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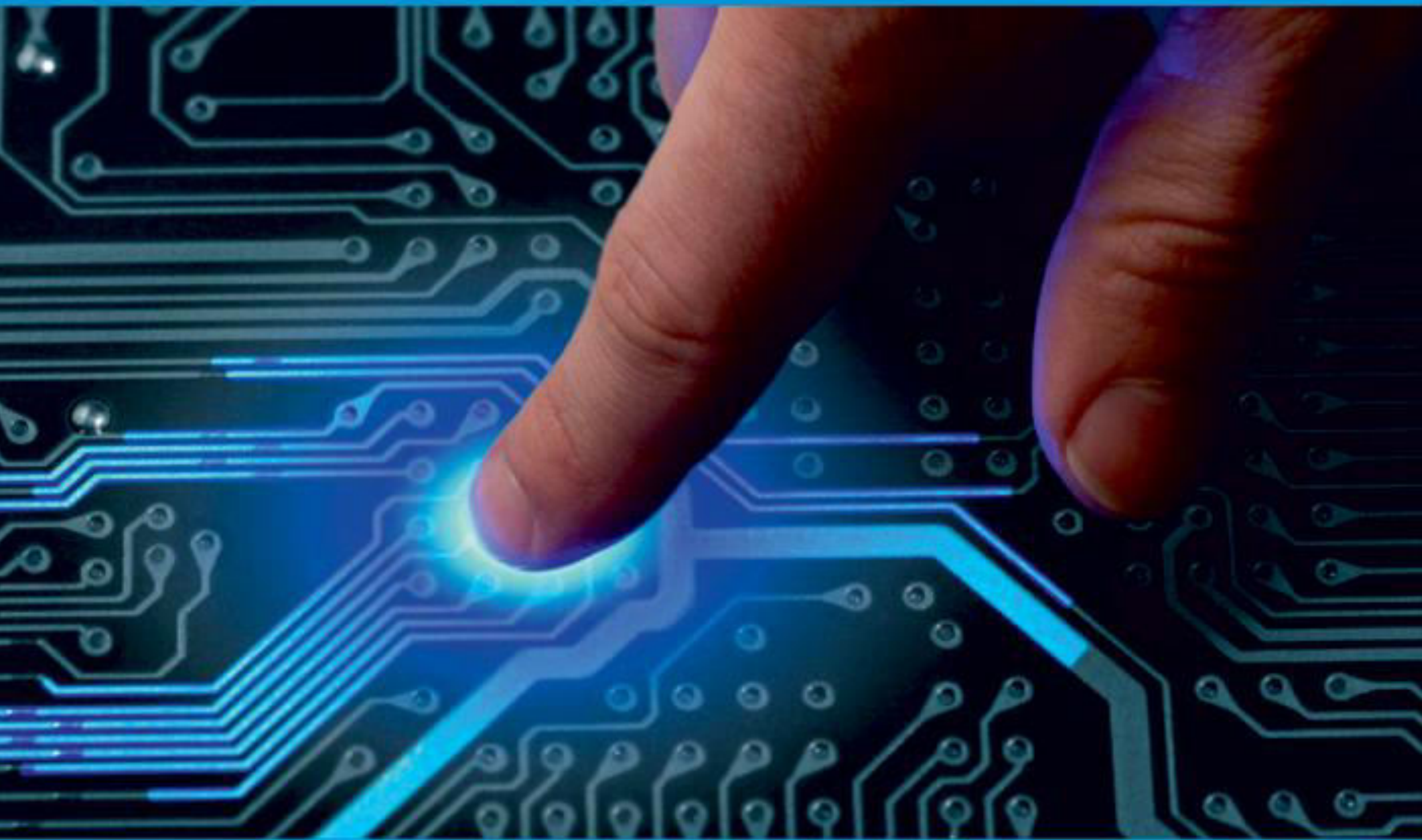

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A CSI-RS-Based 5G NR Downlink Channel Estimation

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ABSTRACT: In 3GPP long term evolution (LTE) specification for uplink, single antenna for transmission is adopted due to its simplicity. However, when it evolves to fifth generation new radio (), more transmit antennas are needed for higher spectrum efficiency, which means more reference signals. In the physical uplink share channel (PUSCH) of , the estimated channel based on sounding reference signal (SRS) is used for precoder and modulation and coding scheme (MCS) selection. In this paper, an improved SRS design is proposed, which achieves minimum interference between different reference signals. More importantly, it is perfectly backwards compatible with the SRS in uplink. In addition, we propose an improved SRS channel estimation for multiple transmit antennas. Simulation results show that the proposed SRS design leads to less channel estimation error, and the proposed SRS channel estimation can reach similar accuracy to exponential power delay profile (PDP) channel estimation, while with much lower complexity.

