Irish Railway Standard IRS-302-A

Requirements for Class B Systems in Republic of Ireland:

Definition of Air Gap (Interface requirements for CCT and CCO)

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1 Foreword

1.1 This Irish Railway Standard:

i. cannot replace any Technical Standard for Interoperability (TSI) or other legal requirements which may be applicable to a given project;
ii. is recommended to be chosen in accordance with RFU-STR-088 as an Alternative Solution in conjunction with a TSI Parameter to demonstrate conformity with the Essential Requirements;
iii. may be called up as a code of practice in conjunction with CSM-REA 352/2009 and 402/2013;
iv. may be called up as good industry practice in conjunction with Railway Safety Act 2005;
v. may be called up as a code of practice in conjunction with the safe integration of projects within the Railway System in the Republic of Ireland as defined under 2008/57/EC Art15 or 2016/797 (EU) Art 18;
vi. may in parts or in full be called up as a National Rule (NR) for the Republic of Ireland in conjunction with 2008/57/EC or 2016/797 (EU).

1.2 Where this document is called up as a National Rule, the reason for its application shall be identified in line with EU 2016/797 Art 13(2):

i. where the TSIs do not cover, or do not fully cover, certain aspects corresponding to the Essential Requirements, including open points as referred to in 2016/797 Article 4(6);
ii. where non-application of one or more TSIs or parts of them has been notified under 2016/797 Article 7 or 2008/57/EC Art9 or Art20;
iii. where a specific case requires the application of technical rules not included in the relevant TSI;
iv. National Rules used to specify existing systems, limited to the aim of assessing technical compatibility of the vehicle with the network;
v. networks and vehicles not covered by TSIs;
vi. as an urgent temporary preventive measure, in particular following an accident.

2 Scope and Application

2.1 Scope

2.1.1 General scope

The focus of this IRS is the specification of the continuous and discontinuous signal transmission interface for the Class B train control command and signalling systems in IRL, in accordance with [TSI-CCS], which indicates that the definition of the requirements for a Class B system are in the responsibility of the relevant Member State.

This document must be read in conjunction with [IRS-CLASSB].

2.1.2 Scope of this version

The scope of applicability of this version of IRS as set out in [IRS-CLASSB] section 2.1 also applies to this IRS.

2.2 Editing rules

The editing rules set out in [IRS-CLASSB] section 2.2 also apply to this IRS.

2.3 Conformity assessment

This IRS shall only be assessed in combination with [IRS-CLASSB].

3 Normative References

In the development, operation and management of the CCO and CCT systems the application of the following standards shall be required. Subsequent revisions may be used instead of the quoted revisions.

All normative References as contained in [IRS-CLASSB] section 3 apply also to this IRS.

The following Normative References are specific to this IRS:

[IRS-CLASSB] IRS-301-A Requirements for Class B CCO and CCT Systems in the Republic of Ireland

[SUB-040] UNISIG ERTMS/ETCS SUBSET-040: Dimensioning and Engineering rules, Issue 3.4.0

4 Terms and Definitions

The list of Terms and Definitions provided in [IRS-CLASSB] section 4 applies also to this IRS.

The following Terms and Definitions are specific to this IRS:

Airgap	The continuous and discontinuous signal transmission interface between CCT and CCO

5 Symbols and Abbreviated Terms

The list of Symbols and Abbreviated Terms provided in [IRS-CLASSB] section 5 applies also to this IRS.

The following Symbols and Abbreviated Terms are specific to this IRS:

PPM	Pulses Per Minute

6 Continuous Signal Transmission Requirements

Note: This section specifies the characteristics of the continuous signal, generated by the CCT and sent through the rail or cable loop circuits, and received by the CCO through the pickup coils.

The information signal between the rail and the on board sub system is inductively coupled, allowing the transfer of information from CCT to CCO in 50Hz (Carrier 1 – C1) and 83.3Hz (Carrier 2 – C2) CCT areas.

