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Title: On aperiodic SRS Transmission in LTE-A
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1. Introduction

In LTE-A, antenna-specific sounding should be supported for multi-antenna UEs. In this case, semi-static scheduled SRS will incur more SRS resource overhead. To improve the efficiency of SRS resources in LTE-A, the enhancement of SRS via aperiodic SRS had been supported and the details were discussed in the last meetings. In RAN1 #61 meeting, some agreements were reached as follows:

- *One-shot SRS transmission is supported.*
- *In case of DCI format 0 is used for SRS triggering, size of DCI format 0 remains the same as defined in Rel8 at least in common search space*
- *Continue email discussion until RAN1#61bis*
 - o *Support of other SRS durations is FFS*
 - o *Resources used for aperiodic SRS*
 - o *Support of aperiodic triggering by DL grant?*
 - o *In case of UL triggering, allow triggering without PUSCH grant?*
 - o *Support of group triggering*

In this contribution, we further discuss the remaining issues above on aperiodic SRS transmission in LTE-A.

2. Triggering of aperiodic SRS

In our view, an important motivation to introduce aperiodic SRS is to reduce the overhead of periodic SRS. If aperiodic SRS can be scheduled dynamically and flexibly, the transmission of periodic SRS can be greatly reduced, and even single port SRS or long-periodic antenna-specific SRS is enough for periodic SRS in most scenarios. In this case, the SRS resources in LTE-A will be more sufficient even without additional enhancement. For this purpose, the flexibility of aperiodic SRS should be ensured as much as possible in scheduling and resource configuration, also taking specification impact into count.

SRS triggering via UL grant, which was agreed in RAN1 #60bis, is a straightforward way for scheduling aperiodic SRS. From the view of scheduling, one triggering IE in DCI message is efficient enough. The PDCCH overhead is hard to accept if a specific UL grant is introduced for SRS resources configuration or just SRS triggering, especially when there are considerable requests for aperiodic SRS. Instead, simultaneous triggering of a group of UEs via a new DCI similar to format 3/3A can be considered to minimize the PDCCH overhead. However, it is uncertain that how many UEs in a semi-static UE-group need to send aperiodic SRS at one time, which results in the uncertain efficiency with this type of triggering.

Dynamic aperiodic scheduling via DL assignments was also discussed in the last meeting. In our view, it is beneficial for aperiodic triggering at least in the following aspects:

- ♦ It provides the capability of frequency-selective scheduling and accurate PMI/CQI for the first transmission(s) or sporadic transmission(s), which is unavailable via UL triggering. In LTE R8, frequency-selective scheduling is useless. But for UL MIMO transmission, especially for spatial multiplexing, accurate scheduling and PMI/CQI indication will provide additional performance gain. It is useful in many application scenarios with sporadic UL transmission when short-delay periodic SRS is unavailable.
- ♦ This type of triggering can reduce the delay of aperiodic SRS. As results shown in [1], UL MIMO transmission with spatial multiplexing is more sensitive to sounding accuracy than SIMO transmission in Rel-8. If the SRS delay gets smaller, the performance can be improved. With only UL triggering, the SRS delay is hard to ensure because the PUSCH scheduling is difficult to match the resource for aperiodic SRS, in case SRS resource is configured via higher layer signaling. A particular example is shown in figure 1, in which the aperiodic SRS is transmitted 9ms after triggering.

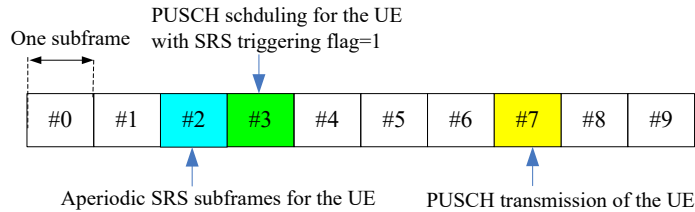


Figure1: An example of triggering and transmission of aperiodic SRS

- It can provide more chance for DL transmission to exploit SRS, for example, to acquire downlink CSI/CQI via channel reciprocity. It is beneficial not only for DL beamforming, but also for DL CoMP transmission.

