AMS PROJECT SPECIFICATIONS

AMS DESIGN GUIDELINE FOR REPOSITIONING EXPECTATION WINDOW

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Guidelines – Applicable to Transport Projects ATP Program

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Foreword

This guideline provides examples of application for the implementation of ATP / AMS on the TfNSW heavy rail network. This guideline specifically covers the ETCS Level 1 System using Limited Supervision.

To gain a complete overview of ATP / AMS signalling design requirements, this document should be read in conjunction with the AMS suite of signalling design principle and guideline modules.

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1. Introduction

AMS requirements and design principles for ETCS level 1 trackside implementation in the electrified rail network of NSW define a specific use of the repositioning function. This specific use of repositioning and its relationship with other ETCS functions differ in various aspects from the most common use of this function in other existing applications.

For example, the ETCS SRS by the ERA provides examples of how to extend a movement authority by balise groups containing repositioning information.

This document provides guidance on how to comply with a specific AMS requirement for repositioning to assist AEO's in the trackside design.

2. Purpose

AMS utilises the repositioning function to link with BGs after a turnout, and requires that only one balise is passed in the repositioning expectation window. The purpose of this guideline is to help Authorised Engineering Organisations (AEOs) carry out the preliminary or detailed signalling design complying with this requirement. The document will provide:

- An explanation of the requirement;
- A more detailed definition of the repositioning expectation window taking into account the onboard odometry errors and trackside location accuracy.
- An example of trackside implementation to comply with the requirement.
- An example of a cascaded case.

3. Terms and definitions

The following terms and definitions apply in this document:

AEO Authorised Engineering Organisation; means a legal entity (which may include a Transport Agency as applicable) to whom the ASA has issued an ASA Authorisation

ASA Asset Standards Authority

AMS Advanced train control Migration System

ATP Automatic Train Protection; a system which supervises train speed and target speed, alerts the driver of the braking requirement, and enforces braking when necessary. The system may be intermittent, semi-continuous or continuous according to its track-to-train transmission updating characteristics

BG Balise Group

CI Confidence interval

D_LINK Incremental linking distance to next linked balise group

D_LRBG Distance between the last relevant balise group and the estimated front end of the train (the side of the active cab)

ERA European Rail Agency

ETCS European Train Control System; a three level, unified, modular automatic train protection specification to enhance interoperability across Europe

LRBG Last Relevant Balise Group

On-board Computer that processes train data and track data to calculate the required braking, speed, distance and intervention functions.

Q_LOCACC Accuracy of the balise location

TfNSW Transport for New South Wales

TSM Target Speed Monitoring

4. Reference documents

To gain a complete overview of the signalling design requirements, the following external documents should be read in conjunction with this AMS Design Guideline.

[REF1] ETCS Subset 026 - System Requirement Specifications

[REF2] ETCS Subset 036 – Form Fit Function Interface Specification (FFFIS)

[REF3] ETCS Subset 041 – Performance Requirements for Interoperability

[REF4] AMS Project Specification Geographical Data

[REF5] AMS Trackside Sub-System Requirements Specification

5. Repositioning requirement for the expectation window

AMS utilizes linking function to link BGs in advance throughout a fitted area. At facing points AMS utilizes a repositioning announcement to link to the BGs after the point.

In relation to the repositioning function the requirement ([REF5], AMS_TSR_989) state that only one linked BG shall be passed in the repositioning expectation window.

The rationale behind this requirement is that when an on-board ETCS receives from a trackside BG a repositioning announcement, the system expects a BG containing repositioning information. As a result, any BG message not containing repositioning information is ignored by the system as long as the repositioning BG is expected.

This means that if a proper distance is not respected by the design after a repositioning, the next BG may be ignored when the BG containing repositioning information is missed.