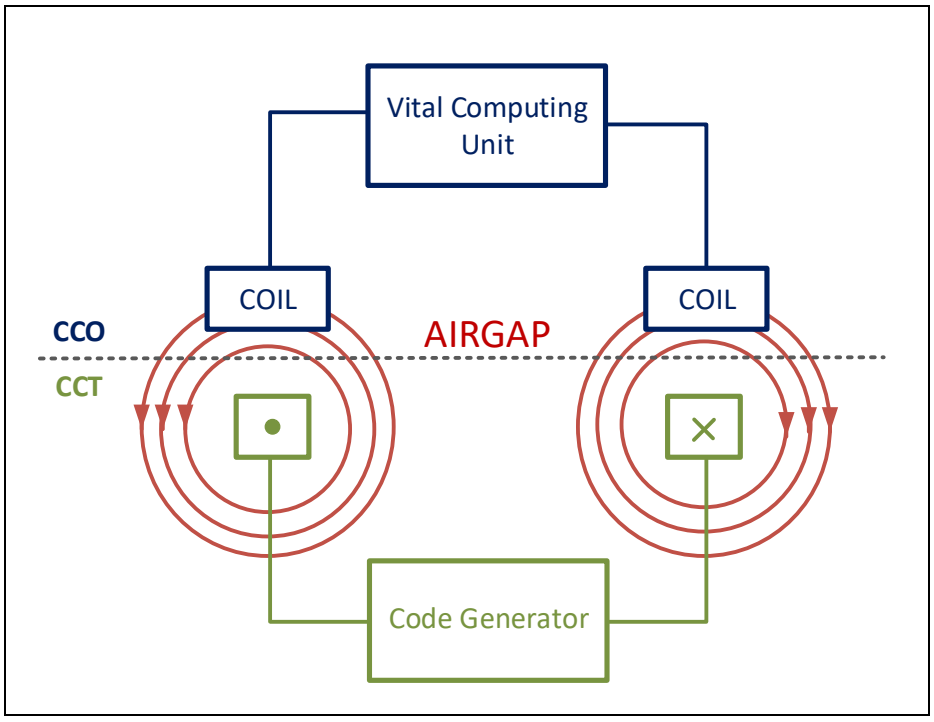


Figure 1 – Continuous signal transmission principle (Airgap)

The modulation of these carriers results in a set of codes expressed in Pulses Per Minute (ppm). This document specifies the characteristics and performances of the two carriers and associated codes.

6.1 CCT Requirements

[REQ:IE-AIRGAP_00001];[Allocation:Trackside];[Type:Mandatory]
The requirements defining the CCT signal characteristics in this section including all subsections must be met in all infrastructure configurations, including e.g. points, crossings, jointed rail, embedded track, impedance bonds, etc.
CCT Equipment to which this IRS applies, and which was installed prior to 01.01.2020 shall be evaluated and be brought into compliance with this IRS by 01.06.2020.
[END_REQ]

6.1.1 Code Transmission Circuit

[REQ:IE-AIRGAP_00002];[Allocation:Trackside];[Type:Mandatory]
The CCT code transmission circuit shall be formed either by the rails themselves – a rail circuit - or by a separate cable loop fitted to the rails.
[END_REQ]

[REQ:IE-AIRGAP_00003];[Allocation:Trackside];[Type:Mandatory]
Where a cable loop is used it shall be fitted onto the foot of the rail, as close as practicable to the web.
A cable loop may consist of a single turn or multiple turns.
[END_REQ]

6.1.2 Code Signal Characteristics

[REQ:IE-AIRGAP_00004];[Allocation:Trackside];[Type:Mandatory]
The CCT signal shall be defined by the following signal characteristics:

- Carrier
- Sinusoidal wave-form
- Total harmonic distortion
- Carrier frequency
- Signal amplitude
- Rail circuit or cable loop voltage
- Modulation
- Square wave-form
- Modulating frequency
- Duty Cycle of modulating signal
- Modulation depth.

[END_REQ]

6.1.2.1 Signal wave-form

[REQ:IE-AIRGAP_00005];[Allocation:Trackside];[Type:Mandatory]
CCT shall generate a signal that consists in the modulation of the carrier amplitude, in accordance with an OOK (On-Off Keying) principle. The electrical shape of the signal is illustrated in
Figure 2 and shall consist of:

- A sinusoidal wave-form of Carrier
- A square wave-form of Modulation

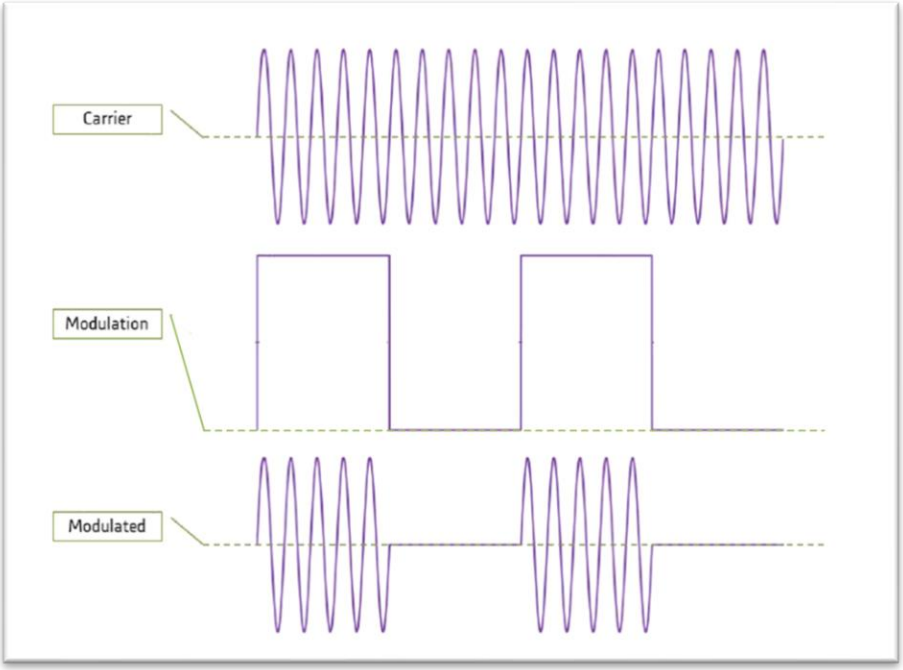


Figure 2 – Signal Modulation Principle

[END_REQ]

