3GPP TSG-RAN1 #56 **R1-090949**
Athens, Greece, February 9-13, 2009

Agenda Item: **12.2**

Source: **Fujitsu**

Title: **An Efficient Reference Signal Design in LTE Advanced**

Document for: **Discussion and Decision**

1. Introduction

In LTE [1], downlink (DL) common reference signal (RS) plays a very important role, at least in DL channel quality measurements, DL channel estimation for coherent demodulation/detection at user equipment (UE), and cell search and initial acquisition. Recently, LTE-Advanced system is potentially seeking many new technologies to meet the fairly aggressive performance targets in terms of peak data rate, sector throughput and cell coverage [2]. Among the potential technologies, the precoding of high order multi-input and multi-output (MIMO) with the larger number of antennas in eNode-B [2][3][4], the relay [5]-[11], and the coordinated multi-point (CoMP) transmission/reception [12][13] become major candidates. All of them require a large amount of resource element (RE) for RS to make the system feasible. This is an intolerant burden if all of RS designs follow the regular design way. Therefore, thinking of a way that reduces the number of REs for RS design in each new technology becomes a crucial issue.

In this contribution, the main intention is to efficiently design a DL RS (either common or dedicated RS in an LTE sub-frame, for instance, multimedia broadcast multicast service (MBMS) sub-frame) using a limited number of REs. In the proposed RS scheme, some RE is assigned with multiple RSs who are overlapped, whereas some RE is assigned with single RS. In the UE receiver, an iterative estimation mechanism can be considered to gradually and precisely distinguish the received RSs from each other, by means of a simple linear interpolation method. As a consequence, the total number of REs dedicated to the RS is able to be condensed significantly, only suffering somewhat negligible performance degradation which will be confirmed in our link level simulation.

2. General Descriptions

2.1. System Model

For the system model explanation, without loss of generality, we simply assume that the overall system contains two transmit points, each with one transmit antenna. Both transmit points serve one UE and send different RSs (RS0 and RS1), as illustrated in Figure 1. This model can be applied for either CoMP system where one point belongs to serving eNode-B and other to collaborative eNode-B, or relay system where one point belongs to eNode-B and other to relay node (RN), or multiple antennas where two points belong to two antennas but in the same eNode-B. More generically, the system model can be simply extended for multiple N points.

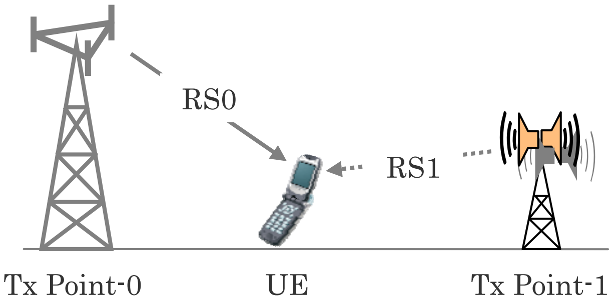

Figure 1: Reference signal for two transmit points.

2.2. Baseline Reference Signals

As a baseline of RS for two-point transmission system, we refer to LTE release-8 common RS pattern [1], which is applied in both transmit points (transmit point 0 and transmit point 1), as illustrated in Figure 2. In this RS structure, each grid called a resource element (RE) is uniquely defined by both OFDM symbol in time domain and OFDM sub-carrier in frequency domain. In time domain, the first seven OFDM symbols from symbol #0 (l = 0) to symbol #6 (l = 6) are located in the first slot of the sub-frame, and the second seven OFDM symbols from symbol #0 (l = 0) to symbol #6 (l = 6) are located in the second slot of the sub-frame. There are five types of REs, belonging to RS0, data0, RS1, data1, and null RE. In our discussion, we assume that the channel for RS0 and the channel for RS1 are completely independent and orthogonal. The reason to introduce the null RE without any transmission for the corresponding link is to reduce the interference and ensure the channel estimation quality. This is because in multi-point transmission, the data signal transmitted on the RE which is simultaneously used for RS could severely degrade the performance of channel estimation particularly for cell edge users; even a power boosting mechanism is involved. Therefore, compared to LTE common RS structure, double REs assigned for baseline RS are required

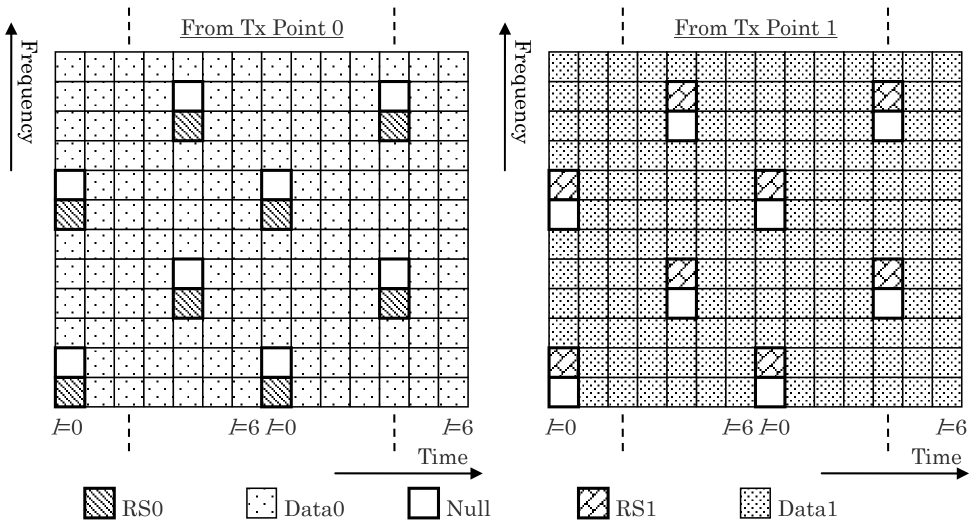

Figure 2: Mapping of down link reference signal (baseline RS structure).

