ERTMS/ETCS

Eurobalise On-board equipment,
Procedure for evaluation of ambiguous metal masses in the track

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THALES		

FOREWORD

This specification details a test procedure for classifying metal situations which are not possible to determine by the rules from the mandatory normative specification (SUBSET-036), allowing air-gap interoperability between any possible combination of wayside and train-borne equipment.

This procedure prevails only when it is not possible to use the SUBSET-036 general rules for metallic masses determination. It shall not be used as a substitute of SUBSET-036, but should be considered as a complement.

1. MODIFICATION HISTORY

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3. SCOPE

Some track situations can have metallic objects that are difficult to categorise according to criteria given in sub-clause 6.5.2 of SUBSET-036, since they are buried, and/or there are multiple objects, and/or their full metallic dimensions are unknown. Nevertheless, such objects can obstruct the ability of the On-board Transmission Equipment to check that it can detect a Balise. In such cases, these objects are considered as outside of the specified Metal Mask (see sub-clause 6.2.1.7 of SUBSET-036) and the On-board Transmission Equipment shall be allowed to give an alarm to the ERTMS/ETCS Kernel. For those ambiguous situations, an ad hoc procedure is presented in order to assess if the specific track metallic objects are outside the tolerated Metal Mask.

The defined test procedure offers a reliable indication about the categorization of the investigated metal object or situation. But the test procedure cannot completely assure in all cases a faultless operation of the On-Board Transmission Equipment along the metal situation.

This specification defines the test procedure, test tools and test setup applicable to the calibration and trackside testing.

4. Normative References

These normative references are cited at the appropriate places in the text, and the publications are listed here-after. The latest edition of the publication referred to apply.

A. SUBSET-085; Test Specification for Eurobalise FFFIS

B. SUBSET-036; FFFIS for Eurobalise

C. SUBSET-023, Glossary of UNISIG Terms and Abbreviations

5. TERMINOLOGY AND DEFINITIONS

5.1 Acronyms and Abbreviations

In general, the acronyms of SUBSET-023 apply.

5.2 Definitions

In general, the definitions of SUBSET-023 apply. Additionally, the following list of definition applies within this specification:

Term	Definition
Antenna Unit	The On-board Transmission Unit, with the main functions to transmit signals to and/or receive signals from the Balise through the air gap.
Balise	A wayside Transmission Unit that uses the Magnetic Transponder Technology. Its main function is to transmit and/or receive signals through the air gap. The Balise is a single device mounted on the track, which communicates with a train passing over it. In this specification, Balise is used as a short word for Eurobalise, unless otherwise stated.
Eurobalise	One set of technical solutions for Balises used in an ERTMS/ETCS installation. A Eurobalise is a Balise that fulfils the mandatory requirements of clauses 4 and 5 of SUBSET-036.
Interoperability	In general, Interoperability between two systems means that they can operate mutually at a specified time and place as to specified function. In particular, Interoperability means the ability of the Trans-European rail system to allow the safe and uninterrupted movement of high-speed trains that accomplish the specified levels of performance.
Network Analyser	Electronic instrument that measures the network parameters of electrical networks. Some network parameters can be reflection or impedance and transmission.
On-board Transmission Equipment	Consists of Antenna Unit(s) (for Magnetic Transponder Technology), and the Balise Transmission Function. It functionally matches the air gap interface and the ERTMS/ETCS Kernel.
Reactance	Imaginary part of the impedance that reflects the inductive or capacitive behaviour of the circuit, measured in ohm (Ω).
Reference Loops	Consists of customized magnetic loops (for Magnetic Transponder Technology) used as laboratory reference test equipment for interoperability testing, defined in SUBSET-085: Annex B2.

5.3 Influence of Tolerances

The requirements in this specification do not involve the error of the test equipment that is used in the test process, unless this is expressly written. The error of the tool used shall be considered when evaluating the results and not to change the acceptance criteria (limits). The same principle applies to propagation of admitted tolerances when several quantities are combined or analysed. Further details are found in SUBSET-085.

6. INTRODUCTION

The procedure uses Reference Loops (defined by SUBSET-085 in sub-clause B2 of Annex B) connected to a Network Analyser measuring loop impedance variations, thus acting as a metal detection set-up. Those measurements shall be preceded by a suitable calibration procedure defined in Chapter 7.

As a first step, Reference Loops reactance measurements shall be done against reference metal profiles (defined by SUBSET-085 in sub-clause B5.3.8 of Annex B) for each category (see sub-clause 6.5.2 of SUBSET-036). From these measurements, the criteria limits are calculated. The final track evaluation procedure will be to measure the reactance variations, positioning the different Reference Loops at a specified height over the Top of Rail, and compare the reactance variations obtained against previous calculated criteria limits.