Note: The mathematical model defining the carrier and the modulating signal follows the following principles:

- *Sinusoidal carrier frequency:*
  - $v_{c(t)} = V_c \sin \omega_c t$
- *Square wave modulating signal with cycle T, frequency* $f_m = \frac{1}{T}$ *and amplitude* A
  - $v_{m(t)} = A$ *for* $0 < t < \frac{T}{2}$
  - $v_{m(t)} = 0$ *for* $\frac{T}{2} < t < T$

The modulated signal is the product of both signals: $v\ \ (t) = \ v_m(t).v_c(t) = \ v_m(t).V_c \sin \omega_c t$

[REQ:IE-AIRGAP_00006];[Allocation:Trackside];[Type:Mandatory]

The equipment modulating the CCT carrier shall do so with a rise time and fall time no greater than 3 ms.

[END_REQ]

6.1.2.1.1 Total Harmonic Distortion

[REQ:IE-AIRGAP_00007];[Allocation:Trackside];[Type:Mandatory]

The equipment supplying the CCT carrier shall operate with a value of Total Harmonic Distortion less than a maximum value of 8%.

[END_REQ]

6.1.2.2 Carrier frequency

[REQ:IE-AIRGAP_00008];[Allocation:Trackside];[Type:Mandatory]
CCT shall deliver carrier frequencies between the values specified in the table below:

Carrier Frequency	CCT_Min [CFreq]	Nominal	CCT_Max [CFreq]
C1 – 50 Hz	49Hz	50Hz	51Hz
C2 – 83.3 Hz	82.8Hz	83.3Hz	83.8Hz

[END_REQ]

6.1.2.3 Signal amplitude

[REQ:IE-AIRGAP_00009];[Allocation:Trackside];[Type:Mandatory]
CCT shall deliver the following minimum code transmission circuit signal amplitude values, for unmodulated carrier and for the ON-half-cycle of the modulated carrier, according to the type of installed trackside circuit:

Carrier Frequency	Transmission circuit formed by a rail circuit	Transmission circuit formed by a single turn cable loop
C1 – 50 Hz	0.8 A_{rms}	1.0 A_{rms}
C2 – 83.3 Hz	2.3 A_{rms}	3.0 A_{rms}
A_{rms} = Ampere root mean square		

This minimum value is referred to as $CCT\_Min_{[Amp]}$
[END_REQ]]

[REQ:IE-AIRGAP_00010];[Allocation:Trackside];[Type:Mandatory]
CCT shall not deliver a rail circuit or cable loop current greater than 20 A_{rms}, for the unmodulated carrier and for the ON-half-cycle of the modulated carrier, for both carrier frequencies (50 Hz [C1] or 83.3 Hz [C2]).
This maximum value is referred to as $CCT\_Max_{[Amp]}$
[END_REQ]

Note: Current values above 20A_{rms} could cause the pickup coils to saturate and should therefore be avoided.

6.1.2.3.1 Rail circuit or cable loop voltage

[REQ:IE-AIRGAP_00011];[Allocation:Trackside];[Type:Mandatory]
CCT shall not deliver a voltage across the two rails of the code transmission circuit of more than 30V_{rms} unmodulated.
[END_REQ]

[REQ:IE-AIRGAP_00012];[Allocation:Trackside];[Type:Mandatory]
CCT shall not deliver a voltage across the terminals of a cable loop transmission circuit of more than 110V_{rms} unmodulated.
[END_REQ]

Note: It is considered that 110V_{rms} is acceptably safe based on the following arguments:

- *There are no exposed terminals or conductors in normal operation.*
- *The cables used in loops shall be double-insulated, so that the likelihood of exposure of a conductor due to damage is minimised.*
- *In the event of exposure of a conductor, the risk of shock to persons is minimised by the use of a supply, feeding the loop, which shall be isolated from earth.*

- *In the event of exposure of a conductor, the risk of imposing code voltage on other circuits through contact with the rail is minimised by the use of a supply which shall be isolated from earth and the fact that code loops are predominantly used in areas where train detection is by means of axle counters and not track circuits.*
- *RU and IM staff that may be present in the vicinity of a cable loop are trained for appropriate behaviour related to these electric hazards.*
- *The railway network is protected from access by members of the public.*

[REQ:IE-AIRGAP_00013];[Allocation:Application condition];[Type:Mandatory]
SRAC: An operating rule shall be established to ensure that

- RU and IM staff that may be present in the vicinity of cable loops are trained for appropriate behaviour related to this electrical hazard, and
- the railway network is protected from access by members of the public.

[END_REQ]

[REQ:IE-AIRGAP_00014];[Allocation:Trackside];[Type:Mandatory]
Cable loop transmission circuits shall be galvanically isolated from any other conductors and from earth. The cables used in loops shall be double-insulated.
[END_REQ]

Note: This is for protection against electrical hazards.

