TDMA 기반의 차세대 위성리턴링크 버스트 구조 설계 및 성능 분석

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Design and Performance Analysis of Burst Structure for TDMA-based Next Generation Satellite Return Link Transmission

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요 약

본 논문에서는 고효율 위성리턴링크 TDMA버스트 전송을 위한 최적의 버스트 구조 설계에 관한 것이다. 일반적인 DVB-RCS, IPOS 표준 등에서는 preamble과 데이터 형태의 전송 구조를 가진다. 현재, 이와 같은 구조에서는 대역폭당 전송효율을 올리기 위한 고차변조방식을 수용하는데 많은 preamble 데이터 또는 높은 SNR환경, 또는 수신기의 복잡도가 증가하게 된다. 이를 개선하기 위해서 분산 파일롯 형태의 전송하는 경우 반송파 복원 측면에서 같은 동일한 preamble 길이에 비해 잔류 주파수 오차를 최소화시킬 수 있다. 특히, 기존에 알려진 다양한 분산 파일롯 형태의 burst 전송 구조를 확인하고 고효율 위성리턴링크 전송을 위한 장단점을 분석하고자 한다.

키워드 : 고차변조방식, 분산 파일롯 버스트 구조, 반송파 복원, TDMA 위성 전송

ABSTRACT

This paper is related with optimum burst structure design for high efficient TDMA satellite return link transmission. In general, some typical burst structure for data transmission is composed of a pair of preamble and traffic data in the DVB-RCS (Digital Video Broadcasting – Return Channel via Satellite) and IPOS (IP over Satellite) standard. This structure has some difficulties to increase spectral efficiency that it requires a large of preamble length, high SNR environment, or receiver complexity. To cope with them, burst structure with distributed pilot symbol can be used to alleviate the residual frequency offset effect by calculating accurate frequency offset than conventional one. In particular, we investigate some relevant to proposed distributed pilot structure, previously and analyze their strong points/drawbacks in terms of synchronization to draw the most appropriate one.

Key Words : High order modulation, distributed pilot burst structure, carrier recovery, TDMA satellite transmission

Ⅰ. Introduction

The growing interest for multimedia applications is encouraging the deployment of fixed telecommunications satellite systems capable of offering high-speed point-to-point links at competitive service fees. Therefore the next generation of broadband satellite systems must be designed to offer higher throughput and spectral efficiency than the one provided by current systems. That will be possible by exploiting the higher frequency bands allocated to fixed satellite systems (e.g. the Ka-band), and by adopting high spectral efficient modulation scheme. In this paper, we focus on the feasibility study of high efficient modulation of the satellite return link path in the Ka band. Specifically, to increase the spectral efficiency based on TDMA

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burst transmission, as the one of the most significant aspects, we investigate the optimum burst design in terms of synchronization technique in the receiver. TDMA burst synchronization technique for satellite communication at very low SNR is challenging, especially in case of short burst. One of the major difficulties is attributed by the frequency recovery that in these conditions can not efficiently compensate the whole frequency error in the low SNR. Therefore, the carrier phase recovery is challenging work as well because it has to cope with a significant residual frequency error. In particular, classical approaches based on feedback loop may fail due to the need of a large loop bandwidth (because acquisition time is very limited) and to the resulting non negligible cyclic slips probability. On the other hand, burst detection and fine timing recovery are generally less critical, although burst detection may be impacted when small preambles are considered due to the requirement of minimizing the burst overhead. In this paper, different kinds of burst are analyzed, with UW (Unique Word) added for the coarse frequency and pilot symbols added for the fine frequency recovery and phase tracking. This paper is organized as follows. In the section 2, four different kinds of burst format design is introduced. In the section 3, some specific synchronization techniques are applied to different kinds of burst format and the best one is selected among them in terms of performance point of view.

2. Burst format design

Four different burst formats have been considered for the synchronization performance analysis and will be described.

2.1 preamble + data structure (Type #1)

The simplest burst is shown in Figure 1. It is composed of a preamble UW and a single payload symbols section. Guard symbols are equally inserted before the preamble and after the payload section. This structure has been applied in the existing DVB-RCS and IPoS system. This is very common to VSAT system.

