3GPP TSG-RAN WG1 Meeting #63 **R1-106222**
Jacksonville, FL, November 15 - November 19, 2010

Agenda Item: 6.4.3
Source: NEC Group
Title: On the remaining issues for PHICH triggered retransmission in UL SU-MIMO
Document for: Discussion and Decision

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1 Introduction

For UL hybrid ARQ, the PHICH triggered non-adaptive HARQ avoids the PDCCH transmissions which incur high transmission energy consumption, thus it is more energy efficient [1]. For UL MIMO, to facilitate multiuser MIMO pairing, the precoding vector for the PHICH triggered retransmission should be specified in the standardization, particularly for the case when the number of transmission blocks (TB) or codewords is less than the original transmission. In RAN1 #62bis meeting, the following text has been agreed [2]:

- When the number of TBs in the PHICH-triggered retransmission is less than in the latest transmission with an associated grant.
  - The precoding matrix with lowest index is chosen from the agreed uplink codebook with the rank same as the transmission rank of the retransmission

In the following are some remaining issues on the PHICH-triggered retransmission in UL SU-MIMO which needs to be addressed in this meeting [2]:

- TB to CW mapping
- PHICH resource
- DMRS resource
- FFS if the Tx power of retransmission is scaled as a function of rank of both initial and retransmission is supported

The first three issues have been captured in [3]. Two alternatives are provided, one is Reset (Alt. 1) and the other is Reuse (Alt. 2). We prefer to Alt. 2, i.e. reuse the same TB-CW

mapping, DM-RS parameters, and PHICH resource for the retransmitted TB as what is in the latest grant, for its robustness to the errors.

In this document, we focus on the last issue, i.e., the Tx power scaling of retransmission when the agreed retransmission precoder is used.

2 Power scaling for PHICH triggered retransmission

Since the retransmission rank is lower than the original retransmission and all antennas are allocated for the retransmissions, an intuitive choice for the power scaling would be using the ratio of retransmission rank r' over the original rank r, i.e., $\theta = \frac{r'}{r}$, as the scaling factor. However, due to the variations of the precoder and MCS assignment in the original transmission, based on the discussions provided in Appendix, we suggest the power scaling factor in a form of $\theta = \frac{r'}{r}\beta$, where β can be determined based on the original precoder and MCS assignment. We can set a upper bound and a lower bound on the power scaling factor. We can use $\frac{r'}{r}$ as the lower bound for the power scaling factor. Therefore, $\max\{\beta, 1\}$ is applied instead of β. Since during the retransmission all antennas are utilized on the retransmitted codeword or TB, power scaling up is typically not an efficient solution. Therefore the power scaling factor can be upper bounded by 1, i.e., $\min\{1, \theta\}$ or $\min\{1, \frac{r'}{r}\max\{\beta, 1\}\}$. Based on the analysis in Appendix, denoting n_T as the number of transmit antennas at the user terminal, we propose the following text for the power scaling.

- The Tx power of retransmission is scaled by a scaling factor from the original power. The power scaling factor for retransmission can be specified as $\min\{1, \frac{r'}{r}\max\{\beta, 1\}\}$ where β is given as follows for different scenarios.
  - For ($n_T = 2$, $r = 2$, $r' = 1$) and ($n_T = 4$, $r = 4$, $r' = 2$), we have
  $$\beta = \frac{MCS_i}{MCS_{\bar{i}}}, \tag{1}$$
    where MCS_i denotes the MCS level assigned to the codeword or TB to be retransmitted and $MCS_{\bar{i}}$ denotes the MCS level assigned to the other one that is already successfully decoded.
  - For ($n_T = 4$, $r = 2$, $r' = 1$), we have
  $$\beta_i = \frac{2}{(a_i + a_{\bar{i}})}\frac{MCS_i}{MCS_{\bar{i}}}, \tag{2}$$
    where the values of a_1 and a_2 are given in Table 2.

