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Asynchronous Message Transmission Technique for Latency Requirements in Time Critical Ship-borne System

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ABSTRACT

A solution to data ageing requirements in time critical ship system like fire control system is presented. In an operational sea borne platform, navigation requirements for the onboard systems are fulfilled by ring laser gyro-based inertial navigation system. For critical systems like fire control system, navigational data must be delivered in real time without any delay. However due to delay occurring in processing of raw information and transmission of data on interface bus some latency is introduced. Algorithm for an asynchronous message transmission technique from inertial navigation system to user system to meet its latency requirements is discussed. Latency requirement is achieved by sending a separate message with the time stamp for the instance the first byte of 100 Hz attitude data is received at the processing computer of navigation system.

Keywords: Inertial navigation system, latency, asynchronous message, time stamp

NOMENCLATURE

A1	Asynchronous message on MIL STD 1553 B bus
BC	Bus controller
EKF	Extended Kalman filter
FCS	Fire control system
GNSS	Global navigation satellite system
INS	Inertial navigation system
M1	Navigation message Array on MIL STD 1553 B bus at update rate of 20 Hz
NC	Navigation computer
NCS	Navigation complex system
PU	Processing unit
RS422	Recommended standard 422 EIA 422 A electrical characteristics of Balanced voltage differential interface circuits
RT	Remote terminal
TA	Transfer alignment
1553	MIL-STD-1553B - military standard aircraft internal time division command/response data bus

1. INTRODUCTION

Inertial navigation system (INS) is an autonomous system for determining the position, orientation and velocity of a naval platform. The main goal of an INS based ship navigation complex system (NCS) is to ensure a safe navigation and the uninterrupted supply of the best possible navigation data to the crewmembers and to the combat systems. In order to meet these requirements, the navigation system is designed as an integrated and redundant system. It has multi-sensors integration capabilities, which means acquisition of all available navigation data from independent sensors and their processing, the result being a common, consistent, highly accurate and reliable set of data available to all users of navigation information.

For mission critical applications, the performance of weapons depends on the accuracy of the data; the worst latency of the navigation system should not exceed the latency limits imposed by a critical system such as FCS for missile firing. Fire control system requires platform navigation data to initialise and calibrate its own inertial navigation system (slave INS). This process of aligning one INS with data supplied by another INS is called transfer alignment. The transfer alignment process must be rapid and accurate. In real-time implementations, the FCS measurements suffer from the delay in navigation data which affects the accuracy of the transfer alignment. This information delay occurs because of time lapse (data ageing) between sensor measurement at ship navigation system and data receipt at slave INS. To solve the latency constraint on FCS side, a data identification technique which allows FCS INS to identify and match received navigation data with previously stored data and know the precise time when the navigation data was generated is highlighted.

2. DATA AGEING

The data ageing or latency corresponds to the maximum time between sensor measurements and end of transmission of the message to users input. For NCS, it includes maximum time of:

(a) Sensor latency due to internal measurement (from sensor measurement to beginning of transmission),
(b) Transmission from sensor to processing computer (baud rate),
(c) Internal computer latency from reception to message

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generation,

(d) Transmission from computer message generation to user input (driver + baud rate).

Hence the total latency is sum of latency values (a), (b), (c) and (d) as shown in Fig. 1.

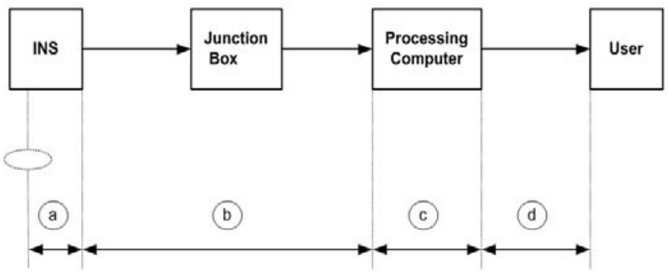

Figure 1. Illustration of latency.

