Sounding Reference signal measurement in LTE system

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Abstract—The SRS are physical signals transmitted in uplink to enable the eNB to estimate the CSI over a range of frequencies in LTE system. The estimation of the CSI assists the eNB scheduler to properly allocate radio resource to the UE. The SRS transmission can be also be used to support downlink beamforming.

The sub-frame in which SRS is transmitted by any UE within the cell is signaled via cell specific broadcast signaling, there are 15 possible sets of subframe in which SRS may be transmitted within each radio frame. The SRS is based on the extended zadoff-chu sequence and transmitted in the last SC-FDMA symbol of an uplink subframe, the SRS transmitted by the UEs are multiplexed in the time and freq. domain through configuring SRS periodicity, SRS, frequency comb pattern, and SRS bandwidth.

Different sets of UE-specific sounding signals are independently allocated for SRS transmission, including transmission bandwidth, frequency comb pattern, cyclic shift.

In this paper, transmission subframe, bandwidth, freq. comb pattern, for it suggests ways to reduce the measurement performance and HW complexity of the UE between the Sounding RS separated by a Cyclic shift value and Timing offset measurement method.

Keywords—LTE, SRS, Measurement

I. INTRODUCTION

The SRS are physical signals transmitted in the uplink to enable the eNB to estimate the channel state information over a range of frequencies. The estimation results in eNB assists the scheduler to properly allocated radio resource to UE. And to select different transmission parameters such as the instantaneous data rate and uplink multi antenna transmission parameters for optimized uplink transmission. The SRS transmission can be used for uplink timing estimation as well as to estimate downlink channel conditions assuming downlink, uplink channel reciprocity. When up/Down channel reciprocity is assumed, SRS measurement can also be used to support downlink transmissions such as angle of arrival measurements on SRS to support downlink beamforming. SRS is not necessarily transmitted together with an uplink physical channel and when transmitted in conjunction with PUSCH, the SRS may cover a different and typically larger frequency region.

In this paper, by sending SRS transmission from multiple UEs to one SRS Transmission BW area, by utilizing the base sequence in the Transmission BW, and reducing the complexity of HW when distinguishing the UE in Cyclic shift it can.

II. SRS TRANSMISSION

The subframe in which SRS is transmitted by any UE within the cell is signalled via cell specific broadcast signalling. Cell specific parameter indicates 15 possibile sets of subframes in which SRS may be transmitted within each radio frame.

Reference signal sequence \( r_{u,v}^{(a)}(n) \) is defined by a cyclic shift \( \alpha \) of a base sequence \( \overline{r}_{u,v}(n) \) according to

\[
\overline{r}_{u,v}(n) = e^{j\alpha n} r_{u,v}(n), \quad 0 \leq n < M_{sc}^{RS}
\]

where \( M_{sc}^{RS} = mN_{sc}^{RB} \) is the length of the reference signal sequence and \( 1 \leq m \leq N_{sc}^{RB} \). Multiple reference signal sequences are defined from a single base sequence through different values of \( \alpha \).

Base sequences \( \overline{r}_{u,v}(n) \) are divided into groups, where \( u \in \{0,1,...,29\} \) is the group number and \( v \) is the base sequence number within the group, such that each group contains one base sequence \( (v = 0) \) of each length \( M_{sc}^{RS} = mN_{sc}^{RB} \). The sequence group number \( u \) and the number \( v \) within the group may vary in time.

The base sequence \( \overline{r}_{u,v}(0),...,\overline{r}_{u,v}(M_{sc}^{RS} - 1) \) is given by

\[
\overline{r}_{u,v}(n) = x_q (n \mod N_{sc}^{RS}) \mod N_{sc}^{RS}, \quad 0 \leq n < M_{sc}^{RS}
\]

where the \( q^{th} \) root Zadoff-Chu sequence is defined by

\[
x_q (m) = e^{-j\pi m (m+1) / q} , \quad 0 \leq m \leq N_{sc}^{RS} - 1
\]

with \( q \) given by

\[
q = \left[ \frac{\overline{q}}{q} + 1/2 \right] + |v| \cdot (\overline{q} - 1) \cdot |v| \mod 1
\]