– For ($n_T = 4$, $r = 3$, $r' = 1$), we have

$$\beta = \frac{3}{b_1 + 2} \frac{MCS_1}{MCS_2}. \tag{3}$$

where $b_1 = \{1, 0, 1, 0, 0, 1, 1, 0, 0, 1, 0, 1\}$ for the original rank-3 precoder in the order of index 0 to 11.

– For ($n_T = 4$, $r = 3$, $r' = 2$), we have

$$\beta = \frac{3}{2} \frac{1}{c_1 + c_2 + c_3 + c_4} \frac{MCS_2}{MCS_1}.. \tag{4}$$

where c_1, c_2, c_3, and c_4 are given in Table 3 for the original rank-3 precoder of index from 0 to 11.

Also as discussed in Appendix A, to remove the dependency to the particular precoder in the original transmission, we can simplify the power scaling factor β by $\frac{MCS_i}{MCS_{\bar{i}}}$, $\frac{MCS_i}{MCS_{\bar{i}}}$, $\bar{a}\frac{MCS_i}{MCS_{\bar{i}}}$, $\bar{b}\frac{MCS_i}{MCS_{\bar{i}}}$, and $\bar{c}\frac{MCS_i}{MCS_{\bar{i}}}$ for above five scenarios, respectively.

3 Conclusions

In this contribution, we have investigated the power scaling for PHICH triggered retransmission in UL MIMO HARQ. The proposed texts are given in Sec. 2.

Appendix A Power Scaling for UL Retransmissions

Wideband Uplink MIMO

We first recapitulate the precoding based on the approximations of channel covariance described in our previous proposal [4]. We consider a UL MIMO system with n_T transmit antennas at UE and n_R receive antennas at the base station (BS), or eNodeB. For wideband uplink MIMO in LTE-A, the DFT spread frequency division multiple access (DFT-S-FDMA) is employed as a multi-access technique for its low complexity on user separation while maintaining low peak-to-average power ratio (PAPR). The QAM modulated symbols

are first processed by a DFT and then transmitted over a certain number of subcarriers with the OFDM interface. We assume that the precoding is operated after the codeword-to-layer mapping and DFT spreading. Denote the $n_R \times n_T$ complex matrix $\boldsymbol{H}$ as the UL channel, $\boldsymbol{G} \in \mathcal{C}^{n_T \times r}$ as the precoding matrix in the latest transmission of rank r, and $\boldsymbol{x} \in \mathcal{C}^{r \times 1}$ as transmitted symbol vector. The received signal can then be written as

$$\boldsymbol{y}[k] = \boldsymbol{H}[k]\boldsymbol{G}\boldsymbol{x}[k] + \boldsymbol{n}[k], \quad k = 1, \cdots, N_{sub}, \tag{A.1}$$

where the index k denotes the kth subcarrier or subchannel and N_{sub} denotes the number of subcarriers or subchannels occupied by the DFT spread codewords. Note that in (A.1) for simplicity we assume that the same precoder is used for all tones. Then, we can obtain the SINR for MMSE receiver at the ith layer and the kth subcarrier, denoted by $\gamma_{i,k}$, given by

$$\gamma_{i,k} = \frac{\boldsymbol{g}_i^\dagger \boldsymbol{H}[k]^\dagger (\boldsymbol{I} + \boldsymbol{H}[k]\boldsymbol{G}\boldsymbol{G}^\dagger \boldsymbol{H}[k]^\dagger)^{-1} \boldsymbol{H}[k]\boldsymbol{g}_i}{1 - \boldsymbol{g}_i^\dagger \boldsymbol{H}[k]^\dagger (\boldsymbol{I} + \boldsymbol{H}[k]\boldsymbol{G}\boldsymbol{G}^\dagger \boldsymbol{H}[k]^\dagger)^{-1} \boldsymbol{H}[k]\boldsymbol{g}_i}, \tag{A.2}$$

where $(\cdot)^\dagger$ denotes the matrix conjugate transpose or Hermitian. The true effective SINR for DFT-S-FDMA can be computed as [5]

$$\mathrm{SINR}'_{i,eff} = \left(\frac{1}{\frac{1}{N_{sub}} \sum_{k=1}^{N_{sub}} \frac{\gamma_{i,k}}{1+\gamma_{i,k}}} - 1 \right)^{-1}. \tag{A.3}$$