3. New Reference Signal Design

We propose a DL common RS structure but it could be used for dedicated RS as well. Our intention in RS designing is to reduce the total number of REs dedicated to RS, as largely as possible, but only allowing sacrificing somewhat negligible estimation performance.

Compared to the baseline RS structure, the expected RS design by means of overlapping the different RSs into the same RE can be described as follows. For simplicity, it is reasonably assumed that the received power level of RS0 is larger than that of RS1. As illustrated in Figure 3, if it is possible for UE to precisely estimate RS0 first, and then the estimation of RS1 can be easily done by subtracting RS0 from the original received RS signal.

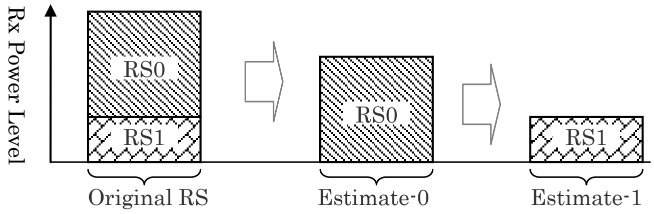

Figure 3: Expected RS design with ideal reception for RS0 and RS1, at UE.

In order to mitigate the impact of RS interference and reduce a large amount of REs involved in RS design, a compromised structure as opposed to baseline RS (in Figure 2) is proposed; that some REs for RS between two transmit points takes orthogonal pattern (denoted normal RS), while some takes overlapping pattern (denoted overlapped RS), as illustrated in Figure 4. The functions of normal RS and overlapped RSs are fundamentally different. normal RS is utilized to smooth the RS signal using, for instance, linear interpolation manner, and in turn, assist overlapped RS signal to distinguish overlapped RSs from each other, whereas overlapped RS is to increase the RS density, make somewhat compensation in channel estimation loss, and diminish the RE burden for RS design. The channel estimation relying on such a RS structure can be carried out by means of an iterative mechanism, which is able to gradually mitigate the impact between the RSs overlapped in the same RE, and beneficially reduce a large amount of REs by a factor of quarter. The detailed description of iterative estimation scheme will be given in section 4.

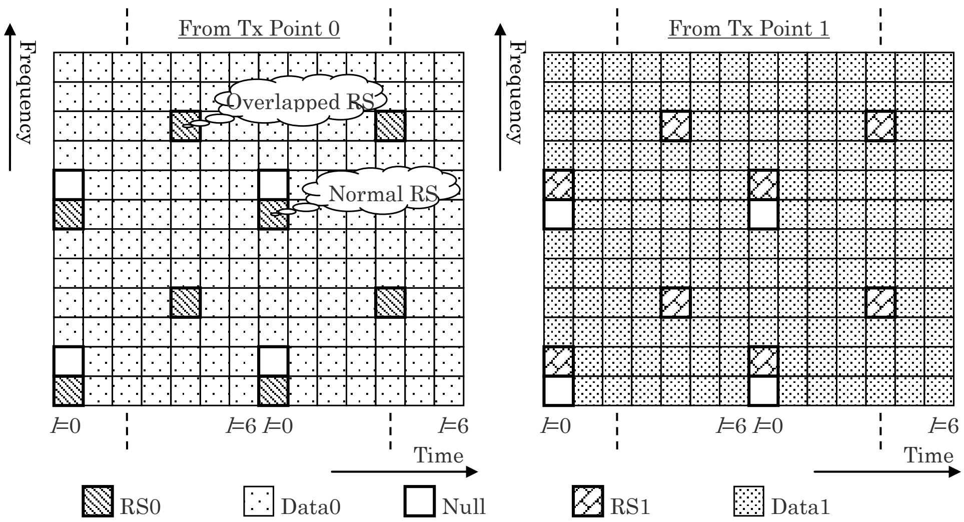

Figure 4: Mapping of down link reference signal (proposed RS structure).

4. Iterative Channel Estimation Scheme

RS based channel estimation, in general, requires a filter to polish the channel and obtain the best achievement of channel estimation. In OFDM system, a linear interpolation scheme may be considered as a practical solution for channel estimation. In the proposed RS scheme, using a filter is mainly to fulfill the function of smoothing channel so as to separate the overlapped RSs by means of an iterative estimation mechanism.

It is reasonably assumed that the UE receiver is capable of estimating the RS power and identifying which link is stronger, whereby the channel estimation process is initialized. Figure 5 exemplifies the procedure of the iterative channel estimation scheme by assuming that the received power from RS0 is stronger.