The specific test set-ups presented herein are recommendations only, and should primarily be regarded of principal nature. However, they are detailed enough to provide a solid basis for designing actual test set-ups, and they do include hints on important properties. Modifications are allowed as long the measurement accuracy is maintained, the same results are obtained, and the same properties are explored.

7. TEST CRITERIA DETERMINATION

7.1 Test Set-up for Criteria Determination

A proposed test set-up is shown in Figure 1 below[1]. An example of suitable test equipment can be found in SUBSET-085 sub-clause F1. The metal masses set-up configuration and metal profiles are according to SUBSET-085 Figure 62 and Test Cases 1 (metal profile 1) and 3 (metal profile 3) from sub-clause B5.3.8.

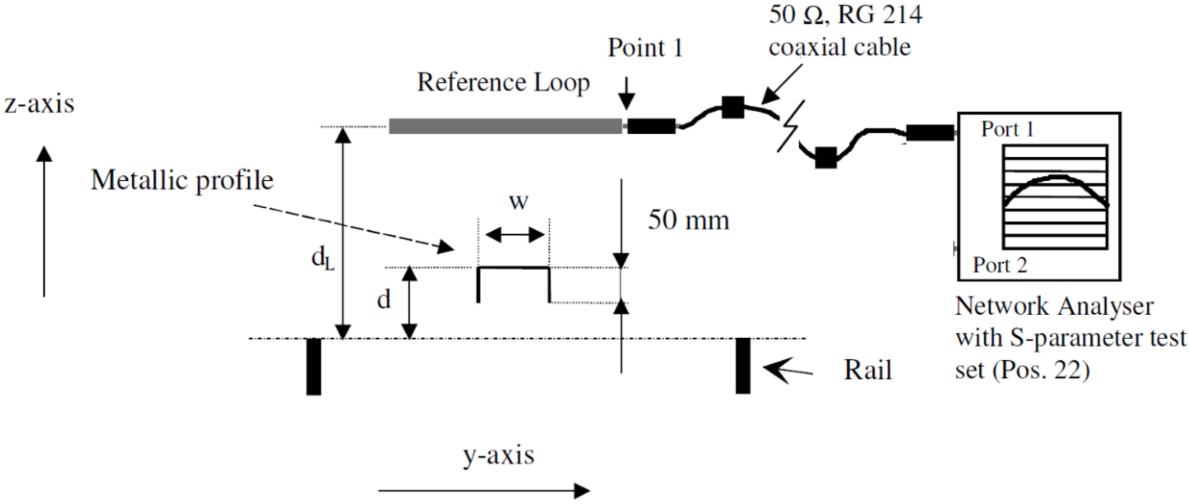

Figure 1: Set-up for previous measurements

The distance between the reference mark of the reference loop and the Top of Rail reference is d_L. The Rails are not part of the test set-up. They simply serve as height references.

The following Network Analyzer settings shall be used for both the previous measurements and the subsequent track testing:

Measurement: S_{11} refl.

Display format: Smith chart: Impedance: resistance [Ω] + reactance [Ω] (reactance corresponds to the imaginary part of the impedance)

Centre freq.: 27.095 MHz

Span: 2 MHz

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[1] The Reference Loops shall be placed on a non-disturbing positioning system, and connected to the network analyser with a 50 Ω coaxial cable with ferrite devices. The positioning system should have an accuracy in displacement in the X, Y, and Z directions of about 1 mm. It is essential that the positioning system does not disturb the field distribution. Ferrite devices shall be used in order to reduce the RF field effect on the measurements. The Baluns shall be placed at the end of the cables, i.e., at the Reference Loop and the network analyser connector. The ferrite blocks shall be placed regularly along the cables evenly spaced at approximately every 70 cm. The core material in the Ferrite Blocks shall be “Amidon 43” or equivalent. It is essential that the cables are of double screened type (e.g., RG 214 coaxial cable).

Power level: 0 dBm

Resolution bandwidth: 300 Hz

Number of test points: >50 (evenly spaced)

Averaging factor: >5

7.2 Measurement Procedure

Follow the next steps to measure and calculate the procedure criteria limits:

1. Connect the port 1 of the Network Analyser to the balun and coaxial cable (without Reference Loop) and perform an S_{11} “full one port calibration” by connecting “open”, “short”, and “50 Ω reference load” to the Point 1 (see Figure 1).
2. Connect the Reduced Size Reference Loop, longitudinally mounted, to Point 1 without any metal near the Reference Loop, free air condition (no metallic objects closer than 1 meter), and measure $X_{Loop\_red\_free\_air}$ (free air reactance).
3. Place Metal profile 1 (w =120 mm) at a distance d = 92 mm from the Top of Rail reference level.
4. Measure $X_{Loop\_red\_cat1\_w1}$ (category 1 used for calculation of reactance change for Reduced Loop).
5. Move Metal profile 1 to a distance d = 42 mm from the Top of Rail reference level.
6. Measure $X_{Loop\_red\_cat2\_w1}$ (category 2 used for calculation of reactance change for Reduced Loop).
7. Replace the Reduced Size Reference Loop by the Standard Size Reference and remove metal profiles near to the Reference Loop, free air condition (no metallic objects closer than 1 meter), and measure $X_{Loop\_std\_free\_air}$ (free air reactance).
8. Place Metal profile 3 (w =800 mm) at a distance d = 0 mm, at the Top of Rail reference level.
9. Measure $X_{Loop\_std\_cat1\_w3}$ (category 1 used for calculation of reactance change for Standard Loop).
10. Move the Metal profile 3 to a distance d = -50 mm from the Top of Rail reference (it will be below the Top of Rail reference level).
11. Measure $X_{Loop\_std\_cat2\_w3}$ (category 2 used for calculation of reactance change for Standard Loop).

7.3 Criteria Limits Calculation

Two reactance variations per Reference Loop are derived from the measurement procedure, one for category 1, and one for category 2. The criteria limits for the Standard Reference Loop are derived from a measurement with metal profile width w_3 and the criteria limits for the Reduced Reference Loop are derived from a measurement with metal profile width w_1. A specific calibration factor (F_{STD}, F_{RED}) is applied to the measured reactance difference:

$$Limit_{Red\_cat1} = (X_{Loop\_red\_free\_air} - X_{Loop\_red\_cat1\_w1}) \cdot F_{RED} - \mu_{meas}$$

$$Limit_{Std\_cat1} = (X_{Loop\_std\_free\_air} - X_{Loop\_std\_cat1\_w3}) \cdot F_{STD} - \mu_{meas}$$

$$Limit_{Red\_cat2} = (X_{Loop\_red\_free\_air} - X_{Loop\_red\_cat2\_w1}) \cdot F_{RED} - \mu_{meas}$$

$$Limit_{Std\_cat2} = (X_{Loop\_std\_free\_air} - X_{Loop\_std\_cat2\_w3}) \cdot F_{STD} - \mu_{meas}$$

Where:

F_{STD} is the calibration factor applicable for Standard Loop, defined as 0.80

F_{RED} is the calibration factor applicable for the Reduced Loop longitudinally positioned, defined as 0.66

μ_{meas} is the measurement uncertainty[2]

[2] Uncertainty of the tools must be considered and added to the calibrated impedance values. The accuracy of positioning distances specified in §7.2 affects the limit criteria. Positioning accuracy of x mm on Reference Loop reference center to metal object distance can be directly compensated in the measurement setup by shifting the Reference Loop position by x mm upward. Uncertainty on reactance due to reactance measurement equipment can be directly subtracted from the limit value by μ_{meas} parameter.

8. TRACK SET-UP AND TEST PROCEDURE

8.1 Track Set-up

A proposed test set-up is shown in Figure 2 below.