With $\mathrm{SINR}'_{i,eff}$, we can obtain the combined SINR for all layers mapped to the same codeword. The MCS can then be assigned by the eNodeB. To obtain the precoder for retransmissions with quantized channel information for such wideband case, we proceed as follows. It can be shown that for any choice of precoder $\boldsymbol{G}$, the true effective SINR of the ith layer can be upper bounded as

$$\mathrm{SINR}'_{i,eff} \leq \frac{\tilde{\boldsymbol{\Xi}}_{i,i}}{1 - \tilde{\boldsymbol{\Xi}}_{i,i}} = \mathrm{SINR}'_i(\boldsymbol{G}) \tag{A.4}$$

where

$$\begin{aligned} \tilde{\boldsymbol{\Xi}} &= (\boldsymbol{I} + \boldsymbol{G}^\dagger \tilde{\boldsymbol{R}} \boldsymbol{G})^{-1} \boldsymbol{G}^\dagger \tilde{\boldsymbol{R}} \boldsymbol{G} \\ \tilde{\boldsymbol{R}} &= \frac{1}{N_{sub}} \sum_{k=1}^{N_{sub}} \boldsymbol{H}[k]^\dagger \boldsymbol{H}[k]. \end{aligned} \tag{A.5}$$

We then approximate $\tilde{\boldsymbol{R}}$ by $\hat{\boldsymbol{R}} \triangleq \boldsymbol{P}\boldsymbol{D}\boldsymbol{P}^\dagger$ with $\boldsymbol{D} = \mathrm{diag}\{\lambda_1/\eta_1, \cdots, \lambda_r/\eta_r\}$, where $\boldsymbol{P}$ is column-wise normalized precoding matrix employed in the first transmission, λ_i denotes the SINR for the ith layer which can be obtained based on the MCSs assigned for the first

transmission as described in [4], and η_i is the norm of the ith column of the precoding matrix employed in the first transmission. We can use the SINR upper bound in (A.4) to approximate the SINR for the retransmission. Denote r' as the rank for retransmission where $r' < r$. Particularly for retransmission rank $r' = 1$ given the precoding vector $\boldsymbol{g}$ used in the retransmission, we have

$$\mathrm{SINR}'(\boldsymbol{g}) = \boldsymbol{g}^{\dagger}\hat{\boldsymbol{R}}\boldsymbol{g}. \tag{A.6}$$

If there is no power scaling, the power employed in each antenna remains the same as that in the first transmission. Therefore, to consider the power scaling, we assume a unit per antenna power. For a given retransmission precoder, we can obtain the general power scaling rule as follows. Denote $\mathcal{T}_t$ as the set of layers mapped to the tth transmission block or codeword. We then have the original rate for the TB_t given by

$$R_t = \sum_{i \in \mathcal{T}_t} \log_2(1 + \lambda_i). \tag{A.7}$$

Then the power scaling factor θ is applied to satisfy

$$R' = \sum_i \log_2(1 + \theta \mathrm{SINR}'_i(\boldsymbol{G}')) = \kappa R_t, \tag{A.8}$$

where R' is the effective information rate assumed in the retransmission and κR_t is the targeted rate for the retransmission. By setting $\kappa = 1$, we want the retransmission power after scaling to achieve the same rate as that in the original transmission. Then for rank-1 retransmission, the rate constraint for power scaling can be directly translated to the power constraint. We then have

$$\theta \boldsymbol{g}^{\dagger}\hat{\boldsymbol{R}}\boldsymbol{g} = \kappa' \lambda_t, \tag{A.9}$$

where κ' is a scaling factor for the targeted retransmission SINR $\kappa'\lambda_t$, i.e., the total scaling factor for retransmission is $\frac{\theta}{\kappa'}$. We usually consider $\kappa' = 1$. Please note that although the power scaling constraint in (A.9) is for rank-1 retransmissions, we can similarly have an explicit power scaling for rank-2 retransmission instead of the rate constraint as in (A.8).