6.1.2.4 Modulation frequency

[REQ:IE-AIRGAP_00015];[Allocation:Trackside];[Type:Mandatory]
CCT shall deliver modulation frequencies between the values specified in the table below:

Code Name	CCT_Min$_{[MFreq]}$	Nominal	CCT_Max$_{[Mod Freq]}$
50 Code	46 ppm	48 ppm	51 ppm
75 Code	69 ppm	72 ppm	77 ppm
120 Code	118 ppm	123 ppm	126 ppm
180 Code	178 ppm	184 ppm	191 ppm
270 Code	267 ppm	276 ppm	281 ppm
420 Code	414 ppm	420 ppm	426 ppm

[END_REQ]

6.1.2.5 Duty Cycle of the modulating signal

[REQ:IE-AIRGAP_00016];[Allocation:Trackside];[Type:Mandatory]
CCT shall deliver a modulating signal duty cycle, for all modulation frequencies, between the values specified in the table below:

Min$_{[Mod Dut]}$	Nominal	Max$_{[Mod Dut]}$
35% ON – 65% OFF	50% ON – 5O% OFF	60% ON – 40% OFF

[END_REQ]

6.1.2.6 Modulation depth

Note: The modulation depth of the code transmission circuit signal is defined as $M_{dph} = \frac{(A_{mod} - A_{res})}{A_{mod}} * 100\ \%$, *where* A_{mod} *represents the maximum value of the modulating signal amplitude assumed during the ON half cycle, and* A_{res} *represents the maximum value of the modulating signal amplitude assumed during the OFF half cycle. Figure 3 shows an example of modulation depth different from 100%.*

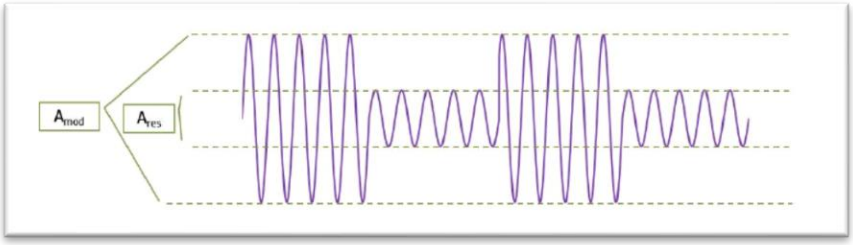


Figure 3 – Signal Modulation depth example

[REQ:IE-AIRGAP_00017];[Allocation:Trackside];[Type:Mandatory]
CCT shall deliver a signal with a modulation depth between 80% and 100%.
[END_REQ]

6.1.3 Signal to noise ratio

Note: Electromagnetic noise is in practical applications unavoidable. This is created by either the trackside environment or by rail vehicles. It is therefore necessary that CCO and CCT shall have a level of tolerance.

[REQ:IE-AIRGAP_00018];[Allocation: Application condition];[Type:Mandatory]
SRAC: An application condition shall be defined to ensure that before a unit fitted with CCO is operated on a section of track, the RU intending that operation must obtain confirmation from the respective IM, that this section of track is subject to a testing regime which demonstrates that the noise level is below the noise limit values.
[END_REQ]

[REQ:IE-AIRGAP_00019];[Allocation:Trackside];[Type:Mandatory]
The level of noise measured on a section of track in the absence of any carrier shall not be greater than the following noise limit value.
The noise limit value for carrier2 (83.3Hz) within the frequency band of 73 to 93Hz shall be equal to the min Carrier Amplitude of $CCO\_min_{[Amp]}$ of Carrier2 (2.2 A_{rms}) divided by a factor of 6.6.

Note: This requirement only addresses the noise limit value for carrier2 in 83.3Hz CCT areas. The requirement will be refined in a future version of this standard to specify the noise limit value for carrier1 in 50Hz CCT areas.

[END_REQ]

[REQ:IE-AIRGAP_00020];[Allocation: Application condition];[Type:Mandatory]
SRAC: An application condition shall be defined to ensure that an IM who permits the operation of units fitted with CCO on a section of track, shall have implemented a testing regime which demonstrates, that the noise level is maintained below the noise limit values as defined in this subsection.

Note: The demonstration for fulfilling this requirement may consist of periodical measurements done via a track recording vehicle or CCO fitted trains in service. The approach and frequency of the test regime shall be developed in accordance with [CSM402], [50126], [50128], and [50129].

[END_REQ]

6.1.4 Performance Test for CCT signal transmission

[REQ:IE-AIRGAP_00021];[Allocation:Trackside];[Type:Mandatory]

The CCT signal characteristics shall be demonstrated as follows:

- Sinusoidal wave-form: By test at end of production or as commissioning test
- Total harmonic distortion : By Generic Product type test
- Carrier frequency : By Generic Product type test and test at end of production
- Signal amplitude : By commissioning test
- Rail circuit or cable loop voltage : By commissioning test
- Square wave-form: By test at end of production or as commissioning test
- Modulating frequency : By Generic Product type test and test at end of production
- Duty Cycle of modulating signal: By type Generic Product test and test at end of production
- Modulation depth : By type Generic Product test and test at end of production or as commissioning test

[END_REQ]

Note: Type tests and tests at end of production are typically performed under the responsibility of the product suppliers. The commissioning tests are typically performed under the responsibility of Infrastructure Manager.

[REQ:IE-AIRGAP_00022];[Allocation:Trackside];[Type:Mandatory]

Type tests, tests at end of production, and commissioning tests for CCT signal transmission shall also include all activities required by the application specific safety cases.

