International Civil Aviation Organization

THE THIRD MEETING OF MODE S DOWNLINKED AIRCRAFT PARAMETERS WORKING GROUP (MODE S DAPs WG/3)

Web-conference, 12 – 15 May 2020

Agenda Item 3: Sharing of State's implementation on Mode S

A METHOD OF MODE-S RADAR ROLL-CALL SCHEDULING MANAGEMENT

(Presented by China)

SUMMARY

This paper introduces a Mode S radar Roll-Call scheduling management method, which to achieve efficient aircraft acquisition and real-time DAPs information extraction via scientific scheduling management.

1. INTRODUCTION

1.1 For Mode S radar, the scientific reception and transmission scheduling and reasonable interrogation strategy are both the foundation to ensure the reliable detection and tracking of the aircraft, and the premise conditions for achieving rapid target acquisition and real-time extraction of DAPs information. In China, as each function of Mode S radar getting into operation, the research on the optimization of the radar transmission and reception scheduling and the interrogation strategy become very important.

1.2 This paper introduces a method for Mode S Roll-Call periods scheduling management under the EHS operating conditions. The related content of the mentioned interrogation strategy will be extensively described in detail within another paper to be submitted by China delegation for this meeting.

2. MODE S TRANSACTION

2.1 The Mode S radar captures the aircraft in the All-Call period, meanwhile in the Roll-Call period, it performs a discrete selective interrogation(Roll-Call) to different aircraft according to the unique 24-bit aircraft address. In distinction with the conventional Mode A /C operational environment, alone with the fundamental surveillance functions (identification & altitude), the Mode S Roll-Call interrogation also perform extraction of DAPs information, meanwhile reduces the probability of garbling and fruits, which improves the accuracy and integrity of the reply. The following figure shows a typical Mode Interlace Pattern (MIP) of the Mode S radar.

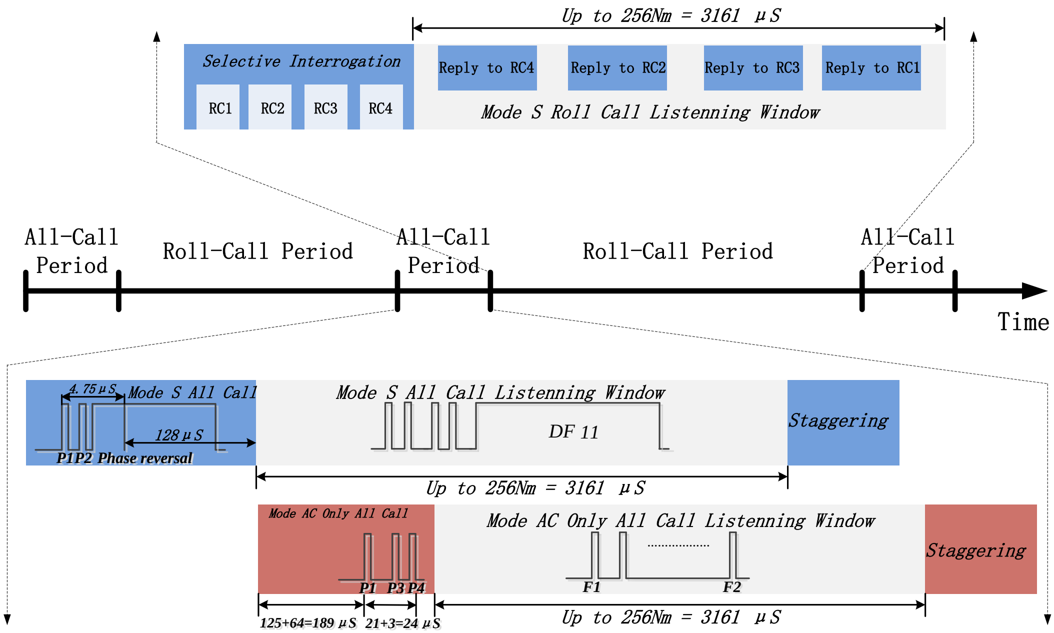

Figure 1 Typical Mode S MIP

2.2 Each Transaction of the Mode S radar can be divided into 4 periods as T_G, T_X, T_L and T_R, where T_G is the transmission protection period (complied with ICAO Annex X & transmitter cooling constraints); T_X is the transmission period(UF11, UF4 and UF5 under EHS operating conditions, T_X = 19.75μS); T_L is the listening window and its value depends on the target's slope distance; T_R is the duration of the response signal (All-Call response DF11 duration T_R = 64μS, Roll-Call response DF20 /DF21 duration T_R = 120μS).

3. SCHEDULING MANAGMENT

3.1 Generally, in the All-Call period, only one transaction occurs between the radar and the aircraft, so the All-Call period is constrained by the time duration of the listening window, and the listening time depending on the detection range of the radar, so the instrument range of the radar determines the duration of the All-Call period (which cannot be controlled manually). However, within

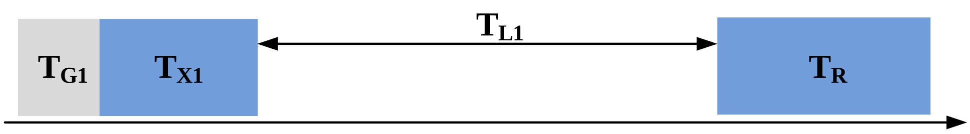

Figure2 A Mode S Transaction

the Roll-Call period, the radar interrogates different aircraft and receives replies from them, so such Roll-Call period may include many transactions. Obviously, if the interrogation, listening and reception of each aircraft are independently scheduling by order within the Roll-Call period, then it is impossible to complete the tracking and DAPs data extraction for each aircraft within the high-density airspace, due to the limitation of the beam dwell time.