KEYWORDS: 5G New radio, channel estimation, sounding reference signal, uplink, PUSCH.

I. INTRODUCTION

Two types of reference signals were defined in LTE uplink. They are demodulation reference signal (DMRS) and sounding reference signal (SRS), both of which should be revised to support multiple transmit antennas in 5G NR. In 5G NR uplink, DMRS is designed to transmit with data, which will experience precoding. So the result of channel estimation based on DMRS is used for equalization. However, SRS is designed antenna-specific, which is not precoded. Therefore, the result of channel estimation based on SRS is preferred for precoder and MCS selection in PUSCH of 5G NR [1]. Fig. 1 demonstrates the difference and connection of DMRS and SRS. In this paper, we only focus on SRS. From [1] we know that SRS is better piggy-backed on top of PUSCH, and better has the same bandwidth with PUSCH for economy.

Channel estimation is one of the key technologies in mobile communication systems and also important for SRS which is used to detect channel quality information in LTE-A uplink. At present, the common channel estimations based on SRS are least-square (LS) and exponential PDP channel estimation. The former has a bad performance for neglection of noise but has a lower complexity. However, it is not applicable to the situation that different pilots coincide in position. The latter achieves an outstanding performance but has a high complexity. In this paper, we propose an improved SRS channel estimation for multiple transmit antennas. Simulation results show that the proposed SRS channel estimation can obtain similar accuracy to exponential PDP channel estimation. Moreover, the former has much lower complexity.

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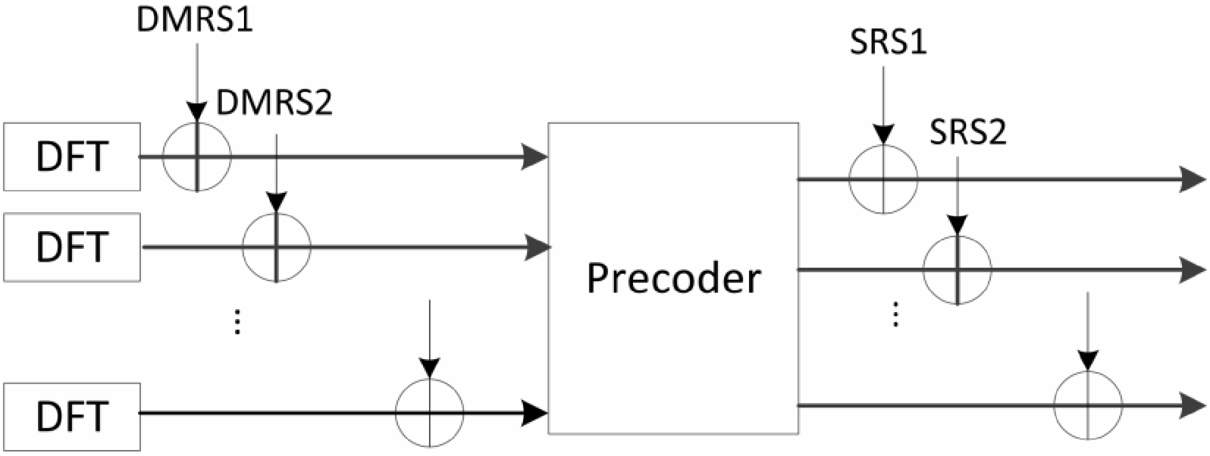

Fig. 1 DMRS and SRS in 5G NR uplink

II. SOUNDING REFERENCE SIGNAL

In 5G NR various UL SRSs configurations are possible as specified in [7]. The SRS is transmitted as part of OFDM symbols allocated in specified subcarrier and slot positions. SRS sequencies are mapped to subcarriers in the last symbol of a subframe in a comb-like pattern as presented in Fig. 1. Up to 4 SRS OFDM symbols transmission is supported in 5G NR. The SRS parameters include SRS configurations with different SRS periodicity and bandwidth allocation. For each SRS sequence the following parameters are configured: number of SRS antenna ports, symbols in a slot allocated to each SRS sequence, slots within a period used for SRS transmission, SRS frequency density in subcarriers.The BS estimates CSI on the basis of SRS transmitted by the UE and employs the estimated CSI to optimize its precoding matrix. SRS transmission is scheduled by the BS. The UE may be configured with multiple SRSs for beam management.

