Interference Cancellation and Coordination Scheme for Sounding Reference Signal in Multiple-beam Mobile Satellite Communication System

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Abstract—**In LTE system, sounding reference signal (SRS) is transmitted for channel detection to obtain uplink scheduling gain. However, in multiple-beam mobile satellite communication system (MMSCS), large inter-beam and intra-beam interference destroy orthogonality for SRS from different users and lead to lower received SNR. Subsequently, the system cannot predict the channel exactly and will suffer from performance loss. In this paper, an interference cancellation and coordination scheme is presented. This new scheme, by taking MMSCS resources and channel conditions into account, can improve SRS performance after reducing and avoiding interference. One aspect of the presented method is interference cancellation scheme which comprises resending scheme for inter-beam interference and orthogonality enhancement scheme for intra-beam interference. Another aspect is interference coordination scheme, which carries out short SRS hopping between users and acquires the full bandwidth information by several detections. Simulation results confirm the correctness and effectiveness of the above scheme.**

Keywords-interference cancellation; interference coordination; SRS; multiple-beam satellite system;

I. INTRODUCTION

As an important wireless communication system, MMSCS is a significant extension of land mobile communication system, which is developing in the direction of high-speed and broadband, following the trajectory of ground systems. However, not only research but also realizations are relatively backward. [1] puts forward the objects and priorities of broadband and high-speed satellite mobile communication system. Furthermore, [2][3][4][5][6] discuss the compatibility of applying existing terrestrial 3G/B3G wireless transmission mode to satellite conditions, in addition, some possible modified proposals are presented. Some new technology may be used in MMSCS [1][15]. In satellite communications, GEO MMSCS is an important subclass, which inherits the merits from GEO system of large single satellite coverage area. Different areas can be divided by beams generated by multi-feed antennas [7]. With the remarkable development of land system standards, study of LTE-compliant satellite mobile communication system has been gradually unfolded. For compatibility, SRS is also used for uplink channel detection for frequency selective scheduling in MMSCS. But because of the special feature of satellite environment, some appropriate changes are needed.

Inter-beam [8] and intra-beam interference are the main problems faced by GEO MMSCS. Compared with data signals, SRS owns specificity including higher requirement for signals quality and more susceptible by interference, so it is significant to achieve an effective method to ensure the systems performance. Current research on SRS is mostly focusing on improvement and optimization of channel estimation algorithm in terrestrial systems, lacking deep study about SRS protection scheme for corresponding satellite systems. This claims the significance and necessity of study in this paper.

This paper is based on SRS configuration in LTE R8 standard. Special interference condition in GEO MMSCS is considered, including inter-beam interference and intra-beam one. Applicability of SRS in MMSCS is carefully analyzed by modeling the system and interference. In order to use SRS in multi-beam satellite environment, inter-beam and intra-beam interference must be solved. Therefore, as the current configuration of SRS cannot meet the said requirement, the feature that satellite has long coherence time is taken into account, an interference cancellation and coordination scheme is presented. Simulation proves the effectiveness and the acceptability of the proposed scheme in satellite conditions

In Section II, system model and interference model are presented. Additionally, the adaptability of existing SRS configuration in LTE be applied in MMSCS is analyzed in this section. In Section III, an interference cancellation and coordination scheme is proposed for MMSCS. In Section IV, a simulation system is designed, and the simulation results are analyzed. Finally, in Section V, a summary is given for the whole paper.

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II. RESEARCH ON LTE SRS ADAPTABILITY IN MMSCS

A. System and Channel Model

GEO satellite communication system consists of UEs, GEO satellites, and gateway stations. For simple exchange mode, the satellite only play as a transponder and will not deal with data. Air interfaces consist of connections from UEs to satellites and from satellites to gateway stations. Both of the two kinds of interfaces can use the same standard, which will not be distinguished here.

For MMSCS, interference includes inter-beam one and intra-beam one, which should be responsible for the system performance loss. As the SRS signal is only related to uplink channel, only the uplink inter-beam and intra-beam interference model is discussed in this paper. Uplink interference model is presented in Fig. 1.