Figure 1. preamble + data type burst

2.2 distributed pilot symbol structure (Type #2)

This burst format is reported in Figure 2. It is composed of a preamble and several payload symbols sections divided by pilot symbols blocks. Guard symbols are equally inserted before the preamble and after the last payload symbols section. The pilot symbols blocks are evenly spaced and each one is composed by a fixed number of pilot symbols. All the payload symbols sections have the same length except for the last section that can be shorter than the other ones. This burst format has been designed with the aim to exploit the pilot symbols blocks for the fine frequency estimation procedure. Pilots may also be used for carrier phase recovery, if a feed-forward strategy is selected.

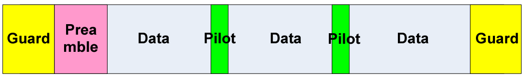

Figure 2. distributed pilot symbol structure

2.3 preamble+postamble structure(Type #3)

This burst format is depicted in Figure 3. It is composed of a preamble, a postamble and several payload symbols sections with pilot symbols blocks inserted among the payload sections. Guard symbols are equally inserted before the preamble and after the postamble. The pilot symbols blocks are evenly spaced and each one is composed by a fixed number of pilot symbols. All the payload symbols sections have the same length except for the last section that can be shorter than the other ones. This burst format has been designed with the aim to exploit the pilot symbols blocks for the fine frequency estimation procedure (like the burst type #2) and to employ the preamble and postamble for obtaining a good phase tracking performance at the edge of the burst when the feed-forward carrier phase estimation using the sliding window technique is selected.

Figure 3. preamble+postamble structure

2.4 midamble structure (Type #4)

The burst type #4 is shown in Figure 4. It is composed of a "midamble" (UW inserted in the burst middle), several payload symbols sections with pilot symbols blocks inserted among the payload sections and two "edge" symbols blocks respectively inserted before the first payload section and after the last payload section. Guard symbols are equally inserted before the first edge symbols block and after the last edge symbols block. The distance, in symbols, between the first pilot symbols block and the others ones is multiple of a fixed value and each pilot symbol block is composed by a fixed number of pilot symbols. All the payload sections delimited by the pilot blocks have the same length except for the payload sections adjacent to the midamble or to the edge symbols blocks. The edge symbols blocks are composed by a fixed number of known symbols. The burst type #4 has been designed with the aim to maximize the number of known symbols that can be used for the channel estimation in case of asynchronous bursts (with respect to the burst type #3). In fact the use of a compact midamble, instead of the pair preamble/postamble, increases the number of overlapping known symbols. In addition, the aim is to exploit the pilot symbols blocks for the fine frequency estimation procedure and to employ the edge symbols blocks for obtaining a good phase tracking performance at the burst edges with the sliding window technique.

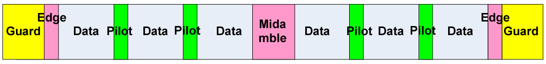

Figure 4. midamble structure

3. Synchronization Design

3.1 UW Detection

The coarse timing recovery, so called as UW detection, is performed on burst types 1, 2 and 4 using the coherent correlation with the UW. Instead, for burst type 3, the coarse timing recovery employs a separate coherent correlation on the preamble and on the postamble with a non-coherent post integration of the two measurements. Note that a ML(Maximum Likelihood) burst detection strategy is selected instead of a threshold based one, i.e. the maximum of the correlation process over the guard time uncertainty is declared as the coarse start of burst.