3. NAVIGATION DATA TRANSMISSION BETWEEN INS AND FCS

On the platform, the INS navigation data is transmitted to FCS through processing unit located in navigation computer (NC). Navigation computer is the brain of ship navigational system which has processing-cum-distribution unit to manage navigation data distribution in order to provide the best navigation information to users. INS data is received by NC through a direct RS422 interface. Processing unit located inside NC processes the data and the processed data is transmitted to the FCS through a dual non-redundant 1553B bus as two remote terminals per bus to receive status data from FCS and to provide navigation data to the FCS. Navigation messages are generated by processing unit (PU) of the Navigation Computer and transmitted to end users through this interface. The interface diagram is as shown in Fig. 2. The two buses managed by the NC are dual non-redundant MIL-STD-1553B transformer coupled data buses. The MIL-STD-1553B bus is defined for serial digital data bus using time division multiplexing techniques: several signal sources communicate through one communication line with different signals staggered in time to form a composite pulse train.

The MIL-STD-1553B bus operates asynchronously: each bus terminal uses an independent clock to send/receive its data. Message decoding is achieved using a local clock synchronized with the message. The MIL-STD-1553B bus operates in a command/response mode: the remote terminals (RT) receive or transmit data or perform other 'modes'

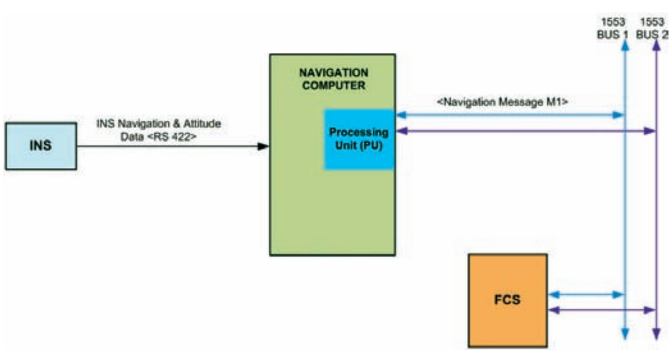

Figure 2. Navigation data transmission from INS to FCS.

only when commanded to do so by the bus controller (BC). Transmission occurs in a half-duplex manner: data transfers are done in either direction over a single line, but not in both directions on that line simultaneously. The information flow on the data bus is composed of messages and messages are made up of words.

The navigation data is sent by NCS to the external users through a broadcast message. The transmitter sends the data once to all the receivers but the receivers do not send their status words to answer to the emitter, this method limits the line load. Transmission of navigation information of INS from NC is done in format 'broadcast BC to RTs' of MIL-STD-1553B in the form of a message array M1 at every 50 ms.

4. REQUIREMENT OF ASYNCHRONOUS MESSAGE

The correlation of FCS own inertial data with that provided by platform navigation system is required for transfer alignment process. The transfer alignment of FCS is necessary to allow it to initialise and calibrate its own INS using the attitude data from ship navigation system. To enable FCS to correlate its own inertial data with the ones provided by the navigation system, FCS:

- shall be informed when the navigation computer receives the first byte of the INS (100Hz) attitude data to internally store its own inertial data,
- shall be able to identify the inertial data corresponding to the ones previously stored.

To fulfil these requirements, the solution requires Navigation Computer to send an asynchronous 1553 message as soon as platform INS 100 Hz attitude data is received. This message shall be required to be sent at the INS 100 Hz data first byte reception and shall contain a time stamp data to enable data identification (to enable matching with 1553 future message). The mechanism principle is presented in the Fig. 3.

The following sections present the solution implemented, data ageing considerations and potential limits of this solution.

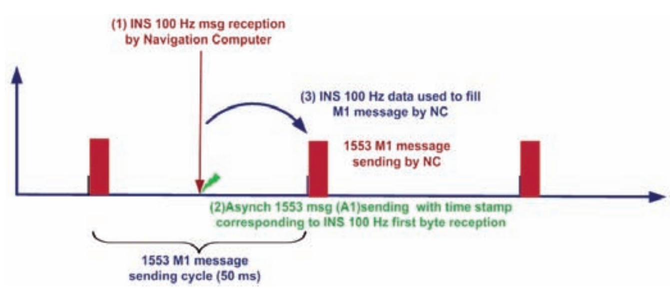

Figure 3. Asynchronous 1553 Message principle.

5. IMPLEMENTATION OF SOLUTION

The solution proposes to use INS 100 Hz data to generate the 1553 asynchronous message. INS 100 Hz data is received by the Navigation Computer, processed and then transmitted in the form of a message array M1 at an interval of 50 ms. The solution defines a temporal window corresponding to the expected INS 100 Hz data reception used to fill the message M1. This temporal window is illustrated in the Fig. 4.