- Take all the normal RS and overlapped RS signals as the inputs.
- Smooth the RS signals and obtain the polished RS0.
- Cancel the component by subtracting the polished RS0 signal from the original overlapped RS signal (in overlapped RS), so that RS1 signal less contaminated by RS0 as an input of the filter can be obtained.
- Smooth the RS signals and obtain the polished RS1.
- This process is iteratively performed until no improvement of channel estimation is achieved.

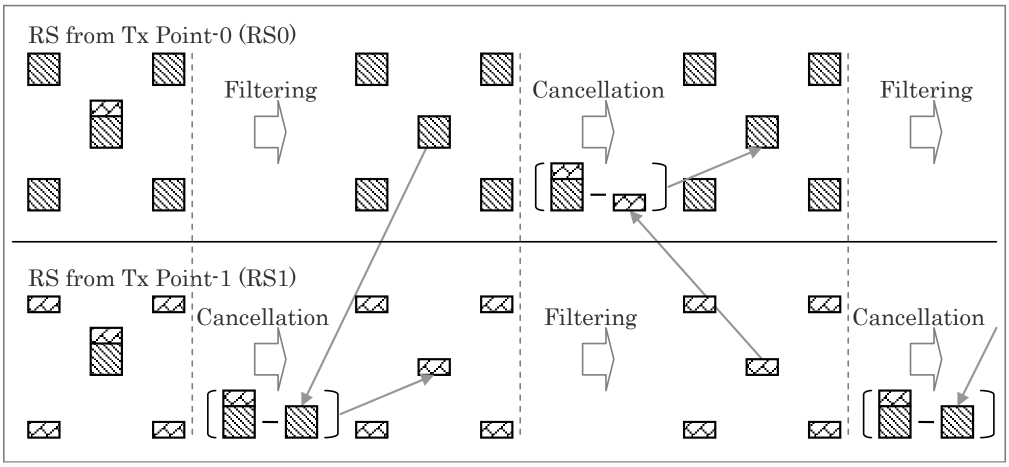

Figure 5: Example of iterative channel estimation.

Since each process of channel estimation between RS0 and RS1 surely reduces the interference between overlapped RSs (RS0 and RS1), it is expected to gradually and precisely separate the overlapped RSs if an enough number of iterative processes are performed.

Figure 6 illustrates the process flow of the iterative channel estimation, where we need to determine the receiver power from RS0 and RS1 first, whereby the RS estimation process is always beginning from the stronger one. In this case, it is assumed that RS0 power is stronger. Thus, the estimation process is performed from RS0 estimator, and then RS1 estimator.

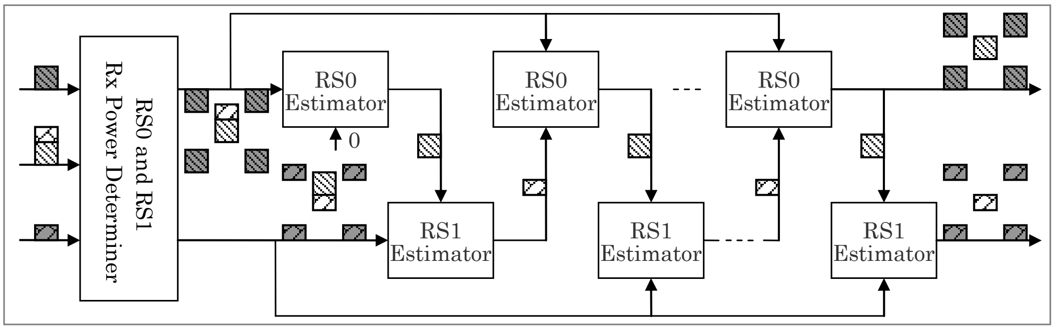

Figure 6: Flow of iterative channel estimation.

The block diagram of RS estimator is depicted in Figure 7, which consists of a canceller and a filter. The function of canceller is to cancel the interference from other RS for overlapped RS, and the function of filter is to smooth and de-noise the OFDM signal on the two-dimensional channel. The output of RS estimator is dependent on whether the iterative channel estimation is terminated or not.

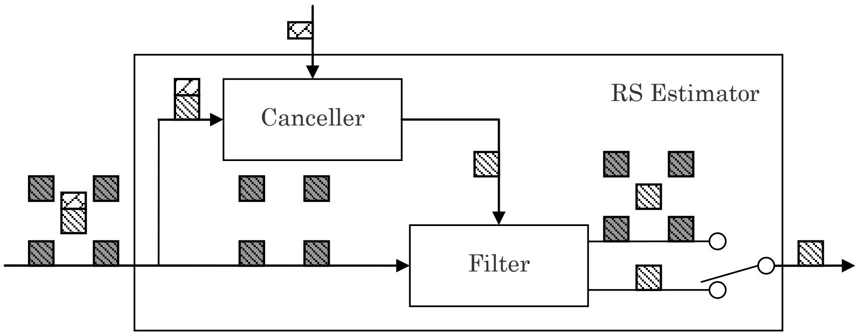

Figure 7: Block diagram for RS estimator.

5. Simulation Evaluations

A link level simulation is taken into account, relying on a linear iterative estimation method. The detailed algorithm involved in the simulation is described in appendix 7. The simulation assumptions are listed in Table 1.

Table 1: Simulation assumptions.