3.2 The T_X and T_R periods are the operating time of transmitter and receiver of radar, as shown in Figure 2. For different transactions, these two periods (T_X and T_R) cannot be preempted, since a radar can only perform a single transmission or a single reception at a time. However, the listening window T_L of some of the transactions can be multiplexed or interleaved in the time domain. Therefore, with reasonable scheduling (without overlapping of T_X and T_R), the T_L can be interleaved with each other to save the beam dwell time.

3.3 The scheduling management of the transactions within the Roll-Call period shall observe three principles: 1. The radar only performs Roll-Call for the aircraft within the beam; 2. Schedule the time of Roll-Call period according to the predicted position of the aircraft within the beam; 3. The Roll-call to the aircraft can be performed more than once during the beam dwell time. (ICAO 9924)

4. Interleaving for Mode S Roll-Call

4.1 Although the T_X and T_R periods of any transaction can't be interleaved, but with the proper scheduling, the T_G (transmission protection interval) and T_L (listening window) of two or more transactions can be interleaved by scheduling the transmission and/or receive time intervals of one transaction in the wait phase of another transaction to save the restricted beam dwell time.

4.2 In the case a transaction can be completely embedded in the listening time window of another transaction, then this paper defines such interleaving as "**Optimal Embedding**". As shown in the figure 3 below, the brown transaction is completely embedded within the blue transaction listening window to form a Multi-Transaction. Obviously, the conditions for "**Optimal Embedding**" are:

$$T_{L1} \geqslant T_{G2}+T_{X2}+T_{L2}+T_{R2} \qquad (1)$$

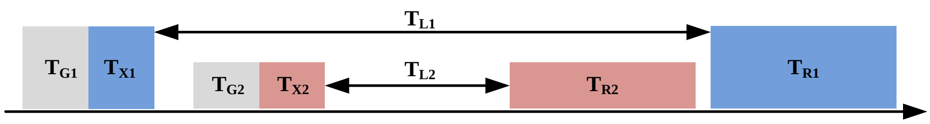

Figure 3

Similarly, if can find another transaction in the queue with time duration less than T_{L2}, then it can continue to embed and interleaved by such way. Meanwhile, a time offset T_O is defined to provide redundancy protection for the aircraft distance estimation within the T_O period.

$$T_O = T_{L1} - (T_{G2}+T_{X2}+T_{L2}+T_{R2}) \qquad (2)$$

In addition, as shown in Figure 3, the time of the "**Optimal Embedding**" is equal to the time taken by the longest distance aircraft to complete its transaction, and the received signals are sorted by time from near to far in the Multi-transaction. As a summary, the core of the "**Optimal Embedding**" algorithm is to identify the transaction with minimum time duration and try to embed it into a transaction that contains the minimum T_L.

4.3 If a transaction partially embedded in the listening window of another transaction, then the interleaving defined as "**General Embedding**". As shown in the following figure 4, the brown Transaction partially embedded in the listening window (T_{L1}) of blue Transaction, where the former transaction defined as a "**Leading Transaction**" and the latter one defined as "**Trailing Transaction**". As shown in Figure 4, the conditions for "**General Embedding**" are:

$$T_{L1} \geqslant T_{G2}+T_{X2} \cap T_{L1}+T_{R1} \leqslant T_{G2}+T_{X2}+T_{L2} \qquad (3)$$

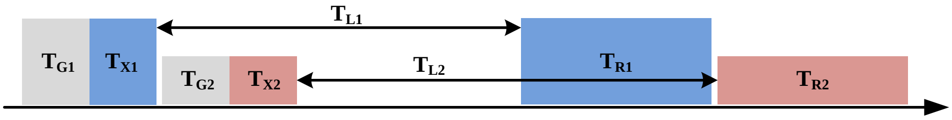

Figure 4 General Embedding

When performing a "**General Embedding**", it should first find out the transaction that contains the maximum T_L as the Leading Transaction, and then find the maximum time duration transaction that fulfil the Principal (3) in the remaining Transactions as the Trailing Transaction, which embedded according to the Figure 4 (shall avoid overlapping of transmission and reception period). The Multi-Transaction generated by Embedding re-entered into the Transaction queue and repeat above process, until all Transactions completely embedded as a Multi-Transaction, or stop whenever the next General Embedding cannot be executed. It can also define a time offset T_O (offset time):

$$T_O=T_{G2}+T_{X2}+T_{L2}-(T_{L1}+T_{R1})$$

According to the above equation, when $T_{G2} = T_{L1}- T_{L2} + T_{R1}- T_{X2}$, $T_O = 0$ (for EHS operation, T_R always larger than T_X, and according to the algorithm, T_{L1} always larger than T_{L2}, so T_{G2} is always greater than 0). The only thing should be taken into account is the protection interval between transmission T_{G2}, and the performance of the transmitter is the constraint condition of the time T_{G2}.

4.4 Obviously, according to the above algorithm. The length of the Multi-Transaction generated by "**Optimal Embedding**" determined by the transaction of maximum time duration within the queue. For "**General Embedding**", the length of the Multi-Transaction is greater than the longest transaction, so the former Embedding is more efficient the latter one. Therefore, when performing the embedding, it shall give priority to " **Optimal Embedding** " and then "**General Embedding**". Meanwhile, for a Multi-Transaction of "**General Embedding**", the transmission and reception signals are scheduled by order, but for Multi-Embedding generated by "**Optimal Embedding**", the transmission and reception signals are in reverse order, and such rule can be used for unambiguous Pairing Inspection of transmission and reception signal.

5. ACTION BY THE MEETING

5.1 The meeting is invited to note the information contained in this paper.

Appendix Algorithms for Interleaving