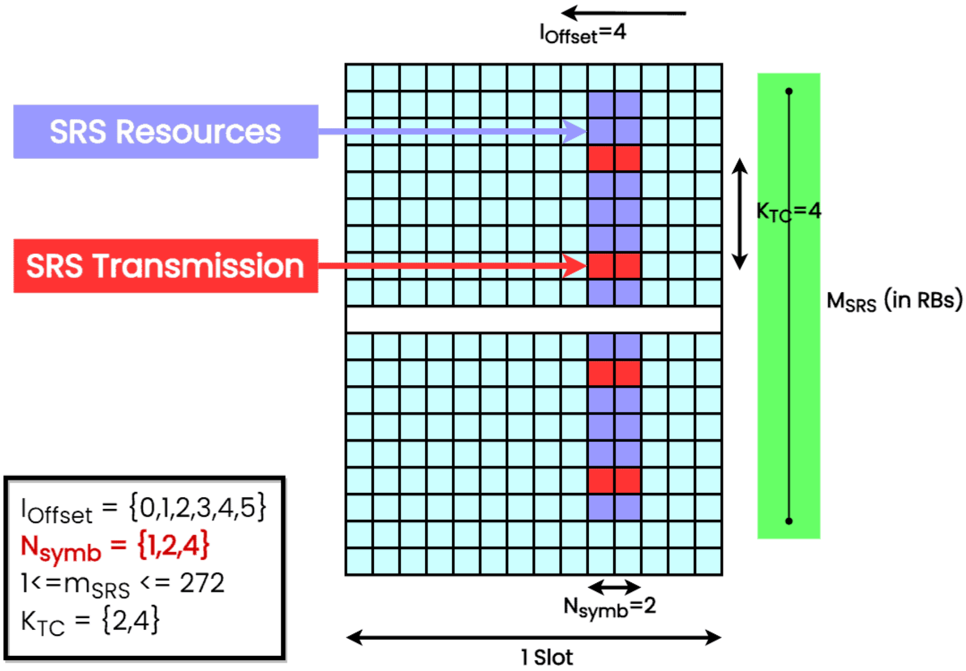

Figure 2: SRS resource allocation

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The SRS sequence is generated by a cyclic shift of a base sequence, which is obtained from Zadoff-Chu sequence. The base sequence is defined as equation rSRSu,v=rαu,v(n),n=0,..,MRSSC, MRSSC - is the length of the reference signal sequence, u=0,..,29 - is the base sequence group number, v=0,1 - is the sequence number within the group [8], [9]. The base sequence is cyclic shifted to increase the total number of available sequences. It is possible to achieve orthogonality between SRS generated from the same base sequence if α=2πnCSSRS8, nCSSRS−=0,…,7. The minimum frequency span covered by the SRS in terms of bandwidth is 4 resource blocks. A maximum of 16 UL SRSs can be multiplexed in one OFDM symbol. In the frequency domain, an SRS allocation has a comb structure where the SRS is transmitted on every Nth subcarrier where N=24 - comb-2 or comb-4. The SRS signals from different UEs can be frequency-multiplexed within the same frequency bandwidth using different comb patterns according to different frequency offsets.Since the number of available SRSs for a given bandwidth is limited UL SRSs must be reused in serving area. SRS reuse results in pilot contamination, which is one of the main limiting factors in massive MIMO systems affecting the multiuser interference.

A. NR Channel Estimation Using CSI-RS

This work shows the generation of channel state information reference signal (CSI-RS) symbols and indices for a given carrier and CSI-RS resource configuration, as defined in TS 38.211 Section 7.4.1.5. The work shows how to map the generated symbols to the carrier resource grid, performs channel estimation at the receiver side, and compares the estimated channel against the actual channel.