Frame Structure	5MHz LTE Frame
Number of Simulation Frames	10000
Number of Transmit Points	2
Number of Receivers	1
Number of Transmit Antennas	1
Number of Receive Antennas	1
Average Rx Power Ratio from Two Points	0dB
Channel Model	AWGN and ETU (5 Hz Doppler frequency) [14]
Estimation Scheme	Linear Interpolation
Number of Iterations	1

Number of Outer Loops	1, 2, 3

The link level simulation is performed in both AWGN channel model and extended typical urban (ETU) fading channel model with 5 Hz Doppler frequency. In our simulation, we have two parameters for channel estimation, α and γ, which are defined in (1) and (2) in Appendix 7. The metrics as the simulation output are mean square error (MSE) of the estimated channel for overlapped RS. We always exhaustively search all the parameters, α and γ, and demonstrate the lowest MSE results as a function of the averaged SNR experienced by UE on the channel. The detailed link level performance is evaluated in what follows.

5.1. AWGN Channel Model

In the link level simulation with AWGN channel model, we need to find a baseline result for comparison purpose. The baseline results are generated based on a single point transmission without any interference from other transmit point for UE. Making exhaustive searching for α and γ, we find that the best $\alpha = 0.3$ and $\gamma = 0$, whereby the baseline MSE results are shown in Figure 8.

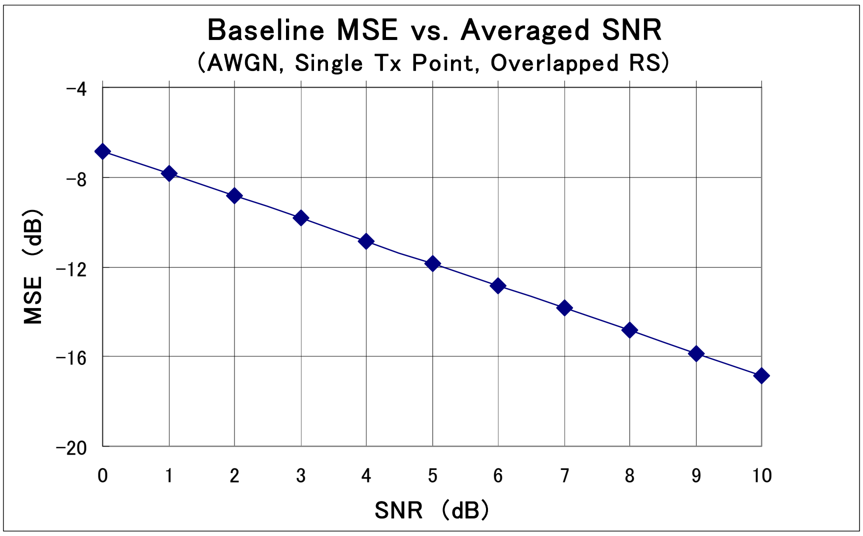

Figure 8: Baseline results of MSE of estimated channel with $\alpha = 0.3$ and $\gamma = 0$.

Figure 9 and Figure 10 show the MSE of estimated channel as a function of SNR experienced by UE, for overlapped RS in transmit point #0 and overlapped RS in transmit point #1, respectively.

It can be observed that with one outer loop, the MSE performance is very close to the baseline. When the number of outer loop increases, more than 1dB MSE gain can be achieved.

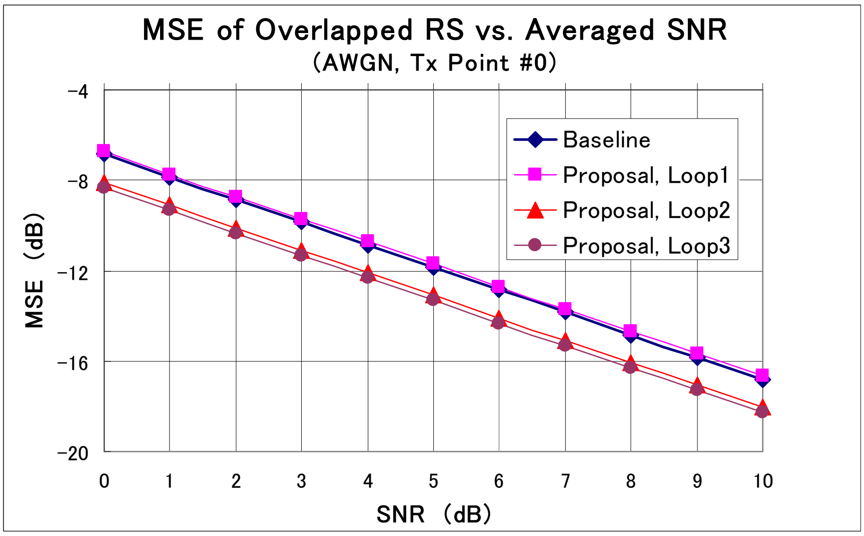

Figure 9: MSE of estimated channel for overlapped RS with $\alpha = 0.2$ and $\gamma = 0$ in Tx point #0.