Concerning implementation of DL triggering, we provide two candidates to be considered:

Alt1: Triggering bits in parts of DL formats including format 1A and the new format(s) for R10 DL transmission

To preserve the backward compatibility to current R8/R9 DCI format, the triggering is only introduced in some of the DL formats. If aperiodic triggering is introduced in DCI format 0, the same triggering in format 1A will be a straightforward idea. Additional one triggering bit in the new format(s) for DL 8x8 transmission in R10 will also have little impact on standardization. In a word, this option will introduce trivial standardization impact, but can only provide aperiodic triggering in few transmission scenarios.

Alt2: Triggering bits in all UL/DL formats

This method can provide the most flexibility for SRS triggering. As the introduction of CIF bits had been agreed for R10 UEs in UL and DL CA, additional one IE in each UL and DL grant will not bring additional blind decodings and significantly increase PDCCH blocking probability. Therefore, we think Alt2 is better for aperiodic SRS triggering though the specification effort is greater.

Proposal: Dynamic aperiodic triggering via DL grant should be supported with one bit in the DCI message.

Proposal: Triggering via UL grant without PUSCH scheduling is not needed.

3. Other issues

3.1. Resources for aperiodic SRS

Resource extension

In previous meetings, whether SRS resource enhancement was needed had been discussed, and no conclusion was made so far. On one hand, the resource for periodic SRS in R8 can be multiplexed by aperiodic SRS. On the other hand, considering SRS resource may be short for both aperiodic SRS and periodic SRS with multi-antenna transmission, additional resource can be considered as discussed in [2]. In [3], resource extension via DMRS multiplexing was proposed by some companies for aperiodic SRS. However, we think it is unfair to exclude other schemes on this issue. Other types of extension, such as extended comb or/and CS, should also be considered when resource enhancement is discussed.

Proposal: If additional resources are introduced for aperiodic SRS, all the proposed schemes should be considered equally.

Resource configuration

Though dynamic configuration of SRS transmission parameters via SRS-specific DCI signaling[4] can offer more benefits of aperiodic SRS, the PDCCH overhead will be a problem when aperiodic SRS is scheduled frequently. Similar parameters configuration as periodic SRS via higher layer signaling can be considered to reduce overhead. As long as the triggering of SRS is dynamic, the benefits of aperiodic SRS can still be obtained including higher efficiency of SRS and less periodic-SRS overhead.

Considering the similarity of periodic and aperiodic SRS, most parameters of aperiodic SRS can be configured independently reusing the content of periodic SRS. At least the following parameters should be redefined:

- ✓ Transmission comb k_{TC}
- ✓ Starting physical resource block assignment n_{RRC}
- ✓ *SRS-ConfigIndex* I_{SRS} for SRS periodicity and SRS subframe offset T_{offset}
- ✓ SRS bandwidth B_{SRS}
- ✓ Frequency hopping bandwidth, b_{hop}

✓ Cyclic shift n_{SRS}^{cs}

To avoid the collision with PUSCH and PUCCH transmission, some cell level SRS parameters, such as cell-specific SRS bandwidths and subframes, should also be reused for aperiodic SRS. The resources for aperiodic SRS can be allocated alone, for example in reserved cell-specific SRS subframes, or share the physical resources of periodic SRS via FDM or CDM.

Proposal: The resources for aperiodic SRS are configured via higher layer signaling in orthogonal resource with periodic SRS in cell-specific SRS subframe.

Exceptionally, the configuration of SRS periodicity and SRS subframe-offset should be carefully reconsidered. It's worth noting that period for periodic SRS can be configured from 2ms to 320ms in LTE R8. But for aperiodic SRS, the configuration period of subframe resource should be short for more dynamic scheduling. Therefore, few short-period configurations are enough for aperiodic SRS, and even predefined period (e.g. one/two frames) can be considered. In this case, the flexibility in subframe-offset configuration can provide higher efficiency for aperiodic SRS. For example, the allocation of multiple aperiodic-SRS-subframes during a configuration period (e.g. UE1 in figure 2) can not only reduce the SRS delay, but also provide the capability of wideband sounding via frequency hopping in multi-subframe. For these purposes, new definition of I_{SRS} is also needed. The details need further study.

Proposal: The signaling of configuration period can be simplified while the subframe configuration should be flexible for aperiodic SRS. Multiple subframe offsets in a configuration period (e.g. one frame) should be allowed.

