THE TIME DISTRIBUTION SYSTEM FOR THE WIDE AREA AUGMENTATION SYSTEM (WAAS)

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Abstract

This paper describes the functions, requirements, and objectives of the Time Distibution System (TDS). It should be pointed out that the WAAS TDS has not yet been developed because it is a componentof the final phase of WAAS development. However, WAAS Phase 1 allows for the inclusion of the TDS into the WAAS if it is developed before the final phase of WAAS.

The TDS will be located at the U.S. Naval Observatory (USNO). It will be used to provide the offset data between WAAS Network Time (WNT) and Coordinated Universal Time (UTC). The offset data will then be passed on to the WAAS Master Station (WMS) for transfer to the Geostationary Uplink Station (GUS) and broadcast to users of precise time through the WAAS Signal-in-Space (SIS).

INTRODUCTION

The WAAS has a secondary mission of time distribution [1]. UTC(USNO), Coordinated Universal Time as determined by the Master Clock at the USNO, represents the approved time standard source for the WAAS. Time distribution will be accomplished by providing users with a time offset between WNT and UTC. This time offset will be determined at the United States Naval Observatory (USNO) by a Time Distribution System (TDS). The TDS receives WAAS messages from the geostationary satellites within its view and computes the time difference between the epoch time of the start of a WAAS message and the 1 Pulse Per Second (PPS) of the USNO Master Clock which is the physical realization of UTC(USNO), the time reference for GPS Time. The data collected from each observed satellite by the TDS receiver are passed on to a USNO data acquisition system. The data are then transferred to the WAAS Master Stations (WMS) through an interface between the WAAS and the USNO. The WMS collects the WNT/UTC offset and creates a Type 12 Message that is then sent to the Geostationary Uplink Station (GUS), which transmits it to the geostationary satellite (GEO). The purpose of the Type 12 Message is to provide time users with an accurate source of time referenced to UTC.

TDS DESCRIPTION

The TDS receiver is a specially modified WAAS receiver that functions in a fashion similar to a GPS Time Transfer Unit. It receives the message from a satellite and reconstructs the WNT time that corresponds to that message and then compares that time to the time being input to the TDS from the USNO Master Clock.

The TDS contains an antenna, receiver, and modem. The TDS Antenna receives the WAAS SIS from the GEO satellites. The TDS Receiver collects the WAAS SIS observable and forwards WAAS GEO navigation message and WNT/UTC offset data to a processor. The receiver will output a data string that contains WNT offset data. As shown in Figure 1, an interface between the USNO Processor and the WAAS Message Center Processor (MCP) will communicate the WNT/UTC offset back to the WAAS system.

The data, produced by measuring each GEO satellite 1 PPS epoch with respect to UTC(USNO), are collected and recorded for computation of correction parameters to WNT. The satellite epoch beginning time will be converted to WNT by utilizing the time offset and drift numbers from the WAAS SIS. The TDS then passes the values of all satellites being tracked to the USNO data acquisition system in a format compatible with USNO reduction programs. The collection of WNT-UTC(USNO) time differences is performed by the WAAS Operations and Maintenance (O&M) function for inclusion by the WMS in WAAS Message 12. Message 12 is not intended for navigation.

Users within the WAAS Service Volume can acquire the WAAS GEO SIS and utilize the correction parameters contained in Message 12 to determine their local receiver time with respect to UTC to within an accuracy of 20 nanoseconds. Since the GEO moves very little in the sky with respect to the user, the use of a high gain antenna will be very effective in mitigating the effects of interference.

TDS REQUIREMENTS

Origin of the Requirements

TDS requirements are originally defined in FAA-E-2892B (Specification for the WAAS), paragraph 3.2.8.2. This was originally a Phase 1 requirement; however, due to funding constraints it was deferred and is now contained in SOW Option 3, paragraph 3.2.3.

- FAA-E-2892B, paragraph 3.2.8.2: "*WNT/UTC Time Maintenance.* The WNT offset error from UTC (after correction as defined in paragraph 3.1.3.9.2.2.12.2) shall be less than 20 nanoseconds."