CSI-RS is a downlink-specific (DL) reference signal. The NR standard defines zero-power (ZP) and non-zero-power (NZP) CSI-RSs.The user equipment (UE) processes utilize NZP-CSI-RSs:

- L1-Reference signal received power (RSRP) measurements for mobility and beam management
- DL CSI acquisition
- Interference measurement
- Time and frequency tracking

ZP-CSI-RS is used for DL CSI acquisition and interference measurement. It also masks certain resource elements (REs) to make them unavailable for PDSCH transmission. As the name ZP indicates, nothing is transmitted in those REs.

III. MATERIALS AND METHODS

A. Synchronization, Channel Estimation and CSI Measurement Configuration

This example performs synchronization and channel estimation in SRS candidate slots. Timing and channel estimates are updated only in slots containing SRS transmissions. In frequency-hopping SRS setups, channel estimates are only updated in those resource blocks containing SRS symbols. When there is no SRS transmission, timing and channel estimates from previous slots are held and used for CSI acquisition. Similarly, noise power estimates are updated only in SRS candidate slots.

B. Propagation Channel Model Configuration

Create a TDL channel model object and specify its propagation characteristics. Select the channel delay spread and maximum Doppler shift to create a time-varying and frequency-selective channel within the simulation duration and carrier bandwidth.

C. Processing Loop

Measure the CSI per slot. The CSI is obtained using the following steps:

- **Generate resource grid**. Use SRS symbols and indices to create a resource element (RE) grid.

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- **Generate waveform.** The generated grid is then OFDM modulated.
- **Model noisy channel.** The waveform is passed through a TDL fading channel. AWGN is added. The SNR for each layer is defined per RE and per receive antenna.
- **Perform synchronization and OFDM demodulation**. For perfect synchronization, the channel impulse response is reconstructed and used to synchronize the received waveform. For practical synchronization, the received waveform is correlated with the SRS. The synchronized signal is then OFDM demodulated.
- **Perform channel estimation**. For perfect channel estimation, the channel impulse response is reconstructed and OFDM demodulated to provide a channel estimate. For practical channel estimation, the transmitted SRS is used.
- **PMI selection.** The SRS-based channel estimate is used to select the best PMI in each CSI estimation subband. The PMI selection criterion maximizes the average signal-to-interference-plus-noise-ratio (SINR) after precoding.
- **PMI selection SINR loss.** The SINR loss is calculated by comparing the SINR after precoding with the estimated and ideal PMIs. Ideal PMIs are selected using perfect channel estimates.

IV. RESULT AND DISCUSSION

This section displays these results for all configured frames:

- Transmitted OFDM grid containing SRS
- Perfect and practical channel estimates, and channel estimation error. The error is calculated as the absolute value of the difference between the perfect and practical channel estimates.
- Selected PMI using perfect and practical channel estimates, and the PMI absolute error.
- Average SINR per subband after precoding with best estimated PMI
- SINR performance loss

Figure 3 displays the transmitted OFDM grid containing SRS. Figure 4 display perfect and practical channel estimates, and channel estimation error per OFDM symbol and subcarrier. The channel estimation error is defined as the absolute value of the difference between the perfect and practical channel estimates.