Since the number of layers used in the retransmission is less than the original retransmission, an intuitive choice for the power scaling factor would be the ratio of retransmission rank over the original rank, i.e., $\theta = \frac{r'}{r}$. However, due to the variations of the precoder and MCS assignment in the original transmission, based on the analysis in the next, we would like to suggest the scaling factor in a form of $\theta = \frac{r'}{r}\beta$, where β can be determined from the

original precoder and MCS assignment. We can use $\frac{r'}{r}$ as the lower bound for the power scaling factor. Therefore, $\max\{\beta, 1\}$ is applied instead of β. Since during the retransmission more antennas are employed for the retransmitted codeword or TB, power scaling up is typically not an efficient solution. Therefore the power scaling factor should be $\min\{1, \theta\}$ or $\min\{1, \frac{r'}{r}\max\{\beta, 1\}\}$. We now investigate the power scaling as a function of rank of both initial and retransmission.

Power Scaling for Retransmissions in LTE-A

Based on the agreement in the last meeting, when the retransmission rank is lower than the latest tranmsission, the precoder for retransmission is the precoding matrix with the lowest index from the agreed uplink codebook with the rank same as the transmission rank of the retransmission r'. We list all retransmission precoders in the following table. Again

$n_T = 2,\ r' = 1$	$n_T = 4, r' = 1$	$n_T = 4, r' = 2$
$\begin{bmatrix} 1 \\ 1 \end{bmatrix}$	$\begin{bmatrix} 1 \\ 1 \\ 1 \\ -1 \end{bmatrix}$	$\begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & -j \end{bmatrix}$

Table 1: Precoding matrices for PHICH triggered retransmission in UL MIMO

we assume unit power for each entry in the precoding matrix. Based on the precoders given in Table 1 and agreed UL precoders in [6] and [7], we now investigate the power scaling for retransmissions.

Power scaling for $n_T = 2$:

For $n_T = 2$ we only have one retransmission scenario, i.e., $(r = 2,\ r' = 1)$. The precoder employed in the original transmission is an identity matrix. Here we assume unit power per antenna. For the codeword or TB to be retransmitted, the SINR in the original transmission is λ_1 or λ_2 depending on which layer is used. Then with the precoder $\boldsymbol{g}'$ for the retransmission given in Table 1, we have

$$\mathrm{SINR}'(\boldsymbol{g}') = \lambda_1 |g_1'|^2 + \lambda_2 |g_2'|^2. \tag{A.10}$$

Applying the precoder given in Table 1, we have

$$\mathrm{SINR}'(\boldsymbol{g}') = \lambda_1 + \lambda_2. \tag{A.11}$$

Therefore the power scaling factor for the retransmission of the ith codeword or TB to reach the scaled rate of the original transmission is given by

$$\theta_i = \kappa' \frac{\lambda_i}{\lambda_1 + \lambda_2}. \tag{A.12}$$

With $\kappa' = 1$ and $\theta = \frac{r'}{r}\beta = \frac{\beta}{2}$, we obtain

$$\beta_i = \frac{2\lambda_i}{\lambda_1 + \lambda_2} = \frac{2}{1 + \lambda_{\bar{i}}/\lambda_i}, \tag{A.13}$$

where $\bar{i}$ denotes the index of the other codeword or TB that is not retransmitted. Since we have set the limit for power scaling factor, we can approximate above expression with

$$\beta_i \approx \frac{2}{1 + MCS_{\bar{i}}/MCS_i} \approx \frac{MCS_i}{MCS_{\bar{i}}}, \tag{A.14}$$

where MCS_i denotes the MCS index.