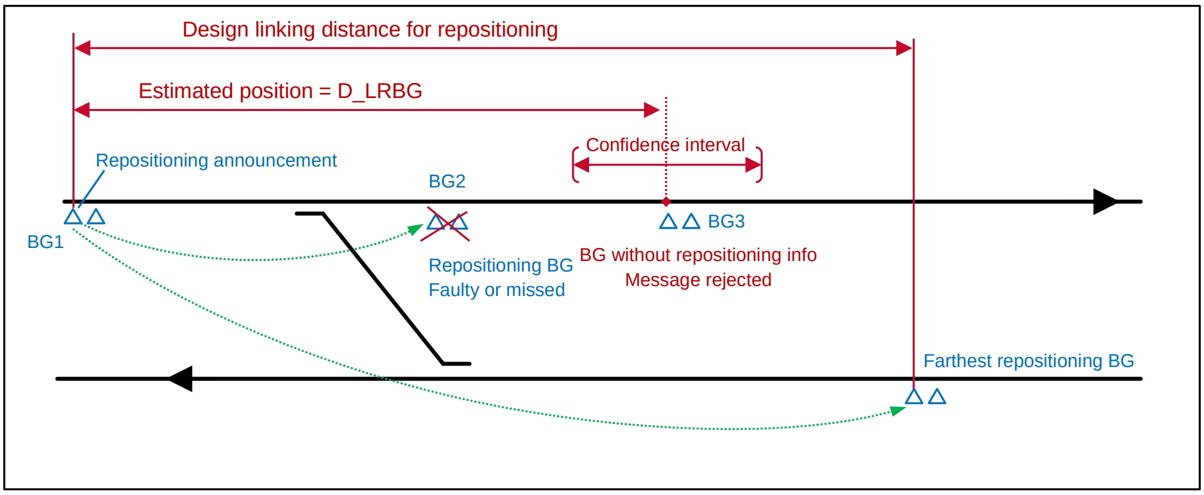

Figure 1: Repositioning. Example of non-compliance with requirement

Figure 1 depicts the situation. After missing BG2, the on-board will ignore the message from BG3 as it will be read while repositioning information is still expected.

Depending on the layout, the consequences can range from an operational impact to no protection for high risk locations (BG2 containing TSM information). The requirement’s intent is to minimize the probability of this occurrence.

To comply with the requirement the design must take into account the limits of the reposition evaluation. These limits are defined by the limits to accept a BG previously announced by linking, which is defined as the expectation window.

According to the ERA this evaluation is performed by the on-board ETCS according to the several factors or parameters described in the next section.

6. Description of the expectation window

The ETCS specifications define the limits to accept information from a BG marked as linked which was previously announced.

According to the definition the start point is where the max safe front end passes the first possible location of the BG. In the case of repositioning, the start point is the location of the BG announcing repositioning.

The end point is where the min safe front end passes the last possible location of the BG. In the case of repositioning this point is referred to the distance to the farthest BG that contains repositioning information.

Note: In both cases the on-board shall consider the offset between the train front end and the balise antenna. This offset will be omitted in the next figures because it does not add value to explanation of the expectation window in this section and is not relevant in the calculation performed in the next section.

The start and end points depend on three components:

- Possible balise position – Defined for the on-board by the linking distance +/- the balise location accuracy.
- Train front end position – Defined as the estimated position calculated by the on-board in relation to the last balise (LRBG) according to the distance measurement.
- Confidence interval – This is a distance calculated by the on-board to allow for a possible discrepancy between the estimated position and the real position of the train (e.g. measurement error due to slip or slide effects).

It is important to understand that this is a function performed by the on-board, evaluated in real time as the train runs and are based on train's estimated position.

Figure 2 depicts the estimated position between the start and end of the expectation window:

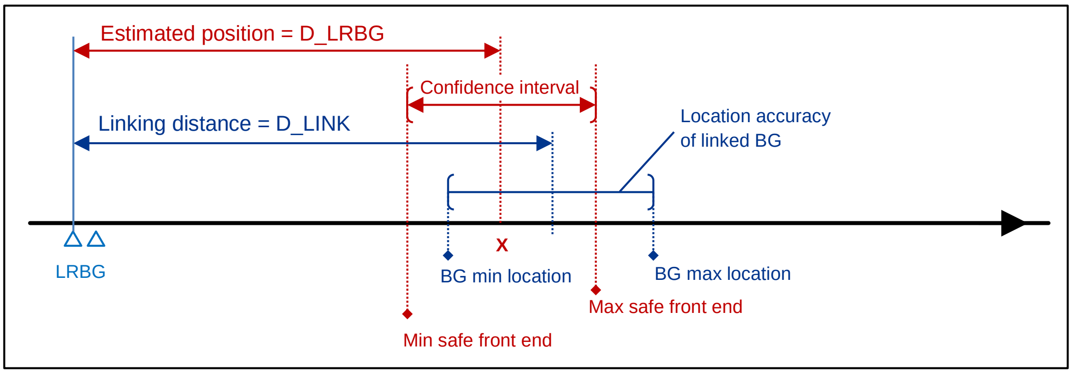

Figure 2: Estimated position within expectation window

In figure 2, the real position of the train can be anywhere within the confidence interval. In addition, the position of the balise can be anywhere between the min and max locations. Therefore the BG may or may not have been passed by the train when the estimated position is 'X' in the above figure.

Figure 3 depicts the estimated position at the end point of the expectation window:

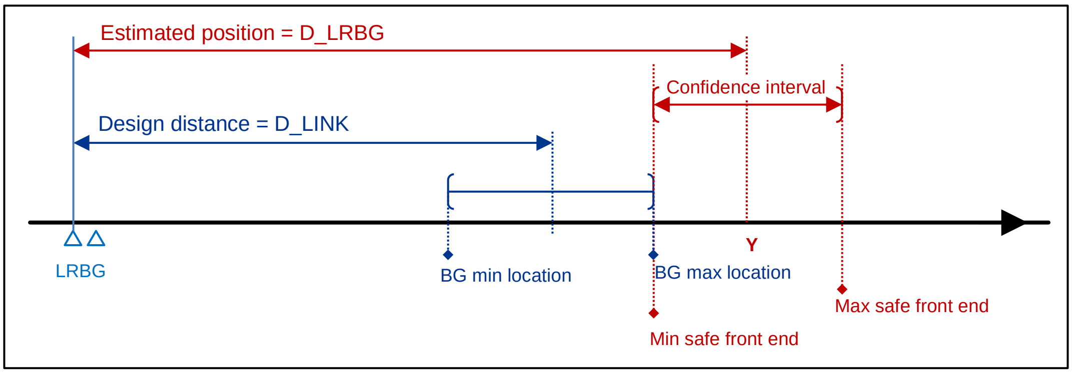

Figure 3: Estimated position at the end point of the expectation window

In the above figure, when the estimated position is ‘Y’ the train must have passed the BG.

However, because the actual position of the train could be at the max safe front end when the estimated position is Y, in the worst possible scenario, the BG will not be declared missed by on-board until the train is at the max safe front end position in the above figure.

7. Trackside implementation example

The trackside design must minimize the risk of passing the next BG before the repositioning window is passed based on the information in the previous section.

This section provides an example for the trackside design. This example will consist of a calculation of the minimum distance between BGs to minimize the risk.

7.1. Variables and assumptions

This minimum distance will be based on the following variables:

- Linking distance (D_LINK) in the repositioning announcement: This is the distance to the farthest BG with repositioning information ([REF5], §5.4). This design distance is the rolling distance between repositioning announcement BG and the farthest repositioning execution BG. Rolling distances are to be calculated in accordance with the AMS Project Specification Geographical Data ([REF4], §5.1.3).
- Balise location accuracy (Q_LOCACC) of all the BGs involved: This includes the BG announcing repositioning, the BG's performing repositioning and the BG found after the repositioning. The value considered in every case is 5m ([REF5], §11.2.4).
- Under-reading and over-reading amounts: The value chosen is the limit defined by the ERA ([REF3], § 5.3.1.1). I.e. 5m + 5% of the measured distance, and refers to the worst possible performance of the system in nominal conditions.
- Maximum distance to read a balise: The reference for this value will be the side lobe of the balise, which is 1.3m ([REF2], §5.2.2.5). The model will assume it is not possible to read a balise if the horizontal distance between the centre of the antenna and the balise centre is more than 1.3m.

Note, the distance between train front end and antenna is not relevant in the calculation. See details in the next section.

7.2. Minimum distance between BGs

This section provides an example explaining how to calculate the minimum distance between the repositioning announcement BG and the next BG after the repositioning execution BG.

Figure 4 depicts the situation when the min safe front end reaches the farthest possible location of a repositioning execution BG.