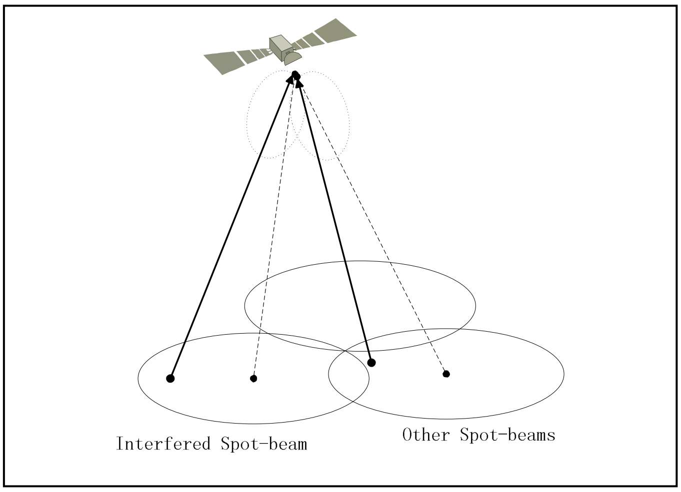

Figure 1. Uplink interference model

We learns from the uplink inter-beam interference model discussed in [8][9][10][11]. The interference caused by other beams is approximate equivalent to K times of local noise, wherein K is defined as inter-beam interference factor. For same frequency networking, K is 1.366[11]. On the other hand, intra-beam interference is mainly caused by other UEs who are using the same time and frequency resources. So the concrete interference is the transmitted signals. We should calculate the large scale fading of the interference signal. For a GEO system, channels for all UEs can be viewed as LOS condition. Distance between satellite and UEs in same beam is nearly the same, so it is feasible to simplify the complex condition to that UEs in same beam own same large scale fading. According to [12], typical value of large scale fading is 177dB.

B. Analysis of LTE SRS Interference and Adaptability Problems

SRS in LTE R8 uses ZC sequence with cyclic shift (CS). Different beam can choose different ZC base sequence to guarantee orthogonality. For UEs in the same beam using the same ZC base sequence, the orthogonality can be ensured by the multiplexing of code and frequency. Specifically, it can be achieved by selecting different CS and comb configuration [13]. In time domain, SRS can occupy the last SC-FDMA symbol of each regular slot, or two symbols in TDD uplink special slot. In R8, available CS and comb number is 8 and 2. If SRS sequence under different resource selection is totally orthogonally, the available SRS sequence number is 16. However, the complete orthogonality cannot be achieved, leading to the available capacity is smaller than 16. What's more, in satellite environment, the received SNR of SRS is always lower than land systems, the non-orthogonality of SRS will result in more performance degradation. Simulation results prove that the current SRS in LTE R8 cannot be directly applied in GEO MMSCS. An interference cancellation and coordination scheme is needed to meet the requirement of SRS capacity and coverage, also to enhance the system performance.

III. INTERFERENCE CANCELLATION AND COORDINATION SCHEME

As mentioned above, MMSCS is suffered with inter-beam and intra-beam interference, which is the crucial reason for performance loss. So in this paper, in the light of physical resources and channel environment of satellite system, an interference cancellation and coordination scheme is designed to improve SRS performance. Details of the proposed scheme include two aspects: in one hand, the interference cancellation scheme to enhance SRS orthogonality and the short SRS hopping scheme dealing with the intra-beam interference; in another hand, the resending scheme for inter-beam interference cancellation.

A. Interference Cancellation Scheme

In MMSCS, interference can be classified into inter-beam interference and intra-beam one according to source. The two kinds of interference have different features and patterns, so customized cancellation is needed.

Because one satellite owns several beams in MMSCS, uplink beams will suffer from serious interference. As mentioned before, interference caused by other beams is treated as noise, so interference cancellation can be viewed as a way to improve SRS received SNR. In satellite system, coherence time can reach the magnitude of 100ms[14], which is much longer than a LTE slot, so it is acceptable to believe that the channel does not change in a few LTE slots. Hence, several SRS can be considered jointly to do channel estimation to achieve interference cancellation. Specifically, several same SRS sequences are transmitted in a few of continuous time slots, and scrambled by orthogonal codes. At the receiver, the transmitted sequences are combined together to improve SRS equivalent SNR. Normal orthogonal code words include OCC codes, which own the feature that with longer words, the performance of interference cancellation is better. While for a longer time period, the channel maybe shows a significant change, thus leading it improper to combine signals. So it is necessary to take different conditions into account to expressly design orthogonal codes. The detail inter-beam interference cancellation scheme can reference to Fig. 2.