[END_REQ]

6.2 CCO Requirements

6.2.1 Code pickup - Overall Description

Note: Figure 4 illustrates the CCO uptake principle: the pickup coil is immersed in the magnetic field generated by the current circulating in the rail or loop circuit, the CCO subsystem is then able to measure the voltage transduced by the pickup coils, which is dependent on the intensity of the current circulating in the code transmission circuit.

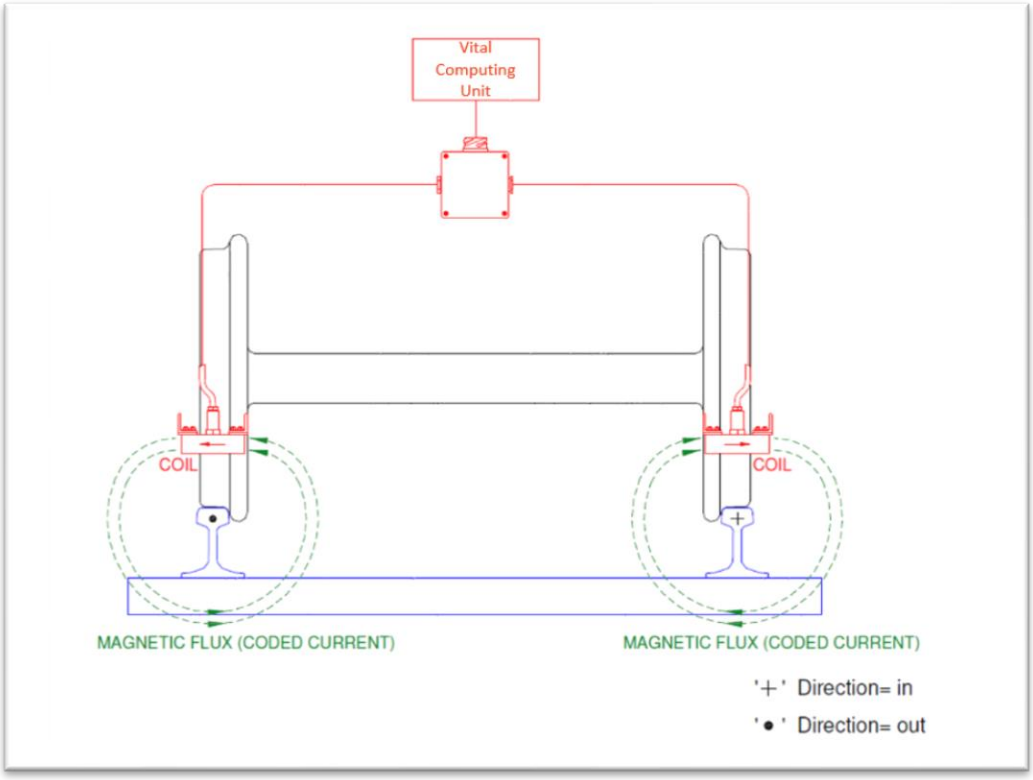


Figure 4 – Continuous code transmission

Note: The magnetic induction $\boldsymbol{B}$ *is measured in Tesla (T). The constant* $\mu_0 = 4.\pi \times 10^{-7}$ *tesla metre/ampere is called the "**permeability of free space**", the magnetic field equation to determine the magnetic field at a point P, with respect to the current flowing in a wire of infinite length, is:*

$$B_p = \frac{\mu_0 i}{2\pi R}$$

Where $\boldsymbol{i}$ *is the current flowing in the wire, and* $\boldsymbol{R}$ *is the distance of* $\boldsymbol{P}$ *with respect to the centre of the wire.*

The pickup coil transduces the magnetic field intensity by means of its characteristic transfer function into an output voltage.

6.2.1.1 Design requirements

[REQ:IE-AIRGAP_00023];[Allocation: Onboard];[Type:Mandatory]

The pickup coil design shall be such that its sensitivity to magnetic fields is greatest for fields generated by current in a conductor located below the pickup coil (Case A of Figure 5) and least for fields generated by a current in a conductor located at the side of the pickup coil, (Case B of Figure 5).