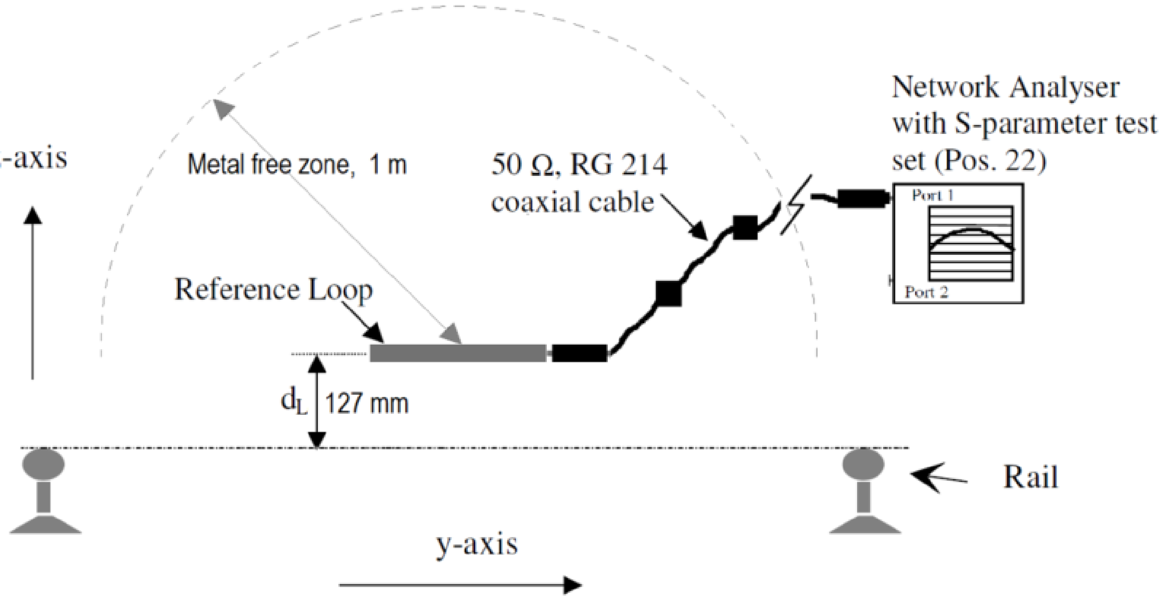

Figure 2: Track test set-up

It shall be guaranteed that the Reference Loops are positioned at least 1 meter from any additional metallic objects than the specific track situation.

The set-up components (Network Analyzer, coaxial cables, Reference Loops and Baluns) shall be the same used in the criteria determination phase, defined in sub-clause 7.1.

8.2 Track Measurement Procedure

Follow the next steps to determine if track objects are to be considered as outside of the specified Metal Mask or not:

1. Connect the port 1 of the Network Analyser to the balun and coaxial cable (without Reference Loop) and perform an S_{11} "full one port calibration" by connecting "open", "short", and "50 Ω reference load" to the Point 1 (see Figure 1).
2. Connect the Standard Reference Loop to the calibrated Network Analyser (see conditions in Figure 2).
3. Position the Standard Reference Loop track centred, 127 mm above Top of Rail. No other metallic object than the track situation can be in proximity of the Reference Loop.

4. Measure over the whole length[3] of the object the reactance value, for each meter distance.
5. Calculate for each measurement point the reactance change compared to free air:

   reactance change = XLoop_std_free_air - measured reactance
6. Evaluation criteria:
   a. If the reactance change is more than the derived criteria limit for category 1 objects ($Limit_{Std\_cat1}$), at any measured point, the metallic object is outside the tolerated Metal Mask.
   b. If the reactance change is more than the derived limit for category 2 objects ($Limit_{Std\_cat2}$), across a length >10 meters, the metallic object is outside the tolerated Metal Mask.
7. Replace the Standard Reference Loop by the Reduced Reference Loop, longitudinally positioned along the track axis. No other metallic object than the track situation can be in proximity of the Reference Loop.
8. Measure over the whole length[3] of the object the reactance value, for each meter.
9. Calculate for each measurement point the reactance change compared to free air:

   reactance change = $X_{Loop\_red\_free\_air}$ - measured reactance
10. Evaluation criteria:
    a. If the reactance change is more than the derived criteria limit for category 1 objects ($Limit_{Red\_cat1}$), at any measured point, the metallic object is outside the tolerated Metal Mask.
    b. If the reactance change is more than the derived limit for category 2 objects ($Limit_{Red\_cat2}$), across a length >10 meters, the metallic object is outside the tolerated Metal Mask.

[3] If the object is invariant along the track axis a single measurement can be performed at the centre of the object. If the length of the object/track condition is not known, measurements evaluating the object along the track must be performed. It is up to the measurer to ensure that enough measurements are performed to guarantee that the criteria can be verified.

ANNEX A, EXAMPLE TABLE OF CRITERIA LIMITS

After the calibration phase the following example table is obtained:

Network Analyzer reactance *Limit* criteria calculation [Ω] @ 27.095MHz loops centered (x=0,y=0) and at distance d [mm] from Top Of Rail reference surface									
	Free air Reactance [Ω]	**Category 1 (SS036 Table 18)**				**Category 2 (SS036 Table 19)**			
Metal profiles §B5.3.8, SUBSET 085 (w_i = width [mm]; d_i = Top Of Rail distance [mm])	N/A	w_1 = 120 mm d_1 = 92 mm	w_3 = 800 mm d_3 = 0 mm	Difference w_1, w_3 and free air	**Limit for Category 1 (correction factor aplied)**	w_1 = 120 mm d_1 = 42 mm	w_3 = 800 mm d_3 = -50 mm	Difference w_1, w_3 and free air	**Limit for Category 2 (correction factor aplied)**
Standard Size Reference Loop (STD)	0,05		-20,61	20,66	**16,5**		-11,56	11,61	**9,3**
Reduced Size Reference Loop (RED)	0,08	-10,34		10,42	**6,9**	-2,71		2,79	**1,8**

Setup correction factor for Standard Loop (F_{STD}) :	0,80
Setup correction factor for Reduced Loop (F_{RED}):	0,66

Figure 3: Example of calibration results report

Example data table and criteria limits calculation:

Criteria_Limit_Calculation.xlsx

Please observe that Excel cells are filled with fictitious data.

Remind that free air reference loop impedance must also comply with SUBSET-085 sub-clause H.2 requirements.