- SOW Option 3, paragraph 3.2.3: "*Option 3 Time Distribution System (TDS) Implementation.* This option shall remain valid for the duration of the WAAS contract. Under the requirements of the Phase 1 WAAS the contractor shall include the TDS in: System Level Documentation - CDRL A121, Configuration Item Level Documentation - CDRLs A042, A043, Interface Control Documentation - CDRL A052, Interface Requirements Specification - CDRL A019, System Orientation Manual - CDRL A123 and the System/Segment Design Document - CDRL A018. Upon exercise of Option 3 the TDS shall be implemented. The contractor is not required to resubmit the Configuration Item Development Specification (A042) and the Interface Control Document (A052) until Option 3 is exercised. The generation of the WAAS Signal in Space Message Type 12, shall be implemented in Phase 1 if WNT/UTC offset information in accordance with the above documentation is provided as GFI."

Description of the Requirement

The requirement states: The WAAS Network Time (WNT) offset from UTC shall be less than 20 nanoseconds. The TDS will include a standard WAAS receiver/antenna. It will be located at the USNO which will determine WNT and compare it with UTC(USNO). The offset will be requested by the WMS for inclusion in the Type 12 message. A TDS Interface Control Document will be required to describe the relation of the TDS with other external systems and equipment.

Justification of the Requirement

The TDS is needed in order for the WAAS to fulfill its secondary mission of time distribution, accomplished by providing users with a time offset between WNT and UTC. The TDS will be valuable to the non-navigation community for synchronizing power grids and telecommunications networks on which the WAAS is dependent. Additionally, it will be of value to other systems within the FAA, such as Automatic Dependent Surveillance (ADS) and ADS-B (Broadcast). Furthermore, the TDS will provide a link with other international Satellite-Based Augmentation Systems (SBAS) through a knowledge of their time offsets with UTC and, therefore, WNT.

TDS OBJECTIVES

WNT, as measured from the GEO SIS epoch timing, is controlled to very close tolerances to the GPS time epoch and will be maintained to a highly accurate time offset with respect to UTC(USNO). The TDS performs a time difference between the GEO beginning of message epoch times and an accurate 1 pulse per second (1 PPS) strobe from the USNO time reference system (Master Clock), which denotes the beginning of a UTC second mark.

Users within the WAAS Service Volume which also have a TDS can acquire the WAAS GEO SIS and utilize the correction parameters contained in Message 12 to determine the offset of their local reference time from UTC to within an accuracy of 20 nanoseconds. WNT provides for the user a continuous, accurate, and redundant timing signal which is not affected by Selective Availability. In addition, if a high gain antenna is used, a TDS receiver should be able to mitigate the effects of interference on the received signal.

DISCUSSION

GPS has become one of the primary means for distribution of time throughout the world. Several manufacturers have developed special timing systems to be used in conjunction with GPS signals. These systems are often called GPS Time Transfer Units (TTUs). Unfortunately, there are no WAAS timing systems in existence. However, the WAAS receivers used at the WAAS Reference Stations (WRS) provide the necessary hardware to allow the development of a WAAS TDS based on the knowledge which has been gained in the development of GPS TTUs.

By placing a scaled-down version of the WAAS Reference Station receiver at the USNO and using the USNO Master Clock as the local reference for the receiver, it is possible to determine the offset between the timed messages coming from the GEO based on WNT and UTC(USNO). The TDS Receiver provides sufficient output data through an RS232 port to allow the calculation of this difference. The

calculations can be done on site at the USNO using a PC system and a time interval counter which is compatible with other USNO timing systems. The results of these calculations will then be passed on to the USNO Data Acquisition System for storage and computation of average values. The WAAS WMS will then retrieve the necessary data for inclusion in the WAAS Message 12 by an Internet connection to the MCP or in a manner to be mutually agreed to by Raytheon and USNO such that the operational concept for the WAAS is satisfied.

Prior to start of operations with the TDS, it will be placed at the USNO for a trial period of data acquisition. During this period, a thorough analysis of the data will be performed in order to verify and validate that all calibration constants have been correctly evaluated through independent checks.

ACKNOWLEDGMENTS

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REFERENCES

[1] W. J. Klepczynski, *"The role of time and frequency in the Wide Area Augmentation System (WAAS),"* Proceedings of the 12th European Frequency and Time Forum, 10-12 March 1998, Warsaw, Poland.

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System Specification for the Wide Area Augmentation System (WAAS), CDRL Sequence No. A121-001B.

System/Segment Design Document for the Wide Area Augmentation System, CDRL Sequence No. A018-001B.

Prime Item Development Specification, Time Distribution Subsystem for the Wide Area Augmentation System (WAAS), CDRL Sequence No. A052-003, 14 March 1997.