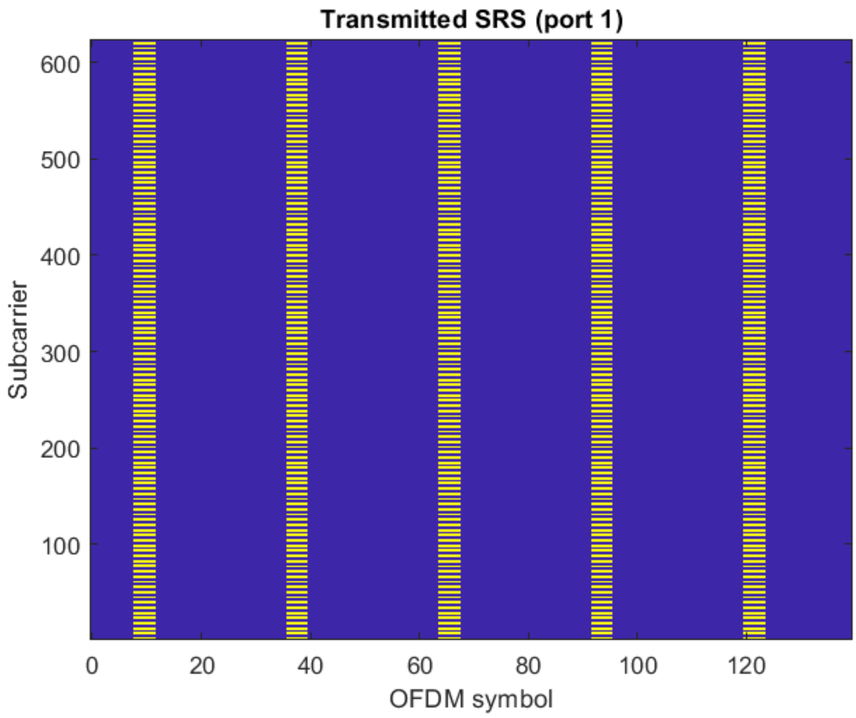

Figure3: The transmitted OFDM grid containing SRS

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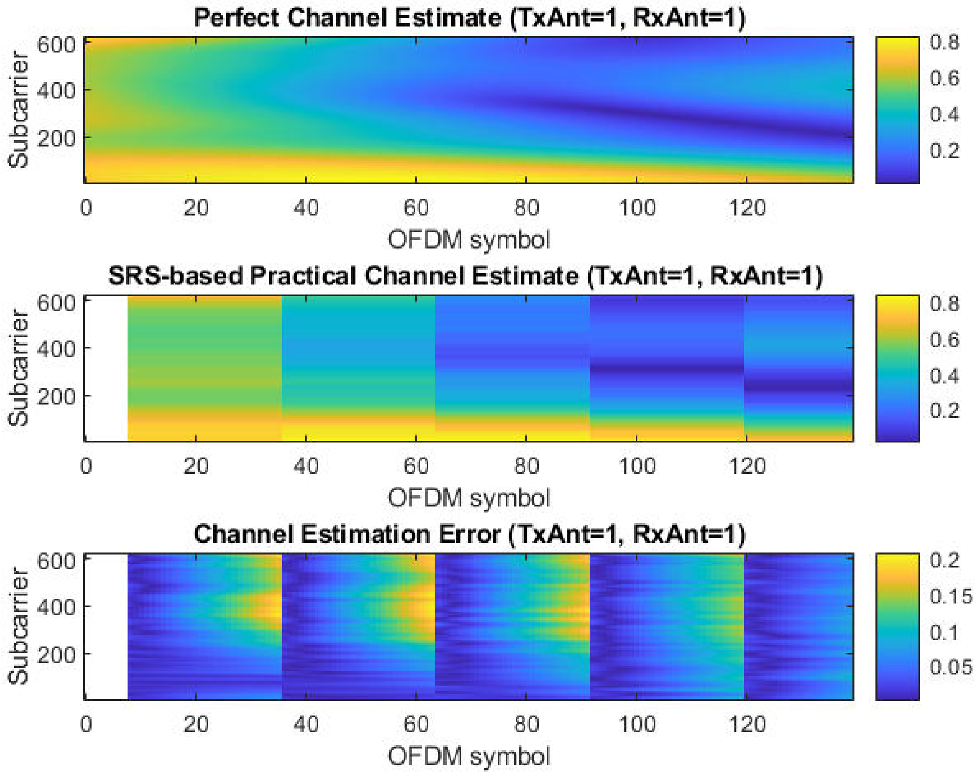

Figure4: perfect and practical channel estimates, and channel estimation error per OFDM symbol and subcarrier

V. CONCLUSION

In this paper, we suggested a novel downlink channel estimation algorithm using uplink SRS based on the channel reciprocity in LTE-TDD systems since the conventional CQI based scheduling algorithm is insufficient to reflect the channel status of each RBG. In order to exploit the uplink SRS to estimate the absolute downlink channel state, we introduced the power headroom report for path loss estimation of SRS. The metric for downlink scheduling is calculated by using SRS as well as power headroom report. Simulation results indicate that the advised algorithm outperforms the conventional method in system throughput for various TDD configurations.

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