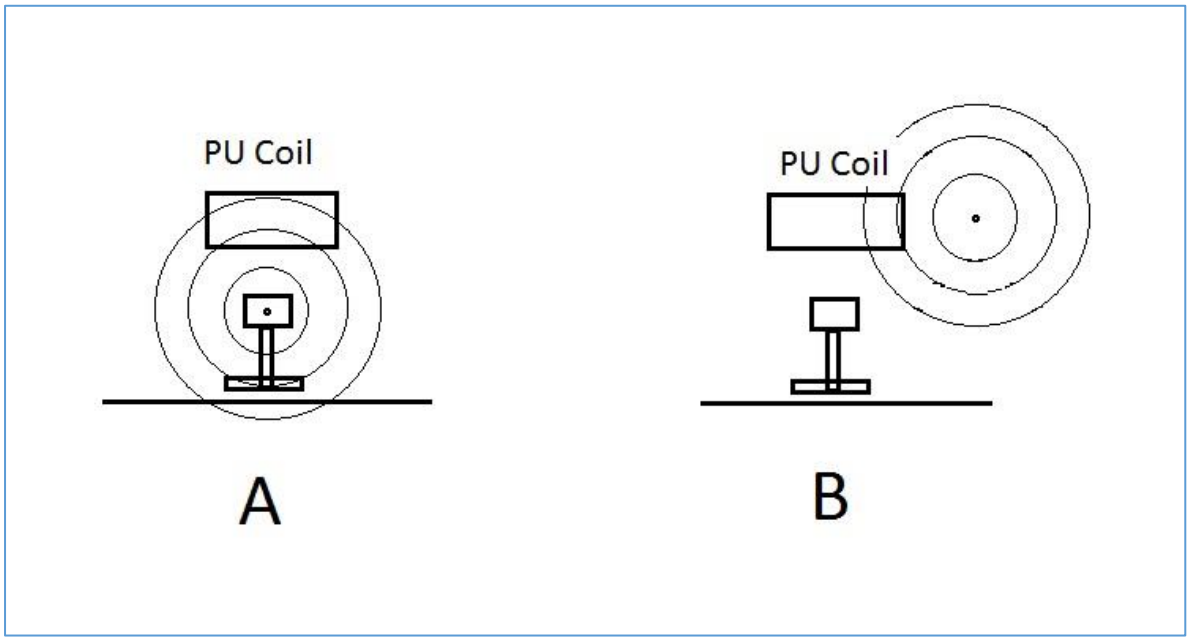


Figure 5 – Sensitivity of Pickup Coil

Note: This directional sensitivity ensures that the magnetic field resulting from a current of 20A_{rms} flowing in an adjacent track would not result in an inadvertent detection of a valid code in this track.

The characteristics of the CCO pickup coil in relation to the reception of carrier from its own track and from an adjacent track shall be demonstrated by means of tests. The tests shall include both,

- a Generic Application level laboratory test (see Test 1 in this subsection) and
- a Specific Application level type test performed on track for each type of unit being fitted (see test 2 in this subsection).

Note: Typical infrastructure dimensions are illustrated in Figure 6. In these tests, conservative assumptions are applied to these infrastructure dimensions to take account of variations in infrastructure topography (alignment) such as cant, vertical curvature, maintenance tolerances, etc., and dynamic effects due to movement of the vehicle.

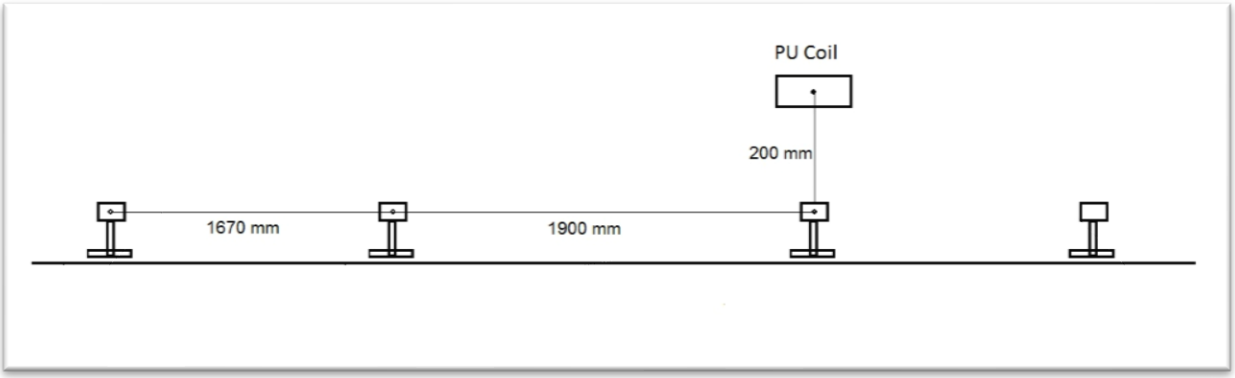


Figure 6 – Typical Infrastructure Dimensions (not to scale)

[END_REQ]

[REQ:IE-AIRGAP_00024];[Allocation: Onboard];[Type:Mandatory]
The following Generic Application level laboratory type test, Test 1, shall demonstrate an acceptable ratio between the output voltage from a pickup coil resulting from a carrier flowing in its own track and the output voltage resulting from a carrier flowing in an adjacent track.
Test requirements in laboratory conditions.

- Test loop: a single conductor in a square configuration 1670 mm (+/- 5 mm) on each side.
- The test loop shall be positioned in a horizontal plane and shall be at least 500 mm away in all directions from any metallic object.
- A single pickup coil shall be located at position (A), which shall be with the electrical centre of the coil 200 mm vertically above the test conductor, half-way along one side of the loop. The coil shall have the same orientation with respect to the loop as the orientation of a pickup coil fitted to a train has with respect to the rail which is replicated by the loop.
- With a current of 0.6 A (+0/-0.1) rms 50 Hz flowing in the loop, the output voltage from the pickup coil shall be measured.
- The pickup coil shall be re-located, in turn, to positions (B), (C) and (D) which shall be with the electrical centre of the pickup coil at a distance horizontally of 1700 mm (+/- 5 mm) from the closest side of the loop and at three heights vertically which shall be;
- in the plane of the loop (+/- 5 mm) (B),
- 200 mm (+/- 5 mm) above the plane of the loop (C) and
- 400 mm (+/- 5 mm) above the plane of the loop (D).
- With a current of 20A (+0.5/-0 A) rms 50 Hz flowing in the loop, the output voltage from the pickup coil shall be measured at each of the positions (B), (C), (D).