3.2 Symbol Timing Estimator

In this paper, O&M(Order and Meyr) algorithm is considered since it's well known in terms of reliability. The operation of algorithm is based on 4 samples/symbols, and it can be applied all the burst symbols because it can be worked by non-data aided mode. The performance is independent on the burst types and only depends on the number of symbols in the burst like Figure 5. Figure 5 shows the performance can be improved as Estimation Interval (EI) for symbol timing error computation is extending. However, timing estimator is not a critical element which performance is influenced

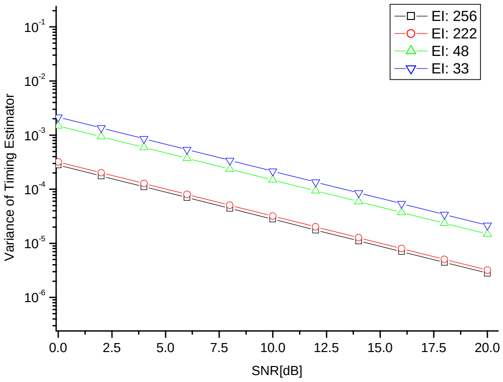

Figure 5. Timing Recovery Performance

3.3 Frequency Recovery Assessment

Coarse frequency recovery is performed jointly with the coarse timing recovery, employing a bank of correlators tuned on different frequencies. Coarse frequency recovery is performed by selecting the frequency error that results in the highest UW correlation value. For the fine frequency recovery, different techniques have been considered. DFT computation on pilot symbols and, optionally, on UW symbols. This technique can be used on all the burst types. And, for fine freq. estimation, M&M algorithm[4] has been considered to operate on the known symbols. This technique can be used on the burst types 1, 3 and 4 exploiting the pilot symbols sequence and the subset of UW symbols that are evenly spaced with the pilot symbol sequence. Also for the minimum SNR values of interest this technique can replace the DFT technique that is more complicated to implement, effectively. The performance description is like Figure 6. The performance gap is shown as different burst types. The simulation condition is the same as the four different kinds of types. We considered the length of 88 preamble/pilot/known symbols. The type #1 and #4 can be applied with 88 preamble and 88 midamble symbols, equivalently. The type #2 consists of 20 preamble, 20 postamble, and 48 pilot symbols. The type #3 is composed of 20 preamble and 68 pilot symbols. The burst type with the best performance is the type #3. The reason which enables to achieve the best performance is that this structure can be suited for facilitating carrier offset estimation. If coarse freq. offset estimator is considered by M&M algorithm, the best performance can be type #2, preamble + distributed pilots types because the accuracy of freq. estimation is improved by frequent pilot data placement period and length.

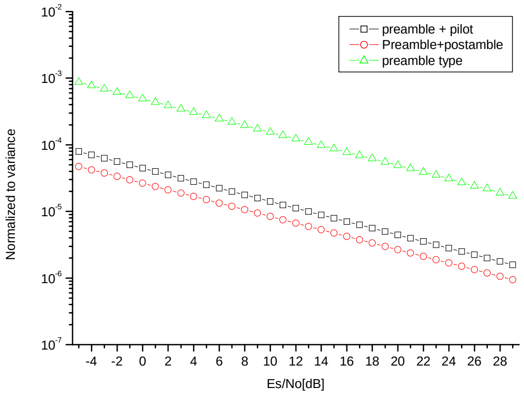

Figure 6. Fine freq. estimation performance

3.4 Phase estimation

The phase estimation has a function to compensate the phase offset and limited residual freq. offset. The V&V(Viterbi & Viterbi) algorithm is appropriate for short burst structure.[5] However, this has the limitation to improve the performance. If the residual freq. offset will be large, the coherent estimation interval should be reduced. Hence, the small number of coherent integration will be degraded in terms of performance in the low SNR environment. As a result, fine freq. estimator should reduce the residual freq. offset as much as possible to increase the number of coherent integration symbol length. The larger number of coherent estimation length is within one freq. cycle, the noise effect will be relieved. In the future, we can consolidate carrier phase estimator algorithm based on reliable data from channel decoder, so called, joint carrier phase synchronization and channel decoder.

4. Conclusion

This paper is mainly dealt with optimum burst structure design for high efficient TDMA satellite return link transmission. The common preamble + data structure burst has some difficulties to increase spectral efficiency that it requires a large of preamble length, high SNR environment, or receiver complexity. To cope with them, burst structure with distributed pilot symbol can be used to alleviate the residual frequency offset effect by calculating accurate frequency offset than conventional one. In particular, we investigate some relevant to proposed distributed pilot structure, previously and analyze their strong points/drawbacks in terms of synchronization to draw the most appropriate one.

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