Power scaling for $n_T = 4$:

We first consider $r = 4$. The retransmission rank $r' = 2$. Since the UL precoding matrices defined in [6] have only one nonzero entry in each row. We can represent the UL precoder by

$$\boldsymbol{G} = \begin{bmatrix} \boldsymbol{e}_{i_1}^T \\ \vdots \\ \boldsymbol{e}_{i_{n_T}}^T \end{bmatrix}, \tag{A.15}$$

where $\boldsymbol{e}_j$ is a length-r vector with only one nonzero element, e_j, at the jth entry, and $e_j \in \{1, -1, j, -j\}$. Therefore, we have

$$\boldsymbol{G}'^{\dagger}\hat{\boldsymbol{R}}\boldsymbol{G}' = \boldsymbol{G}'^{\dagger}\boldsymbol{D}\boldsymbol{G}' = \left[\boldsymbol{e}_{i_1}'^{\,*}, \cdots, \boldsymbol{e}_{i_{n_T}}'^{\,*}\right] \boldsymbol{D} \begin{bmatrix} \boldsymbol{e}_{i_1}'^{\,T} \\ \vdots \\ \boldsymbol{e}_{i_{n_T}}'^{\,T} \end{bmatrix} = \mathrm{diag}\left\{ \sum_{j:\ i_j=1} \lambda_j, \cdots, \sum_{j:\ i_j=r'} \lambda_j \right\} \tag{A.16}$$

where $(\cdot)^*$ and $(\cdot)^T$ denote conjugate and transpose, respectively. The original rate is

$$R_t = \log_2(1 + \lambda_1) + \log_2(1 + \lambda_2) \text{ or } \log_2(1 + \lambda_3) + \log_2(1 + \lambda_4). \tag{A.17}$$

With the precoder for $r' = 2$ given in Table 1, the retransmission rate is

$$R' = \log_2(1 + \lambda_1 + \lambda_2) + \log_2(1 + \lambda_3 + \lambda_4). \tag{A.18}$$

Since we obtain λ_j from MCS assignments in the original retransmission, we then have $\lambda_1 = \lambda_2$ and $\lambda_3 = \lambda_4$. Therefore, the power scaling factor can be obtained by

$$\log_2(1 + 2\theta\lambda_1) + \log_2(1 + 2\theta\lambda_3) = 2\kappa \log_2(1 + \lambda_1) \text{ or } 2\kappa \log_2(1 + \lambda_3). \tag{A.19}$$

With $\kappa = 1$ and $\theta = \frac{r'}{r}\beta = \frac{1}{2}\beta$, we have

$$\log_2(1 + \beta_i\lambda_i) + \log_2(1 + \beta_i\lambda_{\bar{i}}) = 2\log_2(1 + \lambda_i). \tag{A.20}$$

If $\lambda_{\bar{i}} \geq \lambda_i$, we can simply set $\beta = 1$, i.e., the scaling factor $\theta = \frac{r'}{r} = \frac{1}{2}$. Otherwise, we consider that after the scaling the average of SINRs of two layers in the retransmissions is equal to the SINR value in the original codeword, i.e.,

$$\frac{1}{2}(\beta_i\lambda_i + \beta_i\lambda_{\bar{i}}) = \lambda_i \quad \Longrightarrow \quad \beta_i = \frac{2\lambda_i}{\lambda_i + \lambda_{\bar{i}}}. \tag{A.21}$$

So we can use the same simple rule as aforementioned for $n_T = 2$, i.e.,

$$\beta_i \approx \frac{MCS_i}{MCS_{\bar{i}}}. \tag{A.22}$$

For any other r with the retransmission rank $r' = 1$, with UL precoders defined in (A.15), we have

$$\boldsymbol{g}^\dagger \hat{\boldsymbol{R}} \boldsymbol{g} \;=\; \boldsymbol{g}^\dagger \begin{bmatrix} \boldsymbol{e}_{i_1}^T \\ \vdots \\ \boldsymbol{e}_{i_{n_T}}^T \end{bmatrix} \boldsymbol{D}[\boldsymbol{e}_{i_1}^*, \cdots, \boldsymbol{e}_{i_{n_T}}^*]\boldsymbol{g} = \sum_{t=1}^{r} \frac{\lambda_t}{\eta_t} |\boldsymbol{g}^\dagger \boldsymbol{p}_t|^2. \tag{A.23}$$