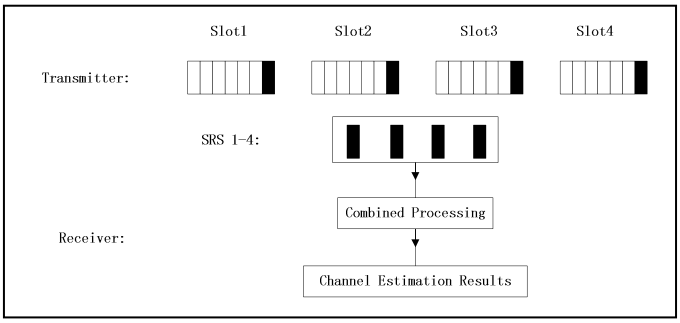

Figure 2. Inter-beam interference cancellation scheme (4 Slots)

Different from inter-beam interference, intra-beam interference is mainly caused by the UEs who are using the same time and frequency resources in the same beam. For normal data, scheduling scheme can solve the interference problem. However, because of the full bandwidth detection requirement and fixed time resource allocation for SRS, the intra-beam interference here is relatively severe. In additionally, the facts that different UE's SRS cannot be completely orthogonal and the received SNR is always lower in satellite system, will lead to performance loss and strong need for interference cancellation. Short of that, the main point for performance loss caused by intra-beam interference is orthogonality. So it is natural to realize interference cancellation by ensuring the orthogonality as much as possible. In current design, different SRS sequence's orthogonality is guaranteed by two aspects: frequency domain and code domain. Simulation shows that under current configuration, frequency domain's orthogonality is better than code domain. As a result, by reducing frequency interval and increasing code domain interval, it is possible to improve the SRS sequence orthogonality and minimize the interference performance impact. Specifically, frequency and code domain's intervals are changed in an equimultiple way, without changing available SRS numbers to hold the system capacity. In LTE original configuration, frequency and code domain configuration are 2 and 8. In this paper, configuration is changed to 4 and 4 to support the proposed intra-beam interference cancellation scheme, while keeping the total capacity as unchanged 16.

B. Interference Coordination Scheme

Besides the above interference cancellation scheme including eliminating SRS equivalent interference and improving resistance for interference, carefully designed scheduling scheme can avoid interference. In this paper, an interference coordination scheme is designed using short SRS dislocation hopping between UEs. In detail, due to coherence time in satellite system is longer; it is acceptable to believe that the channel remains the same for quite a long time. Several SRS can be combined to obtain the channel information. Additionally, there is the requirement for SRS to detect the full bandwidth to realize frequency domain scheduling. A new approach is presented:

Firstly, do channel detection using SRS which occupies less bandwidth in frequency domain. Then do frequency hopping for short SRS in several continuous slots, and obtain the full bandwidth information. Due to the long coherence time of satellite channel, these short SRS channel estimation results are effectiveness for long time. Frequency selective scheduling can be done according to the channel estimation results and the corresponding frequency domain channel prediction result can be refreshed in the next detection. Moreover, on the foundation of detection, different UEs can use different frequency hopping method to ensure that UEs will select dislocation hopping method. So that the frequency bands for SRS transmission at the same time do not overlap and can complete the coordination. Detailed interference coordination scheme can reference to Fig. 3.