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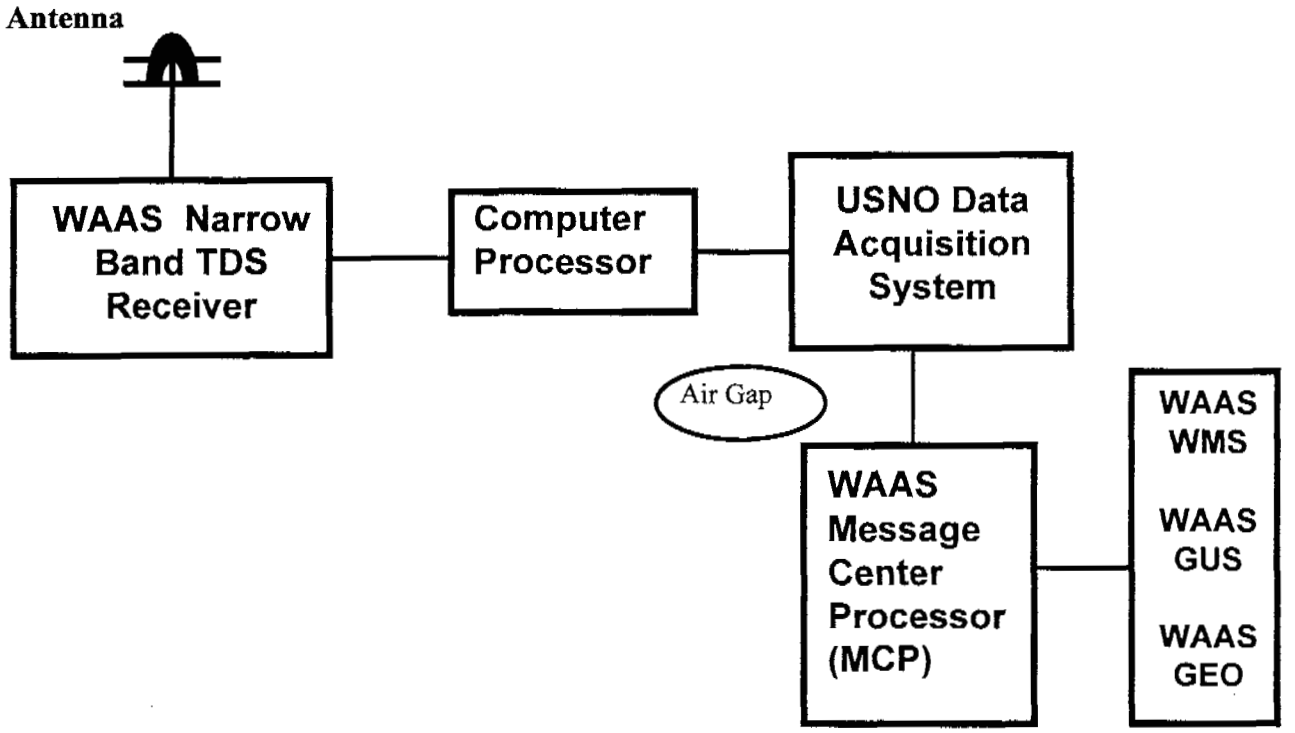

Figure 1 – Architecture of the Time Distribution System (TDS)

Questions and Answers

DENNIS McCARTHY (USNO): My question is regarding the specifications for the WAAS net time. You said it would have worldwide availability. So do you have any numbers on what you expect the specifications will be with respect to GPS time?

WILLIAM KLEPCZYNSKI (ISI): The specification for WAAS net time with regard to GPS time calls for 50 nanoseconds, because that allows the seven meters or so that will allow for a safe navigation in certain conditions.

DENNIS McCARTHY: Is that the only specification on the net time?

WILLIAM KLEPCZYNSKI: No, the second specification on WAAS net time is that it be within 20 nanoseconds of UTC USNO.

DENNIS McCARTHY: Okay, 20 nanoseconds of UTC USNO.

WILLIAM KLEPCZYNSKI: And 50 nanoseconds of GPS time.

JOERG HAHN (DLR): I was listening to some of the problems with the funding of the WAAS system. Can you tell me something about this?

WILLIAM KLEPCZYNSKI: I can not tell you that; I have no idea. Actually, I am a technical type, and I was away on travel and had just come back. All I can say is that unofficially I know that Congress has not been very happy the way the FAA officials have been documenting their budget and things like that. So they have been slapped on the hand a little bit here and there. What the net fallout is, I honestly do not know, at this point in time, just because I have not been at the office for at least a week now. I know that there were some major meetings taking place this week to describe the budget, but I do not know what the result is.