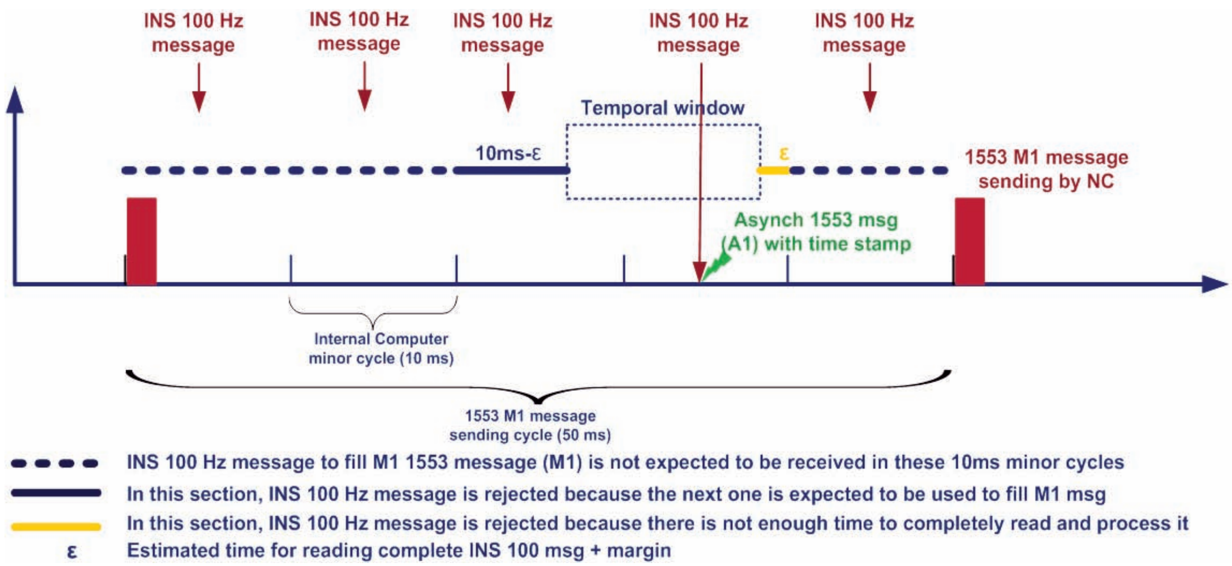

Figure 4. Temporal INS message window definition.

The process performed by the navigation computer is:

- Wait for the temporal window by 'rejecting' the INS 100 Hz messages which do not belong to the window (not expected to fill the M1 1553 messages)
- At first INS 100 Hz message reception in the window, time stamp (using system time) on the first byte and send the asynchronous 1553 message with this time stamp. We call this new message A1.
- The inertial data received with this first INS 100 Hz message are stored to be sent in the next M1 message with the time stamp sent in the asynchronous message. As some special cases may lead to the sending of different inertial data a dedicated flag will indicate in M1 message if the inertial data are consistent with the previous asynchronous 1553 A20 message.

6. AGEING CONSIDERATION

As shown in Figs. 5 and 6, the INS 100 Hz message used to generate the 1553 M1 may be read by the navigation computer in the 10 ms internal PU real time minor cycle preceding the M1 message generation or in the previous internal minor cycle.

The data ageing value for navigation computer component (i.e. internal computer latency) belongs to:

10 ms + $\varepsilon \leq$ Ageing for M1 data coming from INS 100 Hz $\leq$ 20 ms + ε with ε # 4 ms.

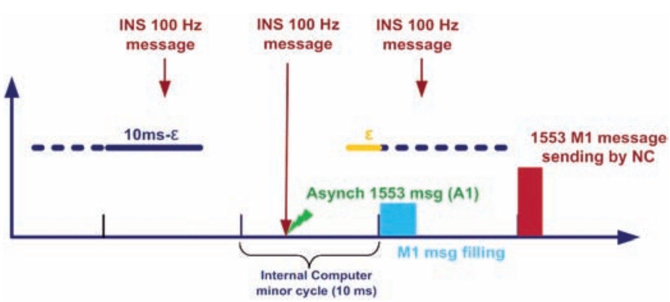

Figure 5. INS 100 Hz reception in 10 ms minor cycle preceding M1 message generation.