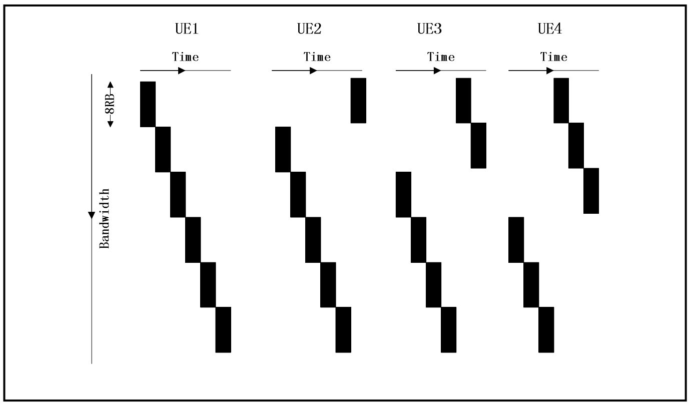

Figure 3. Interference coordination scheme (4UEs)

For the mentioned interference coordination scheme, selection of frequency hopping scheme, SRS length for detection, detection number and period are all needed. In LTE, 10MHZ bandwidth is allocated to 50 RBs. After considering the detection number, anti-interference ability and compatibility, SRS length is defined as 8 RBs here, and detection number is 6. To avoid confliction, inter-beam group and sequence hopping scheme is proposed. Specifically, UEs which carry out interference coordination can select different detection starting point and detect in turn. The number of UEs available for interference coordination is 6, which is enough to meet the coordination requirement for relatively close UEs. Given the coherence time of satellite channel can reach 100ms, the detection period can choose 20ms or 40ms according to the concrete overhead requirement and resource configuration.

IV. SIMULATION RESULTS

The most direct indicator for measuring the performance of SRS is the accuracy of channel estimation. In order to verify the accuracy and effectiveness of the proposed interference cancellation and coordination scheme, a simulation platform as Fig. 4. is built. The platform consist of modules like multi-beam scenario generation module, SRS sequence generation module, channel, channel estimation module. The simulation parameters and algorithm can reference to Table 1. The result of channel estimation is as follows.

Fig. 5 presents that the channel estimation MSE results for SRS in LTE R8 under multiple-beam environment. Channel estimation performance suffer a large degradation with inter-beam and intra-beam interference, which proves that the interference cancellation and coordination scheme is needed.

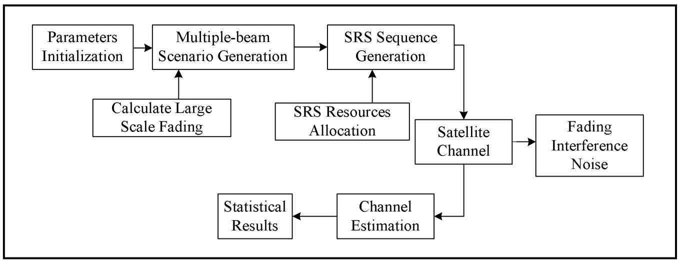

Figure 4. Simulation platform structure.

