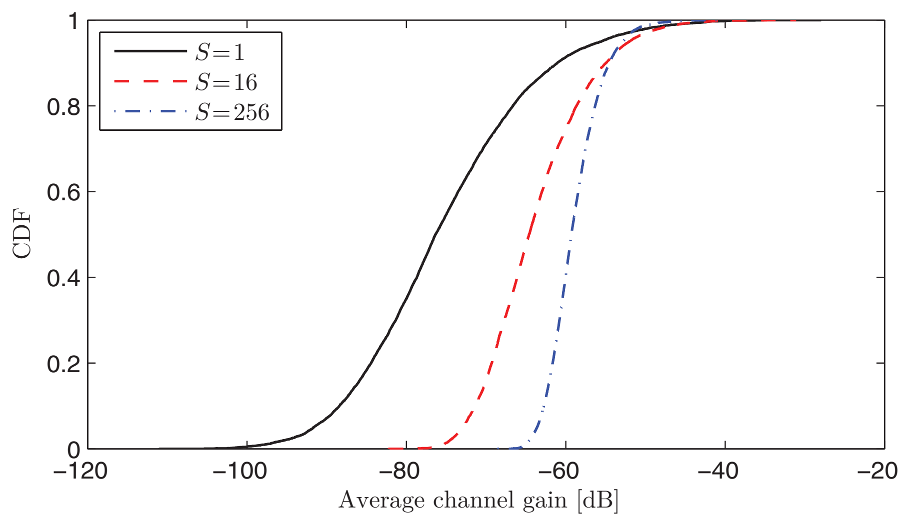
13. Figure 7.26 is shown as



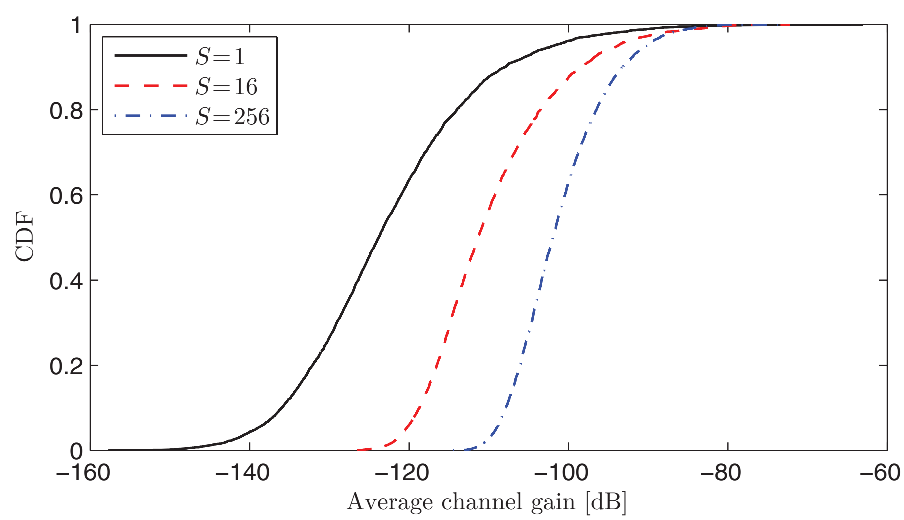
but should be



14. Figure 7.27 is shown as



but should be



In the paragraph that describes this figure, the sentence "However, going from $S = 1$ to $S = 16$ improves the median of β by around 9 dB; increasing this number to $S = 256$ adds another 5 dB." should read as: "However, going from $S = 1$ to $S = 16$ improves the median of β by around 12.5 dB; increasing this number to $S = 256$ adds another 9.5 dB."

15. The proof of Lemma B.14 only holds when $\mathbf{B}$ is a Hermitian matrix. A correct proof that applies to any deterministic $\mathbf{B}$ is:

"Note that $\mathbf{a} = \mathbf{A}^{\frac{1}{2}}\mathbf{w}$ for $\mathbf{w} = [w_1 \ \dots \ w_N]^{\mathrm{T}} \sim \mathcal{N}_{\mathbb{C}}(\mathbf{0}_N, \mathbf{I}_N)$, thus we can write

$$\mathbb{E}\{|\mathbf{a}^{\mathrm{H}}\mathbf{B}\mathbf{a}|^2\} = \mathbb{E}\{|\mathbf{w}^{\mathrm{H}}(\mathbf{A}^{\mathrm{H}})^{\frac{1}{2}}\mathbf{B}\mathbf{A}^{\frac{1}{2}}\mathbf{w}|^2\} = \mathbb{E}\{|\mathbf{w}^{\mathrm{H}}\mathbf{C}\mathbf{w}|^2\} \tag{B.23}$$