The rms output voltage measured at position (A) shall be at least five times the rms voltage measured at any of positions (B), (C) or (D).

Note: The dimensions of 1700 mm horizontally and heights which represent a neighbouring rail

- *at same top of rail as the own track,*
- *at 200 mm above and*
- *at 200 mm below that height*

are conservative values which take into account variations in infrastructure topography and dynamic movement of the vehicle.

[END_REQ]

[REQ:IE-AIRGAP_00025];[Allocation: Onboard];[Type:Mandatory]
The following Specific Application level type test, Test 2, shall demonstrate, for each type of unit to which CCO is fitted, an acceptable ratio between the output voltage from any installed pair of pickup coils resulting from a carrier present in their own track and the output voltage resulting from a carrier present in an adjacent track.
Test requirements on track with the fitted unit

- Test loop: a single conductor in a square configuration 1670 mm (+/- 5 mm) on each side.
- The test loop shall be located at position (A), which shall be on top of the rails, and located centrally under the pickup coils of the train. The centre of the conductor forming the loop shall not be more than 5 mm above the top of the rail.
- With a current of 0.6A (+0/-0.1 A) rms 50 Hz flowing in the loop, the rms output voltage from the pair of pickup coils shall be measured.
- The test loop shall be re-located, in turn, to positions (B), (C) and (D) which shall be in a horizontal

plane, with the closest side of the loop at a distance horizontally of 1700 mm (+/- 5 mm) from the rail above which the pickup coil is located and at three heights vertically which shall be;

- in the plane of the rail above which the pickup coil is located, (B)
- 200mm (+/- 5 mm) above the plane (C) and
- 200 mm (+/- 5 mm) below the plane (D).
- With a current of 20A (+0.5/-0 A) rms 50 Hz flowing in the loop, the rms output voltage from the pair of pickup coils shall be measured at each of the positions.

The output voltage measured at position (A) shall be at least five times the voltage measured at any of positions (B), (C) or (D).

Figure 7 illustrates the test loop positions described in this requirement

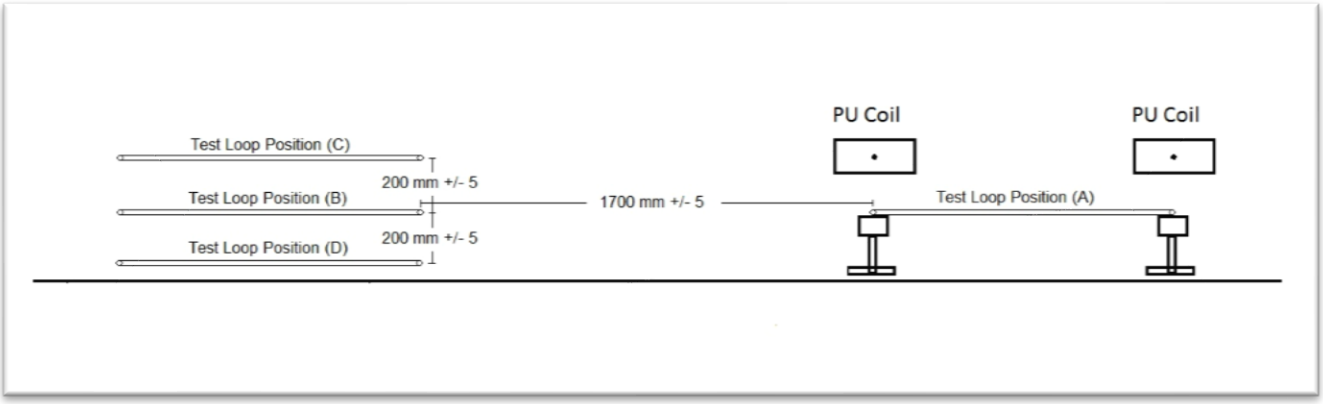


Figure 7 – Pickup Coil test – Adjacent track current output voltage measurement

[END_REQ]

6.2.1.2 Installation requirements

[REQ:IE-AIRGAP_00026];[Allocation:Onboard];[Type:Mandatory]
A pickup coil shall be mounted in front of each wheel of the first axle of the vehicle.
[END_REQ]

[REQ:IE-AIRGAP_00027];[Allocation:Onboard];[Type:Mandatory]
The vertical distance of the pickup coil electrical centre from the top of the rail shall be 200mm +/- 5 mm in static empty condition of the unit.
[END_REQ]

[REQ:IE-AIRGAP_00028];[Allocation:Onboard];[Type:Mandatory]
In static condition, considering all permitted tolerances of vehicle and track, the pickup coils shall be mounted such that the lateral deviation of their electrical centres does not, due to 'end throw' of the vehicle, exceed 230 mm from the centre of the rail head, when considering a minimum curve radius of 120m.
[END_REQ]

Note: Pickup coil electrical centre refers to the centre of the magnetic core of the pickup coil.