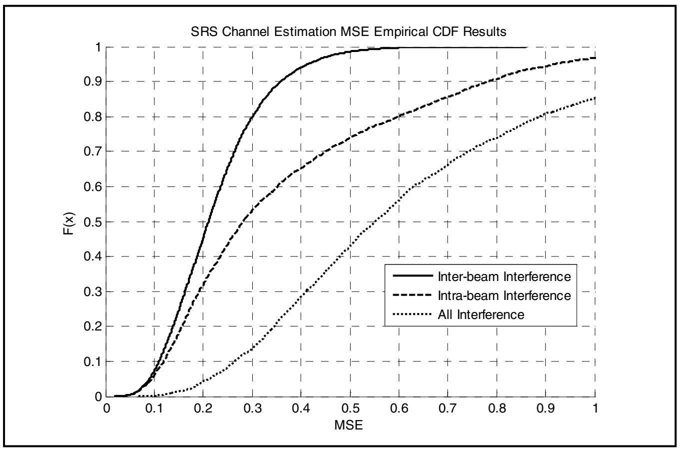

Figure 5. SRS channel estimation results for LTE R8 SRS configurations

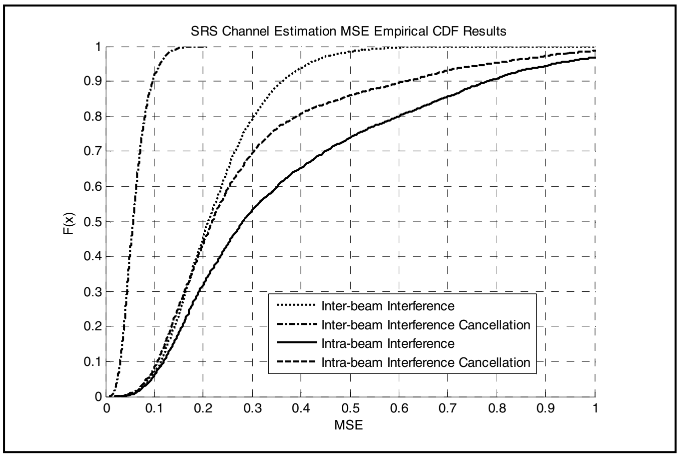

Figure 6. SRS channel estimation results for interference cancellation scheme (inter-beam and intra-beam respectively)

From Fig. 6, we can conclude that the interference cancellation scheme in this paper can obviously improve the system performance, both inter-beam and intra-beam methods are included. In conclusion, the interference cancellation scheme performance is shown in Fig. 7. A channel estimation improvement is achieved by using interference cancellation.

TABLE I. SIMULATION PARAMETERS

Parameters	***Value***
Bandwidth	10Mhz
FFT Size	1024
Channel Model	ITU.R.M. 1225
Channel Estimation Algorithm	DFT-Based
Velocity	3km/h
Large Scale Fading	-177dB

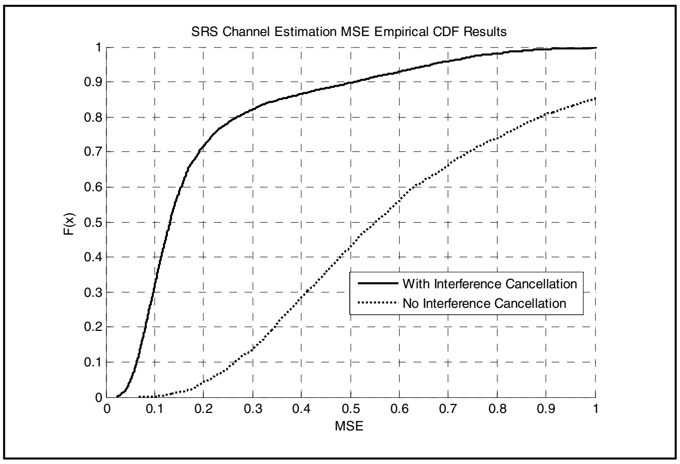

Figure 7. SRS channel estimation results for the whole interference cancellation scheme

Fig. 8 illustrates the interference coordination performance in this paper. Comparing to the no coordination situation, we reach a higher performance after using interference coordination scheme.