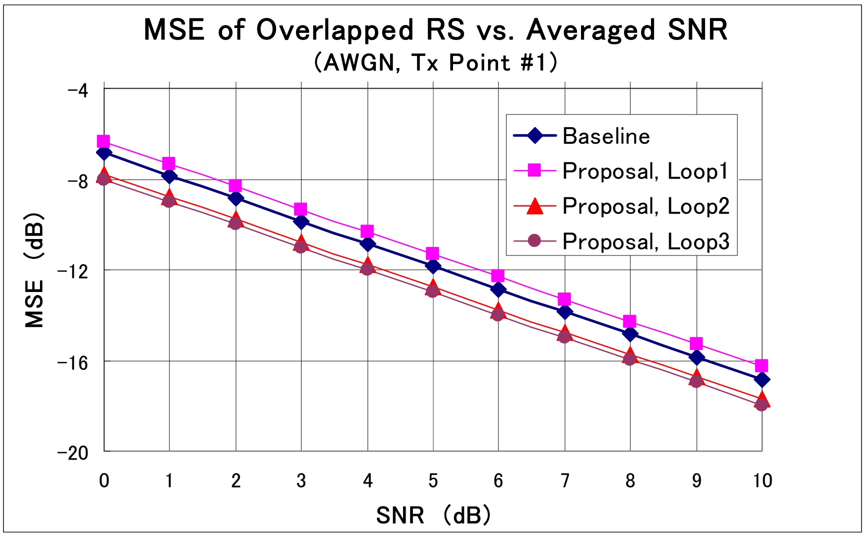

Figure 10: MSE of estimated channel for overlapped RS with $\alpha = 0.2$ and $\gamma = 0$ in Tx point #1.

5.2. ETU Fading Channel Model

Similarly, with ETU fading channel model, the baseline results are also generated based on a single point transmission without any interference from other transmit point for UE. Making exhaustive searching for α and γ, we find that the best $\alpha = 0.4$ and $\gamma = 0.3$, whereby the baseline MSE results are shown in Figure 11.

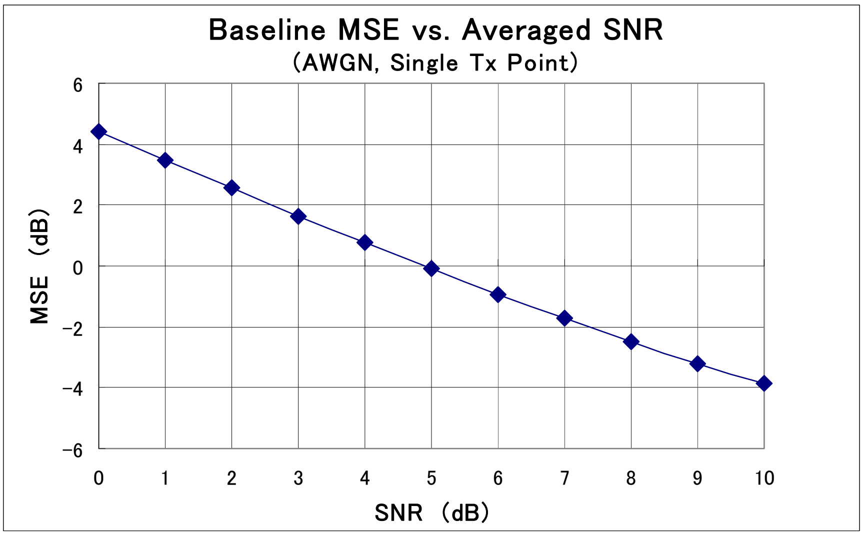

Figure 11: Baseline results of MSE of estimated channel with $\alpha = 0.4$ **and** $\gamma = 0.3$**.**

Figure 12 and Figure 13 show the MSE of estimated channel as a function of SNR experienced by UE, for overlapped RS in transmit point #0 and overlapped RS in transmit point #1, respectively.

It can be observed that using one outer loop provides the best overall MSE performance which is very close to the baseline although increasing the number of outer loop may give somewhat benefit in the low SNR region. This can be considered that in ETU channel model, the outer loop introduces the propagation error, particularly in high SNR region. Nevertheless, the outer loop is properly functioned in low SNR region.

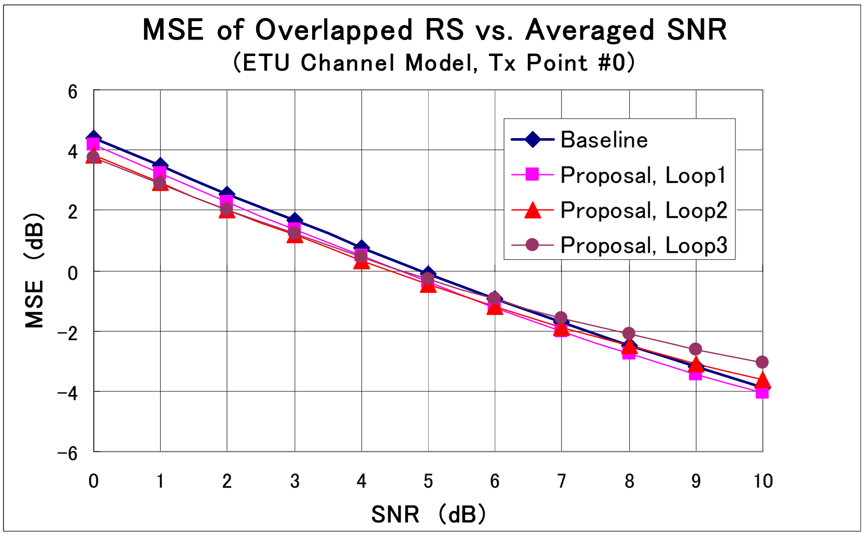

Figure 12: MSE of estimated channel for overlapped RS with $\alpha = 0.6$ **and** $\gamma = 0.1$ **in Tx point #0.**