When $r = 2$, we have

$$\boldsymbol{g}^\dagger \hat{\boldsymbol{R}} \boldsymbol{g} \;=\; \frac{\lambda_1}{\eta_1}|\boldsymbol{g}^\dagger \boldsymbol{p}_1|^2 + \frac{\lambda_2}{\eta_2}|\boldsymbol{g}^\dagger \boldsymbol{p}_2|^2. \tag{A.24}$$

For original transmission, the SINR is λ_1 or λ_2. For the agreed retransmission precoder specified in Table 1, i.e., rank-1 precoder of index 0, , we have $\boldsymbol{g}^\dagger \hat{\boldsymbol{R}} \boldsymbol{g} = a_1\lambda_1 + a_2\lambda_2$, where $a_i = |\boldsymbol{g}^\dagger \boldsymbol{p}_i|^2/\eta_i$ with $\eta_i = 2$ for all rank-2 precoders and (a_1, a_2) given in Table 2, for the precoder of index 0 to 15 in the first transmission.

With power scaling down to the desired SINR $\kappa'\lambda_i$ in the original transmission, we have the scaling factor θ_i for retransmission of TB i, given by

$$\theta_i = \frac{\kappa'\lambda_i}{a_1\lambda_1 + a_2\lambda_2}. \tag{A.25}$$

We can see from Table 2 for either a_i, six of them are equal to one, e.g., (0, 1, 8, 9, 14, 15) for a_1 and (3, 7, 9, 11,12, 14) for a_2, indicating that for retransmitting codeword i with

index for $r=2$	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
a_1	1	1	$\frac{1}{2}$	$\frac{1}{2}$	0	0	$\frac{1}{2}$	$\frac{1}{2}$	1	1	0	0	0	0	1	1
a_2	$\frac{1}{2}$	$\frac{1}{2}$	0	1	$\frac{1}{2}$	$\frac{1}{2}$	0	1	0	1	0	1	1	0	1	0

Table 2: Parameters a_i for the initial rank-2 precoder of index 0 to 15.

agreed retransmission precoder, the retransmission SINR is no less than that in the initial transmission. Therefore, we can have a certain power down scaling but not smaller than that in the original transmission (considering $\kappa' = 1$). For the other cases, depends on the SINR values or MCS assignment in the original transmissions. For the original precoders of index 10 and 13, the resulting approximate SINRs are zero, meaning that the retransmission precoder is orthogonal to the original precoder which is so called null trap. For these two null traps, it would be better not to have a power down scaling.

With $\kappa' = 1$ and $\theta_i = \frac{r'}{r}\beta_i$, we then have

$$\beta_i = \frac{2\lambda_i}{a_1\lambda_1 + a_2\lambda_2} = \frac{2}{a_i + a_{\bar{i}}\frac{\lambda_{\bar{i}}}{\lambda_i}}. \tag{A.26}$$

Similarly with the MCS approximation, we have

$$\beta_i \approx \frac{2}{a_i + a_{\bar{i}}\frac{MCS_{\bar{i}}}{MCS_i}}, \tag{A.27}$$

or

$$\beta_i \approx \frac{2}{(a_i + a_{\bar{i}})\frac{\lambda_{\bar{i}}}{\lambda_i}} = \frac{2}{(a_i + a_{\bar{i}})}\frac{\lambda_i}{\lambda_{\bar{i}}} \approx \frac{2}{(a_i + a_{\bar{i}})}\frac{MCS_i}{MCS_{\bar{i}}}. \tag{A.28}$$

We can further simplify the power scaling rule independent of original precoder, i.e., $\beta_i \approx \bar{a}\frac{MCS_i}{MCS_{\bar{i}}}$, where $\bar{a}$ can be the average of $\frac{2}{(a_i+a_{\bar{i}})}$ over channel realizations.