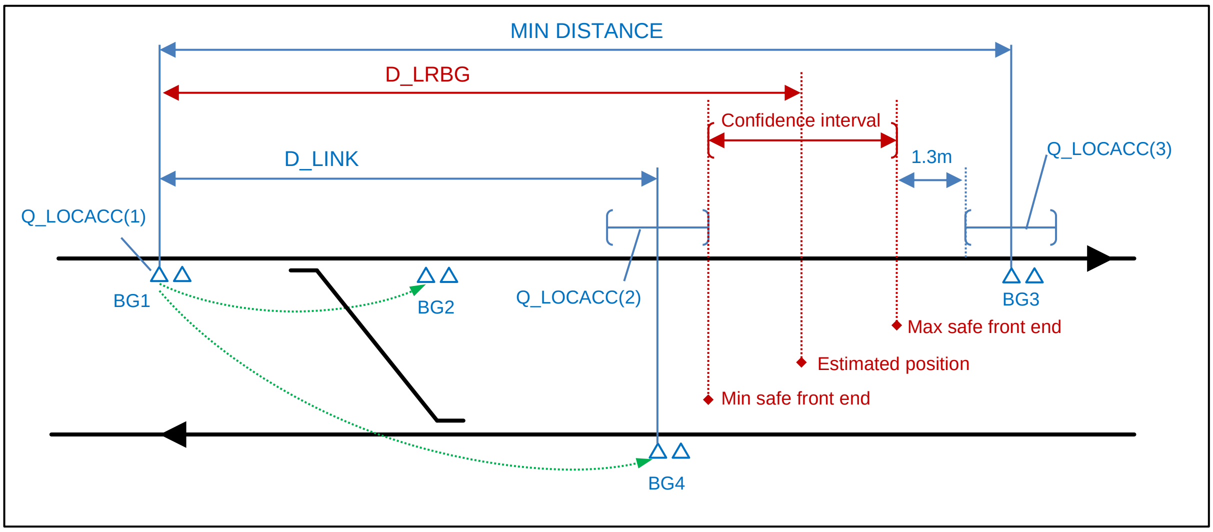

Figure 4: Min distance between repositioning announcement BG and BG in advance of repositioning execution BG

In figure 4 the estimated position is D_LRBG. As explained in previous sections the figure considers that the train can be positioned anywhere within the confidence interval.

Note: the offset introduced by the distance from train front end to antenna is omitted in the calculation because if it was added to the calculation of the estimated position, it had to be subtracted when the position of BG3 was considered. Besides, this offset does not affect the distance run.

From figure 4:

The minimum distance:

$$\text{MIN DISTANCE} = \text{D\_LINK} + \text{Q\_LOCACC}(2) + \text{CI} + 1.3 + \text{Q\_LOCACC}(3)$$

The confidence interval:

$$\text{CI} = 2 * (5\% * \text{D\_LRBG} + 5 + \text{Q\_LOCACC}(1))$$

The distance between BG1 and the estimated front end:

$$\text{D\_LRBG} = \text{D\_LINK} + \text{Q\_LOCACC}(2) + \frac{\text{CI}}{2}$$

Therefore, the minimum distance as a function of the linking distance and the balise position accuracies:

$$\text{MIN DISTANCE} = \frac{1.05}{0.95} * \text{D\_LINK} + \frac{1.05}{0.95} * \text{Q\_LOCACC}(2) + \frac{2}{0.95} * \text{Q\_LOCACC}(1) + \frac{10}{0.95} + 1.3 + \text{Q\_LOCACC}(3)$$

As previously stated, the location accuracies,

$$\text{Q\_LOCACC}(1) = \text{Q\_LOCACC}(2) = \text{Q\_LOCACC}(3) = 5\text{m}$$

Substituting the values for the location accuracies, the resulting formula for minimum distance is:

$$\text{MIN DISTANCE} = \frac{1.05}{0.95} * \text{D\_LINK} + \frac{25.25}{0.95} + 6.3$$

The above formula for the minimum distance can be used to position BGs after the repositioning BG to comply with the requirement. This minimum distance is to be respected for all routes where the repositioning is used.