\[
\overline{q} = N_{ZC}^{RS} \cdot (u + 1) / 31
\]
The sequence-group number \( u \) in slot \( n_s \) is defined by a group hopping pattern \( f_{gh}(n_s) \) and a sequence-shift pattern \( f_{ss} \) according to
\[
u = (f_{gh}(n_s) + f_{ss}) \mod 30
\]
if group hopping enabled. The group-hopping pattern \( f_{gh}(n_s) \) is
\[
f_{gh}(n_s) = (\sum_{i=0}^{29} c(8n_s + i) \cdot 2^i) \mod 30
\]
where \( c(i) \) is a pseudo-random sequence. The pseudo-random sequence generator shall be initialized with \( c_{\text{init}} = \left\lfloor \frac{n_{\text{ID}}}{30} \right\rfloor \) at the beginning of each radio frame where \( n_{\text{ID}} \) is the base sequence number and \( n_{\text{ID}} = N_{\text{cell}}^{\text{RS}} \).

The sequence shift pattern \( f_{ss}^{\text{SRS}} \) given by
\[
f_{ss}^{\text{SRS}} = n_{\text{ID}}^{\text{RS}} \mod 30
\]
sequence shift pattern

If group hopping is disabled and sequence hopping is enabled, the base sequence number \( v \) within the base sequence group in slot \( n_s \) is defined by
\[
v = c(n_s)
\]
The pseudo-random sequence generator shall be initialized with
\[
c_{\text{init}} = \left\lfloor \frac{n_{\text{ID}}^{\text{RS}}}{30} \right\rfloor \cdot 2^5 + \left( n_{\text{ID}}^{\text{RS}} + \Delta_{ss} \right) \mod 30 , \quad n_{\text{ID}}^{\text{RS}} = N_{\text{cell}}^{\text{RS}}
\]
\( \Delta_{ss} \in \{0,1,\ldots,29\} \), configured by higher layers.

Reference signal sequence \( r_{u,v}^{(\alpha)}(n) \) can be defined as sounding reference signal sequence.
\[
f_{\text{SRS}}^{(\alpha)}(n) = r_{u,v}^{(\alpha)}(n)
\]
The Cyclic shift \( \alpha_{\bar{p}} \) of the sounding reference signal is given as
\[
\alpha_{\bar{p}} = 2\pi n_{\text{SRS}}^{\text{cs}} \bar{p} \cdot \frac{8}{n_{\text{SRS}}^{\text{cs}}}, \quad n_{\text{SRS}}^{\text{cs}} = \left\lfloor \frac{n_{\text{SRS}}^{\text{cs}} + 8\bar{p}}{N_{\text{ap}}} \right\rfloor \mod 8 , \quad \bar{p} \in \{0,1,\ldots,N_{\text{ap}} - 1\}
\]
Where \( n_{\text{SRS}}^{\text{cs}} \in \{0,1,2,3,4,5,6,7\} \) is configured separately for periodic and each configuration of aperiodic sounding by the higher-layer parameters cyclicShift. \( N_{\text{ap}} \) is the number of antenna ports used for sounding reference signal transmission.

**III. SRS Measurement**

SRS Demodulation block operates in subframe units, definition of SRS transmission subframe is cell specific parameters.

eNB request an individual SRS transmission from a UE, or configure a UE to transmit SRS periodically until it is no longer necessary. The periodicity of SRS is 2,5,10,20,40,80,160,320ms. The SRS periodicity and SRS subframe offset within the period in which the UE should transmit its SRS are configured via a UE specific dedicated signaling parameters. The SRS transmitted by the UEs are multiplexed in the time and frequency domain through configuring SRS periodicity. Up to eight orthogonal SRS transmissions can be cod-division multiplexed over a frequency region using different cyclic shifts of the root zadoff-cha sequence. SRS transmission was not sufficiently flexible to support sounding from an increased number of UE antennas and an increased number of UEs due to use of semi-static RRC signalling for UE configuration. So aperiodic SRS transmission was introduced to complement periodic SRS transmission, where the eNB dynamically schedules a UE for SRS transmission on demand. It allows efficient management if a fixed set of time/frequency/code SRS resources for a larger number of UEs.