When $r = 3$ and $r' = 1$, we have

$$\boldsymbol{g}^\dagger \hat{\boldsymbol{R}}\boldsymbol{g} = \frac{\lambda_1}{\eta_1}|\boldsymbol{g}^\dagger \boldsymbol{p}_1|^2 + \lambda_2 + \lambda_3, \tag{A.29}$$

The SINR from original transmission is λ_1. The power scaling constraint is then

$$\theta(\frac{\lambda_1}{\eta_1}|\boldsymbol{g}^\dagger \boldsymbol{p}_1|^2 + \lambda_2 + \lambda_3) = \kappa'\lambda_1. \tag{A.30}$$

With the agreed rank-1 precoding given in Table 1, we have $\boldsymbol{g}^\dagger \hat{\boldsymbol{R}}\boldsymbol{g} = b_1\lambda_1 + \lambda_2 + \lambda_3$ where $b_1 \triangleq |\boldsymbol{g}^\dagger \boldsymbol{p}_1|^2/\eta_1$ and $\eta_1 = 2$ for all rank-3 precoders. We then obtain $b_1 = (1, 0, 1, 0, 0, 1, 1, 0, 0, 1, 0, 1)$ for the original rank-3 precoder of index in order from 0 to 11.

We can see that half of them have $b_1 = 1$, meaning that a power down scaling can be applied to these cases without reducing the retransmission rate. Therefore, we have

$$\theta = \frac{\lambda_1}{\lambda_1 + \lambda_2 + \lambda_3} \quad \text{or} \quad \frac{\lambda_1}{\lambda_2 + \lambda_3}. \tag{A.31}$$

If $\lambda_2 = \lambda_3 \geq 2\lambda_1$, and set $\kappa' = 1$, we can have the power scaling factor $\theta \geq \frac{1}{3}$ for those six cases of $b_1 = 1$ and $\theta \geq \frac{1}{2}$ for the other cases. Since $\lambda_2 = \lambda_3$ due to same MCS assignment for one codeword, with $\theta = \frac{r'}{r}\beta = \frac{\beta}{3}$, we have

$$\beta = \frac{3}{b + 2\lambda_2/\lambda_1} \approx \frac{3}{b + 2\frac{MCS_2}{MCS_1}} \approx \frac{3}{b+2}\frac{MCS_1}{MCS_2}. \tag{A.32}$$

Similarly, we can further simplify the power scaling for this case as $\beta =\approx \bar{b}\frac{MCS_1}{MCS_2}$ where b can be the average of $\frac{3}{b+2}$.

When $r = 3$ and $r' = 2$, the sum-rate in the original transmission is

$$W(\boldsymbol{G}') = \log_2(1 + \lambda_2) + \log_2(1 + \lambda_3). \tag{A.33}$$

With the retransmission precoding, we have

$$\boldsymbol{G}^\dagger \hat{\boldsymbol{R}} \boldsymbol{G} = \begin{bmatrix} \sum_{t=1}^{r} \frac{\lambda_t}{\eta_t} |\boldsymbol{g}_1^\dagger \boldsymbol{p}_t|^2 & \sum_{t=1}^{r} \frac{\lambda_t}{\eta_t} (\boldsymbol{g}_1^\dagger \boldsymbol{p}_t)(\boldsymbol{p}_t^\dagger \boldsymbol{g}_2) \\ \sum_{t=1}^{r} \frac{\lambda_t}{\eta_t} (\boldsymbol{g}_2^\dagger \boldsymbol{p}_t)(\boldsymbol{p}_t^\dagger \boldsymbol{g}_1) & \sum_{t=1}^{r} \frac{\lambda_t}{\eta_t} |\boldsymbol{g}_2^\dagger \boldsymbol{p}_t|^2 \end{bmatrix}, \tag{A.34}$$

where $\eta_1 = 2$ and $\eta_2 = \eta_3 = 1$. To simplify the analysis, we assume the cross entries are zero.[1] Then the SINRs for two layers in the retransmissions are $\sum_{t=1}^{r} \frac{\lambda_t}{\eta_t} |\boldsymbol{g}_1^\dagger \boldsymbol{p}_t|^2$ and $\sum_{t=1}^{r} \frac{\lambda_t}{\eta_t} |\boldsymbol{g}_2^\dagger \boldsymbol{p}_t|^2$. Assuming $\lambda_2 = \lambda_3$ and defining