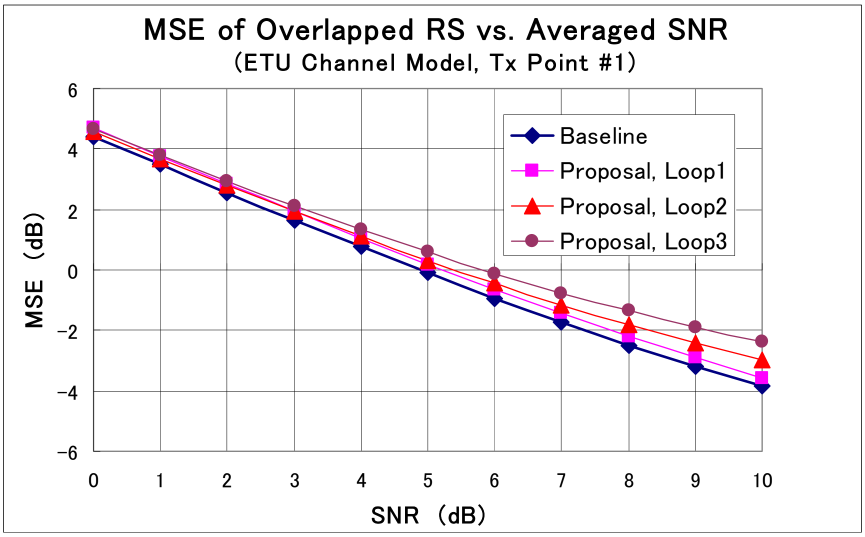

Figure 13: MSE of estimated channel for overlapped RS with $\alpha = 0.6$ and $\gamma = 0.1$ in Tx point #1.

6. Conclusions

In this contribution, we have designed a reference signal by considering partially overlapped RSs to diminish the channel resource burden. In the scenario of two transmit points, we have proposed a new RS structure, where some part of RSs are orthogonally located, whereas some part of RSs are fully overlapped. At the receiver, an iterative channel estimation scheme can be implemented to gradually mitigate the interference between the overlapped RSs (RS0 and RS1). This RS design may surely reduce the large amount of REs by factor of quarter, only with somewhat negligible performance impact. The link level simulation confirmed that the SNR degradation due to the overlapped RS is negligible. In addition, the newly designed RS structure can be applied for both common RS and dedicated RS.

7. Appendix: Algorithm for RS Estimation

In the algorithm for RS estimation, 12 steps may be taken into account as indicated in Figure 14.

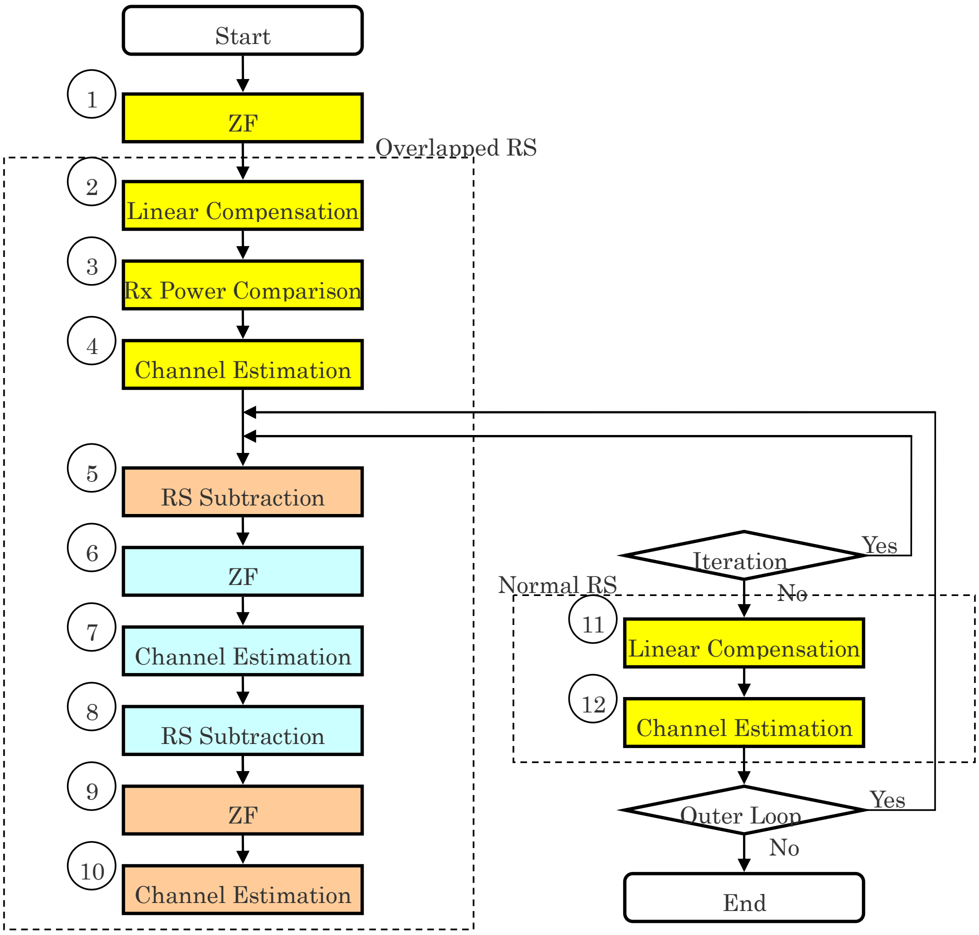

Figure 14: Flowchart for iteration loop.