where we defined $\mathbf{C} = (\mathbf{A}^{\mathrm{H}})^{\frac{1}{2}}\mathbf{B}\mathbf{A}^{\frac{1}{2}}$. Let c_{n_1,n_2} denote the element in $\mathbf{C}$ on row n_1 and column n_2. Using this notation, we can expand (B.23) as

$$\begin{aligned}
\mathbb{E}\{|\mathbf{w}^{\mathrm{H}}\mathbf{C}\mathbf{w}|^2\} &= \sum_{n_1=1}^{N}\sum_{n_2=1}^{N}\sum_{m_1=1}^{N}\sum_{m_2=1}^{N} \mathbb{E}\{w_{n_1}^{\star} c_{n_1,n_2} w_{n_2} w_{m_1} c_{m_1,m_2}^{\star} w_{m_2}^{\star}\} \\
&\stackrel{(a)}{=} \sum_{n=1}^{N} \mathbb{E}\{|w_n|^4\}|c_{n,n}|^2 + \sum_{n=1}^{N}\sum_{\substack{m=1 \\ m\neq n}}^{N} \mathbb{E}\{|w_n|^2\}\mathbb{E}\{|w_m|^2\} c_{n,n} c_{m,m}^{\star} \\
&+ \sum_{n_1=1}^{N}\sum_{\substack{n_2=1 \\ n_2\neq n_1}}^{N} \mathbb{E}\{|w_{n_1}|^2\}\mathbb{E}\{|w_{n_2}|^2\}|c_{n_1,n_2}|^2 \\
&\stackrel{(b)}{=} \sum_{n=1}^{N} 2|c_{n,n}|^2 + \sum_{n=1}^{N}\sum_{\substack{m=1 \\ m\neq n}}^{N} c_{n,n} c_{m,m}^{\star} + \sum_{n_1=1}^{N}\sum_{\substack{n_2=1 \\ n_2\neq n_1}}^{N} |c_{n_1,n_2}|^2 \\
&= \sum_{n=1}^{N}\sum_{m=1}^{N} c_{n,n} c_{m,m}^{\star} + \sum_{n_1=1}^{N}\sum_{n_2=1}^{N} |c_{n_1,n_2}|^2 \\
&\stackrel{(c)}{=} |\mathrm{tr}(\mathbf{C})|^2 + \mathrm{tr}(\mathbf{C}\mathbf{C}^{\mathrm{H}})
\end{aligned} \tag{B.24}$$

where (a) utilizes that circular symmetry implies that $\mathbb{E}\{w_{n_1}^{\star} w_{n_2} w_{m_1} w_{m_2}^{\star}\}$ is only non-zero when the terms with conjugates have matching indices to the terms without conjugates. The first expression is given by $n_1 = n_2 = m_1 = m_2$, the second term is given by $n_1 = n_2$ and $m_1 = m_2$ with $n_1 \neq m_1$, and the third term is given by $n_1 = m_1$ and $n_2 = m_2$ with $n_1 \neq n_2$. In (b), we utilize that $\mathbb{E}\{|w_n|^2\} = 1$ and $\mathbb{E}\{|w_n|^4\} = 2$. In (c), we write the sums of elements in $\mathbf{C}$ using the trace. The resulting expression is equivalent to (**??**), which is shown by replacing $\mathbf{C}$ with $\mathbf{A}$ and $\mathbf{B}$ and utilizing the fact that $\mathrm{tr}(\mathbf{C}_1\mathbf{C}_2) = \mathrm{tr}(\mathbf{C}_2\mathbf{C}_1)$ for any matrices $\mathbf{C}_1, \mathbf{C}_2$ such that $\mathbf{C}_1$ and $\mathbf{C}_2^{\mathrm{T}}$ have the same dimensions."

16. The second paragraph of Definition B.8 should read as follows:

"If the random variable x, with support in $\mathcal{X}$ and PDF $f(x)$, is given and the conditional PDF is $f(y|x)$, then the conditional differential entropy is

$$\mathcal{H}(y|x) = -\int_{\mathcal{Y}}\int_{\mathcal{X}} \log_2\big(f(y|x)\big) f(y|x) f(x)\,dx\,dy.\text{"} \tag{B.57}$$

17. In the paragraph after (C.63), $\mathbf{A} = \tau_p \mathbf{\Psi}_{jk}^{j}$ should be $\mathbf{A} = \tau_p (\mathbf{\Psi}_{jk}^{j})^{-1}$.