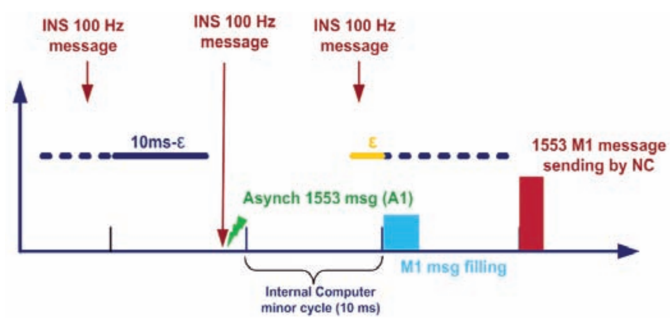

Figure 6. INS 100 Hz reception before 10 ms minor cycle preceding M1 message generation.

7. SPECIAL CASES AND ASSOCIATED PROCESS

This section lists the non-nominal cases that may occur and the solution implemented for their management.

7.1 INS 100 Hz Message is Incomplete or has an Incorrect Checksum

As at INS 100 Hz first byte reception the correctness of the complete message cannot be evaluated before sending the A1 asynchronous 1553 message, there is a possibility of sending inconsistent data in next M1 messages in comparison with the A1 emission. The consistency flag of the M1 messages will be set to FALSE to handle this non-nominal case as shown in Fig. 7.

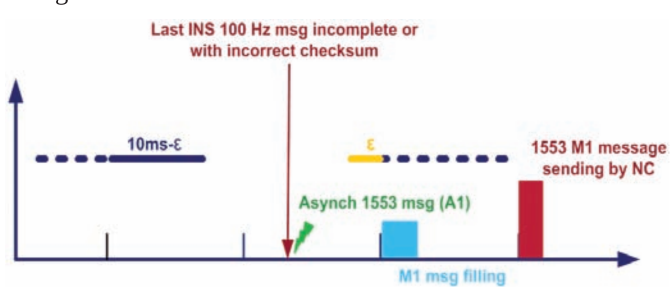

Figure 7. INS 100 Hz message is incomplete or has an incorrect checksum.

7.2 No Incoming INS 100 Hz Message in the Temporal Window

Because of relative INS/NC jitter or because of an INS 100 Hz message delay (including special case of INS dialog failure) it shall be possible that no INS 100 Hz messages are transmitted in the temporal window. In such a case the Navigation Computer will not send A1 asynchronous message and the consistency flag of the M1 message will be set to FALSE as shown in Fig. 8.

Figure 8. No incoming INS 100 Hz message in the temporal window.

7.3 Two Incoming INS 100 Hz Messages in the Temporal Window

Because of relative INS/NC jitter it shall be possible that two last selected INS 100 Hz messages are transmitted in the temporal window. In such a case the Navigation Computer will send A1 asynchronous message only for the first INS 100 Hz reception. Furthermore the inertial data of M1 will be set with the first INS 100 Hz message data (i.e. the second INS 100 Hz reception will be ignored) as shown in Fig. 9.

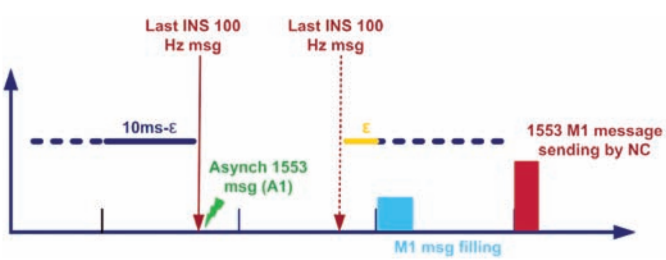

Figure 9. Two incoming INS 100 Hz messages in the temporal window.

By enlarging or reducing the temporal window it is possible to favour no incoming or two incoming INS 100 Hz messages cases. For robustness purpose the two incoming INS 100 Hz messages case will be favoured by adding a margin to the 10 ms temporal window to ensure the reception of at least one INS 100 Hz message.

8. CONCLUSION

A time field is added in M1 message which contains the time stamp corresponding to INS 100 Hz first byte reception (i.e. the time stamp just before sending A1 asynchronous message). This time stamp information in M1 message and in asynchronous A1 message enable data identification and matching with future messages. A consistent flag is also added in M1 message to indicate if the acquisition of the inertial data of M1 corresponds to previous A1 sending. The algorithm presented in this paper has been implemented in Navigation System software. The developed software has been successfully integrated and tested with FCS interface simulator.

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He has contributed in the design and development of the algorithm, software implementation and integration testing of the developed solution.

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He has contributed in the design and development of the algorithm, software implementation and integration testing of the developed solution.