For the exposition purpose, we denote RS without any overlapping as normal RS, and RS with overlapping as overlapped RS. Further, we simplify the illustration of RS structure from two transmit points, and utilize a merged depiction as shown in Figure 15, which is basically equivalent to Figure 4.

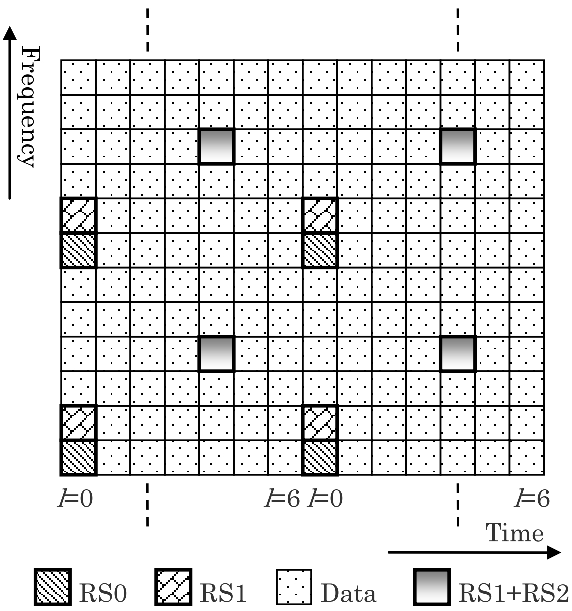

Figure 15: Mapping of down link reference signal (proposed RS structure).

The procedure of the RS estimation as illustrated in Figure 14 can be described as follows:

- Step-1: Calculate the zero forcing (ZF) value for normal RS and overlapped RS.
- Step-2: Based on normal RS after ZF, overlapped RS is computed by means of a linear interpolation as depicted in Figure 16. This belongs to the first compensation process.
- Step-3: Based on the normal RS, calculate the averaged power from two transmit points.
- Step-4: Estimate the overlapped RS which UE experiences higher received power.
- Step-5: Subtract the estimated RS from original overlapped RS for lower power RS estimation.
- Step-6: Update the ZF value for overlapped RS with lower received power.
- Step-7: Estimate the overlapped RS which UE experiences lower received power.
- Step-8: Subtract the estimated RS from original overlapped RS for higher power RS estimation.
- Step-9: Update the ZF value for overlapped RS with higher received power.
- Step-10: Estimate the overlapped RS which UE experiences higher received power.
- Step-11: Based on overlapped RS after ZF, normal RS is computed by means of a linear interpolation as depicted in Figure 17. This belongs to the second compensation process.
- Step-12: Estimate the normal RS.

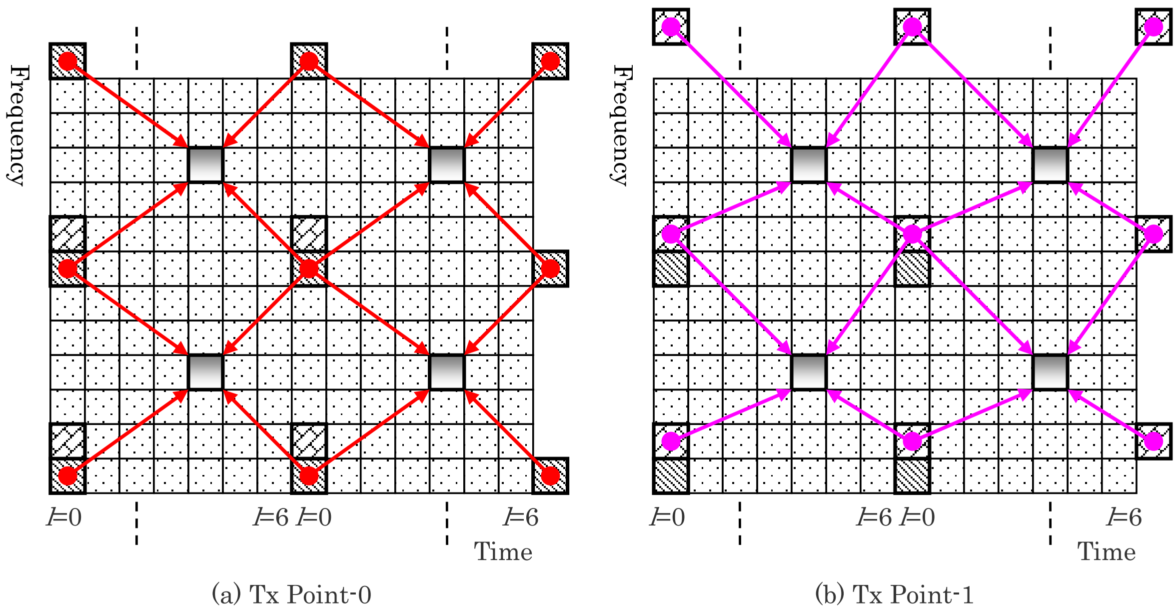

Figure 16: Overlapped RS compensation based on normal RS.