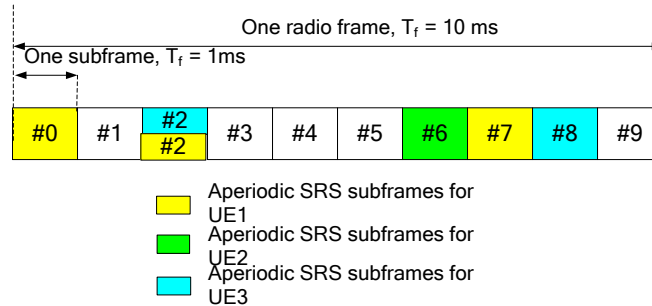


Figure2: An example of subframe configuration for aperiodic SRS (configuration period = 10ms)

3.2. UE procedure

It is simpler in terms of standardization for aperiodic SRS to be transmitted in the same subframe where the UE's PUSCH is transmitted. Nevertheless, since there are only few subframes for aperiodic SRS transmission, this type of timing restricts both the scheduling of PUSCH and transmission of aperiodic SRS, and will lead to degraded efficiency of aperiodic SRS. Thus, it is more flexible for one UE to sound in the nearest aperiodic SRS subframe(s) once triggered (or 4 subframes after triggering). By this way aperiodic SRS can be transmitted with lower delay even without PUSCH scheduling.

Proposal: Dynamic aperiodic SRS should be transmitted with flexible timing, for example, in the nearest aperiodic SRS subframe(s) once triggered.

Multi-shot aperiodic SRS with duration of N transmission(s) was proposed in the last meeting [5]. One-shot SRS, which was agreed in the meeting, can be a special case of this scheme. In general, multi-shot SRS is beneficial for wideband sounding and accurate channel estimation, but will consume more SRS resources and bring additional complexity for resource allocation and scheduling. If no SRS multiplexing enhancement is introduced, there may be not enough resource for multi-shot SRS especially with multi-antenna. Nevertheless, with one-shot SRS as a baseline, the duration of aperiodic SRS can be more robust taking SRS resource into count. As mentioned in [6], if multi-shot SRS is supported, the duration N can be indicated via higher layer signaling implicitly or explicitly.

In addition, if multi-shot SRS is agreed, hopping among the multiple shots activated by one triggering should also be considered for wider sounding BW. The configuration can be similar to hopping configuration of periodic SRS in LTE R8.

Proposal: Multi-shot SRS can be considered with one-shot SRS as a fallback case via explicit/implicit higher-layer signaling.

Proposal: Hopping among the multiple shots should also be considered associated with multi-shot SRS.

4. Conclusions

In this contribution, we analyze some schemes for aperiodic SRS transmission in LTE-A. From the above discussion, we propose that:

- ♦ *Dynamic aperiodic triggering via DL grant should be supported with one bit in the DCI message.*
- ♦ *Triggering via UL grant without PUSCH scheduling is not needed.*
- ♦ *If additional resources are introduced for aperiodic SRS, all the proposed schemes should be considered equally.*
- ♦ *The resources for aperiodic SRS are configured via higher layer signaling in orthogonal resource with periodic SRS in cell-specific SRS subframe.*
- ♦ *The signaling of configuration period can be simplified while the subframe configuration should be flexible for aperiodic SRS. Multiple subframe offsets in a configuration period (e.g. one frame) should be allowed.*
- ♦ *Dynamic aperiodic SRS should be transmitted with flexible timing, for example, in the nearest aperiodic SRS subframe(s) once triggered.*
- ♦ *Multi-shot SRS can be considered with one-shot SRS as a fallback case via explicit/implicit higher-layer signaling.*
- ♦ *Hopping among the multiple shots should also be considered associated with multi-shot SRS.*

5. References

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- [2]. R1-102662, “Considerations on increasing SRS multiplexing”, CATT, 3GPP RAN1#61, Montreal, Canada, May 10 – 14, 2010
- [3]. R1-103336, “Proposal for uplink sounding resource extension”, Huawei, CMCC, Fujitsu, HTC, Potevio, RIM, Texas Instruments, 3GPP RAN1#61, Montreal, Canada, May 10 – 14, 2010
- [4]. R1-102215, “Resource Allocation for Dynamic SRS Activation and SRS Multiplexing”, Samsung, 3GPP RAN1#60bis, Beijing, China, April 12 – 16, 2010
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- [6]. R1-102661, “Aperiodic SRS transmission in LTE-A”, CATT, 3GPP RAN1#61, Montreal, Canada, May 10 – 14, 2010