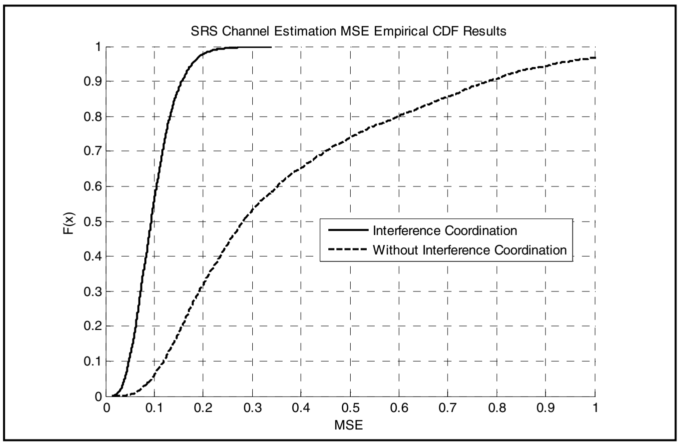

Figure 8. SRS channel estimation results for interference coordination scheme

V. SUMMARY

In LTE compatible MMSCS, SRS is still used to do channel detection. However, inter-beam and intra-beam interference cannot be ignored in multi-beam environment. Directly using LTE R8 SRS configuration will lead to poor performance. So interference cancellation and coordination scheme is needed to improve the performance. One of this paper's contribution is that resending scheme is used to eliminate inter beam interference and lower jam between cells. The other aspect is that a SRS physical resource configuration scheme is presented to improve the orthogonality among different sequences and lower jam in one cell. It is strongly advised to use narrow band frequency hopping to do detection for interference coordination. Full bandwidth information can be obtained by several detections, and a hopping scheme is carefully designed to ensure that the frequency bands detected for different UE at same period are not same. At the end, a simulation platform for SRS performance evaluation is presented, which proves that current LTE SRS configuration cannot be directly used in multi-beam GEO satellite environment. The proposed interference cancellation and coordination scheme can greatly improve the system performance, solve the application problem of SRS, and meet the design requirement. The result can be meaningful reference to practical LTE compatible MMSCS, and also provides the basis knowledge for designing and research of other layers.

REFERENCES

[1] Mohamed Ibankahla, Quazi Mehbubar Rahman, Ahmed Iyanda Sulyman, Hisham Abdulhussein Al-asady, Jun Yuan, Ahmed Safwat, "High-Speed Satellite Mobile Communications: Technologies and Challenges", Proceedings of the IEEE, Vol.92, No.2, Feb, 2004.

[2] ETSI, "Satellite Earth Stations and Systems (SES); Satellite component of UMTS/IMT-2000; General aspects and principles [S]." ETSI TR 101 805v1.21, 2002

[3] Jianjun Wu, Shubo Ren, Xi Luan, Xiaoyan Xu, and Yuxin Cheng, "Scheme of Uplink Synchronization for Mobile Satellite system compatible with TD-SCDMA frame", The 7th Forum of New Technology and Service in Satellite Communication, Beijing, 2011.3, pp. 185-194

[4] Jian Guo, Shubo Ren, Xiaoyan Xu, and Jianjun Wu, "Uplink Capacity Analysis of GEO Satellite Mobile Communication System Compatible with TD-SCDMA", ICCNT 2011, pp.247-251

[5] Ying Si, Xi Luan, Shubo Ren and Jianjun Wu. "An Interleaver Scheme for TD-SCDMA Compatible GEO Satellite Communication System." ICIST 2011, pp.627-630.

[6] Arif A, Dutta S, Tseytlin M. S-Wimax: Adaption of IEEE 802.16e for Mobile Satellite Services [J]. IEEE Communications Magazine, 2009, 47(6): 150-155

[7] P.D. Patel, C.Eng., K.K.Chan, "Optimisation of controured beams for satellite antennas", IEE Proceedings, Vol.132, Pt. H, No.6, Oct, 1985.

[8] A.J. Viterbi, A.M. Viterbi and E. Zehavi, "Other-cell interference in cellular power-controlled CDMA", IEEE Trans. on Common., vol. 42, pp. 1501-1504, Feb. /March/April 1994.

[9] "Satellite antenna patterns in the fixed-satellite service" CCIR report 558-3 (MOF F), Nov. 1989.

[10] Kilic, O., "Interference Analysis for Spot Beam Partitioning in Cellular Satellite Communication System", Antennas and Propagation Society International Symposium, 2008. AP-S 2008. IEEE, pp. 1-4

[11] Jian Guo, Shubo Ren, Ying Si, Jianjun Wu, "Analysis of Other Spot-beam Interference in TD-SCDMA Compatible Satellite System". International Conference on Wireless Communications and Signal Processing, WCSP2011.

[12] Wu Shiqi, Feng Kai, "Link Budget Margin of Mobile Satellite Communication System", Telecommunication bulletin, 1995.12.

[13] 3GPP Technical Specification 36.211, 'Evolved Universal Terrestrial Radio Access(E-UTRA); Physical Channels and Modulation (Release 8)', www.3gpp.org

[14] Sadowsky, John S. Lee, David K. "The MUOS-WCDMA air interface", Military Communications Conference, 2007. MILCOM 2007, IEEE, Page(s): 1-6;

[15] Lingyang Song, Youhui Li, and Bingli Jiao, "Differential Modulation for Bi-directional Relaying with Analog Network Coding", IEEE Transactions on Signal Processing, Vol. 58, No. 7, pp. 3933 – 3938, Jul. 2010