$$c_1 = \frac{1}{\eta_1}|\boldsymbol{g}_1^\dagger \boldsymbol{p}_1|^2 \quad c_2 = \frac{1}{\eta_2}|\boldsymbol{g}_1^\dagger \boldsymbol{p}_2|^2 + \frac{1}{\eta_3}|\boldsymbol{g}_1^\dagger \boldsymbol{p}_3|^2, \tag{A.35}$$

$$c_3 = \frac{1}{\eta_1}|\boldsymbol{g}_2^\dagger \boldsymbol{p}_1|^2 \quad c_4 = \frac{1}{\eta_2}|\boldsymbol{g}_2^\dagger \boldsymbol{p}_2|^2 + \frac{1}{\eta_3}|\boldsymbol{g}_2^\dagger \boldsymbol{p}_3|^2, \tag{A.36}$$

we then have

$$\text{SNR}_1' = c_1\lambda_1 + c_2\lambda_2, \quad \text{and} \quad \text{SNR}_2' = c_3\lambda_1 + c_4\lambda_2, \tag{A.37}$$

with $c_1, \cdots, c_4$ are given in Table 3 for different rank-3 precoders when the retransmission rank-2 precoder in Table 1 is applied. Therefore the power scaling factor θ is set by

$$\log_2(1 + \theta c_1\lambda_1 + \theta c_2\lambda_2) + \log_2(1 + \theta c_3\lambda_1 + \theta c_4\lambda_2) = 2\kappa \log_2(1 + \lambda_2). \tag{A.38}$$

[1] If the cross entries are not zero, the resulting SINRs for the two layers in the retransmissions would be lower than the estimate, consequently, the SINRs after power down scaling. This is fine for the retransmission as we have a lower bound on power down scaling.

With $\kappa = 1$, to simplify the power scaling rule, we set the power scaling factor so that $\theta(c_1\lambda_1 + c_2\lambda_2) = \lambda_2$ or $\theta(c_3\lambda_1 + c_4\lambda_2) = \lambda_2$, or the average SINR after scaling in the retransmission is equal to the SINR for the same TB in the original transmission, i.e., or the average of these two, i.e.,

$$\frac{1}{2}\theta(c_1\lambda_1 + c_2\lambda_2 + c_3\lambda_1 + c_4\lambda_2) = \lambda_2 \implies \theta = \frac{\lambda_2}{(c_1 + c_3)\lambda_1 + (c_2 + c_4)\lambda_2}. \tag{A.39}$$

With $\theta = \frac{r'}{r}\beta = \frac{2}{3}\beta$ and similar approximation procedures, we have

$$\begin{aligned} \beta &= \frac{3}{2}\frac{1}{(c_1 + c_3)\lambda_1/\lambda_2 + (c_2 + c_4)} \approx \frac{3}{2}\frac{1}{(c_1 + c_3)MCS_1/MCS_2 + (c_2 + c_4)} \\ &\approx \frac{3}{2}\frac{1}{c_1 + c_2 + c_3 + c_4}\frac{MCS_2}{MCS_1}. \end{aligned} \tag{A.40}$$

Again, we can further simplify the power scaling rule by using $\beta \approx \bar{c}\frac{MCS_2}{MCS_1}$.

index for $r = 3$	0	1	2	3	4	5	6	7	8	9	10	11
c_1, c_2	$1, 0$	$0, 0$	$\frac{1}{4}, 1$	$\frac{1}{4}, 1$	$\frac{1}{4}, 1$	$\frac{1}{4}, 1$	$\frac{1}{4}, 1$	$\frac{1}{4}, 1$	$\frac{1}{4}, 1$	$\frac{1}{4}, 1$	$0, 2$	$0, 2$
c_3, c_4	$0, 2$	$0, 2$	$\frac{1}{4}, 1$	$\frac{1}{4}, 1$	$\frac{1}{4}, 1$	$\frac{1}{4}, 1$	$\frac{1}{4}, 1$	$\frac{1}{4}, 1$	$\frac{1}{4}, 1$	$\frac{1}{4}, 1$	$\frac{1}{2}, 0$	$\frac{1}{2}, 0$

Table 3: Power scaling parameters c_i for the initial rank-3 precoder of index 0 to 11.

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