SRS transmission share a common set of cell specific SRS resources. It is subframe configuration period, subframe offset, SRS Bandwidth. Different sets of UE-Specific sounding parameters are independently allocated for periodic and aperiodic SRS transmission including transmission bandwidth, periodicity, frequency comb pattern, and cyclic shift.

The figure below shows a top structure of the SRS measurement block.

![Figure 1. Top structure of SRS measurement block](image)

The SRS measurement block is enabled by L1 Control. L1 Control Block makes the enable signal by subframe configuration period, subframe offset, SRS bandwidth. In the Received signal processing, CP removed, and changed to frequency domain signal by FFT block, the SRS measurement block generate the SRS reference signal.

The generated reference signal is base reference signal which cyclic shift value is 0.

Then, conjugated base reference signal are lease squared by received signal.
\[
G_u^{(\bar{p})}(k) = \bar{r}_u^{(\bar{p})}(k) \times (r_u^{(\bar{p})} (k))^* , k = 0,1,\ldots,M_{\text{cs}}^{\text{RS}} - 1
\]
P is antenna index.
Then, least squared signal mapped in IFFT resource.

\[ \hat{G}_w(p) = \left[ G_w^{(p)}(0), G_w^{(p)}(1), \ldots, G_w^{(p)}(M_{sc}^{RS} - 1), 0, \ldots, 0 \right] \]

Then 1024 point IFFT,

\[ g_w^{(p)}(m) = \frac{1}{\sqrt{1024}} \sum_{k=0}^{1024-1} \hat{G}_w^{(p)}(k) \cdot e^{j2\pi mk/1024} \quad m = 0, 1, \ldots, 1023 \]

IFFT size can be changed by system bandwidth. The IFFT size is associated with a timing accuracy. The timing accuracy varies from system bandwidth.

The out of IFFT, makes the impulse, then Find the greatest impulse in the UE-specific time-axis measures the timing offset.

The figure below shows the results of the IFFT output signal impulse when 8 UE transmits the SRS.

m01, m02 area is a windowing area corresponding to the base sequence. m51, m52 area is a windowing area corresponding to the cyclic shift 5 from the base sequence.

It estimates the CQI as follows, average power per Resource block.

\[ CQI_u^{RS}(m) = \frac{1}{6P} \sum_{k=1}^{P} \sum_{m=0}^{M_{sc}^{RS} / 6 - 1} \hat{H}_u^{(p)}(k) \]

The simulation results are as follows.

**Figure 2. Windowing of IFFT output**

Peak detector is a function block to find the greatest signal of the impulse. Peak detector also determines whether the SRS transmission. As shown in the following formula.

\[ \eta_u = \frac{y_u^{(p)}(n_{max})}{1024 / 8 - 1} \sum_{n=n_{max}}^{1024/8-1} |\hat{G}_u^{(p)}(n)|^2 \]

\[ y_u^{(p)}(n) = \sum_{m=0}^{1024} |g_u^{(p)}(m)|^2 \]

\[ n_{max} = \arg \max_u y_u^{(p)}(n) \]

Estimated for each UEs channel signal by the windowing is changed to the frequency domain.

\[ \tilde{G}_w^{(p)}(k) = \frac{1}{\sqrt{1024}} \sum_{m=0}^{1024-1} \tilde{g}_u^{(p)}(m) \cdot e^{j2\pi mk/1024} \]

\[ \hat{H}_u^{(p)}(k) = \tilde{G}_w^{(p)}(k) \]
The timing resolution of 512 FFT is lower, CDF converge more quickly.

IV. CONCLUSIONS

In this paper, by using the base sequence proposes a method that can be applied to measurement of the number of UE.

This method reduces the HW complexity. Maximum complexity of SRS measurement, 8 IFFT, 8 FFT operations are needed. But this way, it needs 1 IFFT, 8 FFT operations.

This method is more effective when the multiple SRS measurement BW.

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