The distance calculated using this formula will be valid as long as:

- BGs are located within 5m of the design position
- Under-reading amount is equal or less than 5% of the distance run plus 5m
- Over-reading amount is equal or less than 5% of the distance run plus 5m
- Train actual position is within the confidence interval
- Balise is not read from more than 1.3m from the antenna

Actually, the objective will be achieved as long the combination of the above variables is such that the length of the expectation window is less than required. For example, an abnormal increase of the odometry error could be compensated if the balise positions match the design location.

8. Expectation Window for Cascading Repositioning

This section provides guidance about the expectation window for repositioning in cases where the function is iterated sequentially. This means, when two consecutive BGs contain repositioning information.

Figure 5 depicts an example of this scenario.

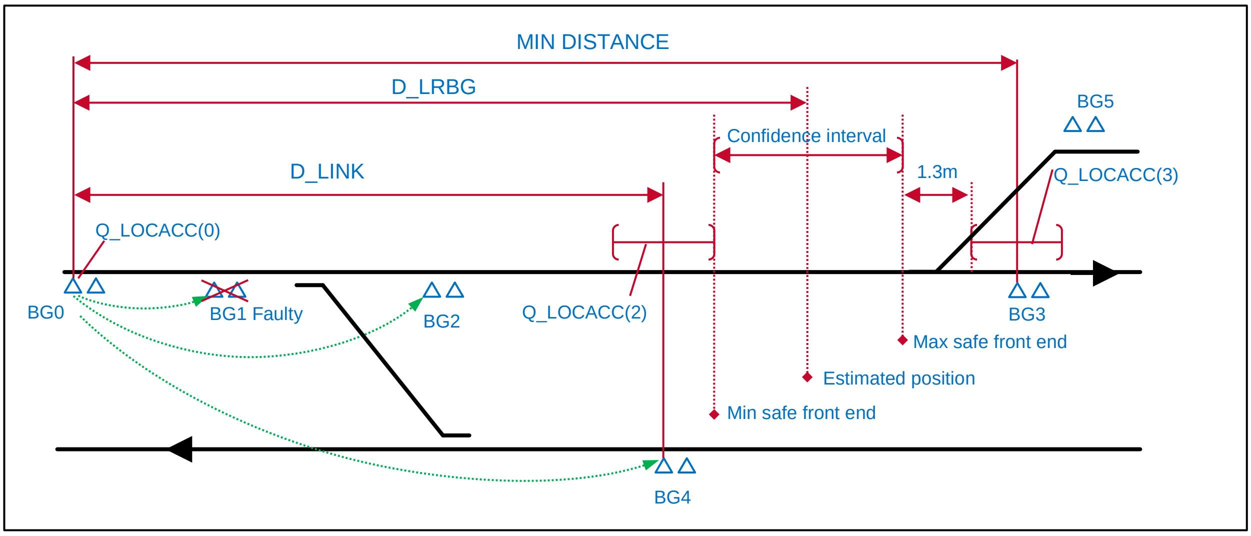

Figure 5: Min distance for consecutive repositioning execution

In this example, BG0 and BG1 announce repositioning. Following the straight route, BG2 contains repositioning information and also announces repositioning. After BG2 both BG3 and BG5 contain repositioning information.

Apart from the expectation window from BG1 described in section 7, another particularity of the ETCS functions regarding repositioning shall be considered as part of the design. According to the specifications there is a function to mitigate balise cross-talk while expecting repositioning information ([REF1], §3.16.2.7.2).

According to the definition of this function, even after a BG containing repositioning is found, the on-board must monitor the reception of a BG with repositioning information. If a second BG containing repositioning is found within the expectation window for repositioning, the on-board shall command a service brake.

Going back to our example, if BG1 was missed or faulty, the applicable expectation window would be referred to the LRBG, which in the example is BG0. If BG3 was to be found within the expectation window the result would be an unwarranted service brake after a single trackside failure. This circumstance would have a clear operational impact. Therefore the design is expected to implement an adequate engineering control to mitigate this risk sufficiently.

One possible solution to this issue is to apply the formula in section 7.2, using as D_LINK the design distance between the BG in rear of the nominal repositioning announcement (BG0 in the example) and the farthest BG for the first repositioning (BG4 in the example). The resulting minimum distance can be used to define the location of the BGs after the first repositioning (BG3 and BG5 in the example).