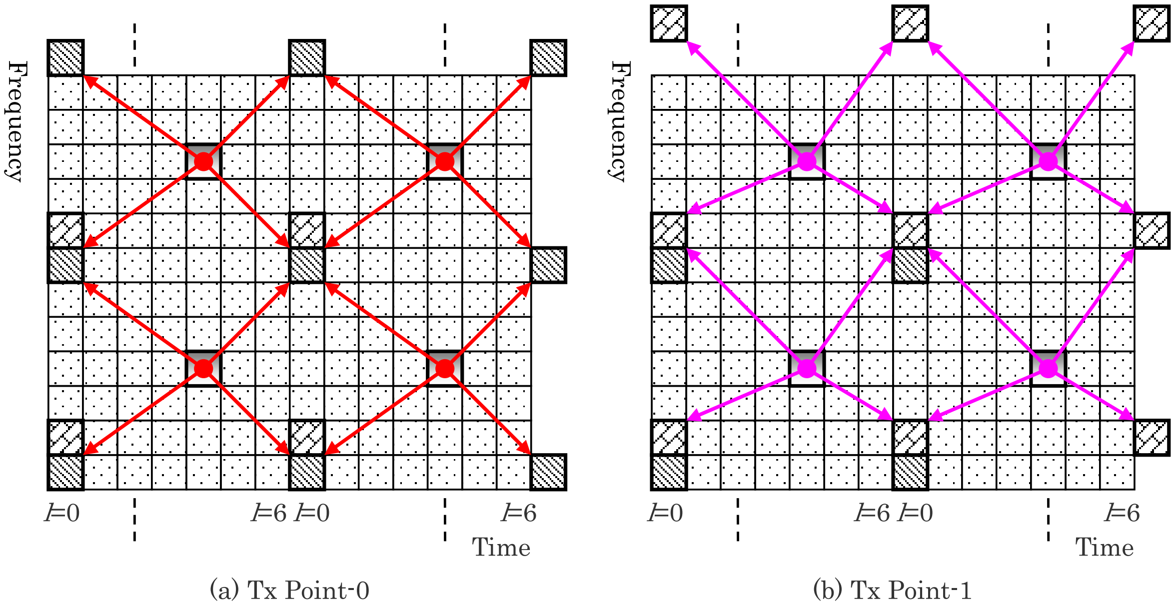

Figure 17: Normal RS compensation based on overlapped RS.

Here, we need to give more details of how to make the channel estimation with some specific formulas in step-4, step-7 and step-12. The channel estimation is performed by linear interpolated result H_{Linear} and zero forced result H_{ZF}, which can be expressed as

$$H_{Est} = \frac{H_{Linear} + \alpha \cdot H_{ZF}}{1+\alpha} \quad (1)$$

for step-4 and step-7, and

$$H_{Est} = \frac{H_{Linear} + \gamma \cdot H_{ZF}}{1+\gamma} \quad (2)$$

for step-12, where α and γ are the weight factor to optimize the channel estimation.

In addition, the procedure is implemented with one iteration loop and one outer loop, in order to mitigate the interference impact for overlapped RS.

Reference

[1] 3GPP TS 36.211, “Physical Channels and Modulation”, Release-8.

[2] 3GPP TR 36.913 v8.0.0, Requirement for further advancements for E-UTRA, release-8, June 2008.

[3] D. J. Love, R. W. Heath Jr., and T. Strohmer, “Grassmannian beamforming for multiple-input multiple-output wireless systems”, *IEEE Trans. Info. Theory*, Vol 49, No. 10, October 2003.

[4] D. J. Love and R. W. Heath Jr., “Limited feedback unitary precoding for spatial multiplexing system”, *IEEE Trans. Info. Theory*, Vol 51, No. 8, August 2005.

[5] Ericsson, “Self backhauling and lower layer relaying”, R1-082470, June 30-July 4, 2008.

[6] Samsung, “Application of network coding in LTE-advanced relay”, R1-082327, June 30-July 4, 2008.

[7] Panasonic, “Evaluation Methodologies for the SLS with Relay”, R1-082397, June 30-July 4, 2008.

[8] LG Electronics, “Consideration on relaying frame structure design in LTE-A FDD mode”, R1-082944, August 18-22, 2008.

[9] Panasonic, “Discussion on the TD relay and FD relay for FDD system”, R1-083002, August 18-22, 2008.

[10] Qualcomm Europe, “Operation of relays in LTE-A”, R1-083191, August 18-22, 2008.

[11] China Mobile, Vodafone, and Huawei, “Application Scenarios for LTE-Advanced Relay”, R1-082975, August 18-22, 2008.

[12] Alcatel Lucent, “Collaborative MIMO for LTE-A downlink”, R1-082501, June 30 – July 4, 2008.

[13] Texas Instruments, “Network MIMO Precoding”, R1-082497, June 30 – July 4, 2008.

[14] 3GPP TS 36.101, “User Equipment (UE) radio transmission and reception”, Release-8.