Note: Dynamic tolerances are not specified. They are dependent on the vehicle's suspension travel. As long as the body of the vehicle remains in the authorised kinematic envelope, it is reasonable to expect that dynamic

movements away from the code transmission circuit will not result in any relevant degradation of continuous code transmission.

Note: The pickup coils shall be mounted as close as practicable to the first axle, to reduce the lateral deviation from the rail on curved tracks.

[REQ:IE-AIRGAP_00029];[Allocation:Onboard];[Type:Mandatory]
The electrical centres of the pickup coils shall be located vertically above the rails.
[END_REQ]

[REQ:IE-AIRGAP_00030];[Allocation:Onboard];[Type:Mandatory]
The pickup coils shall be mounted on the body of the vehicle to minimise the amount of vibration.
[END_REQ]

[REQ:IE-AIRGAP_00031];[Allocation:Onboard];[Type:Mandatory]
The pickup coils shall be mounted within the following angle tolerances:

- +/- 5° Tilt, an angular deviation where the axis of rotation coincides with the X-axis.
- +/- 5° Pitch, an angular deviation where the axis of rotation coincides with the Y-axis
- +/- 5° Yaw, an angular deviation where the axis of rotation coincides with the Z-axis

Where x, y, and z axis are related to the rail position in straight track as per the figure below.

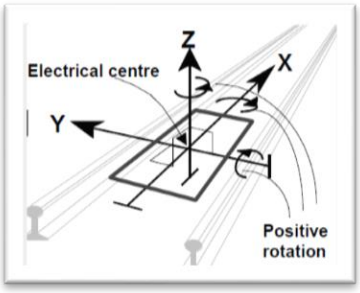
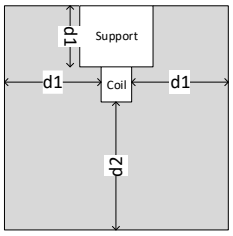


Figure 8 – Pickup Coil angle tolerances

[END_REQ]

[REQ:IE-AIRGAP_00032];[Allocation:Onboard];[Type:Mandatory]
Except for its metallic support, the pickup coil shall be surrounded by a volume free from metallic objects. This volume is identified by a length of 100 mm in all directions and by the distance between pickup coil and the top of rail downward.

Grey Area shall be free of Metallic objects on-board the unit	
 Lateral View	d1= 100 mm d2 = distance to top of rail

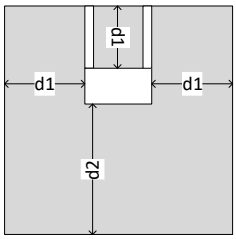
 Front View	d1= 100 mm d2 = distance to top of rail

Figure 9 – Pickup Coil Metal-free area

[END_REQ]

Note: It should be avoided, that the mounting presents a magnetic field or distorts the magnetic field around the pickup coil, as this may interfere with the correct reception of the CCT signal, and could cause an availability issue.

[REQ:IE-AIRGAP_00033];[Allocation:Onboard];[Type:Mandatory]

The pickup coil and its support shall be suitably protected against external conditions present in its exposed environment: e.g. snow, objects on track, projected ballast, etc.

[END_REQ]

6.2.2 Acceptance and Rejection thresholds for valid code

Note: To set a level requirement for all CCT and CCO installations, the signal characteristics for valid and invalid codes have been defined as interface values characterising the magnetic field which must be generated by CCT and must be picked up by CCO. The values that are specified in this section are not the internal values that are interpreted by the CCO Vital Computing Unit; they are the values that must be present at the airgap interface between CCT and CCO.

Note: This section describes the on board acceptability criteria related to the signal characteristics mentioned in section 6.1.

[REQ:IE-AIRGAP_00034];[Allocation:Onboard];[Type:Mandatory]

For the signal characteristics

- Carrier Frequency,
- Signal Amplitude,
- Modulation Frequency,
- Duty Cycle of the modulation, and
- Modulation Depth,

relevant values have been defined in this section for:

- a minimum and a maximum **acceptance threshold** $CCO\_min_{[x]}$ and $CCO\_max_{[x]}$
- a minimum and a maximum **rejection threshold** $CCO\_minRj_{[x]}$ and $CCO\_maxRj_{[x]}$.

[END_REQ]

Note: It is a safety requirement to reject the signal characteristics if they are not within these rejection thresholds.

Depending on component tolerances and environmental conditions, some CCO installations may accept signal characteristics close to and within the boundaries of these rejection thresholds, while others may have a larger margin between the actual rejection characteristic and the rejection thresholds.

The acceptance thresholds are defined for availability purposes, to ensure that all CCO installations accept the characteristics within a certain acceptable range.

[REQ:IE-AIRGAP_00035];[Allocation:Onboard];[Type:Mandatory]
If any signal characteristic is rejected by the CCO, the CCO shall consider the code as invalid.
If all signal characteristics are accepted, the CCO shall consider the code as valid.
[END_REQ]

Note: To summarise, the CCO evaluates each CCT signal characteristic based on the following thresholds:

- *Reject Below : any value below this threshold shall be rejected*
- *Accept Above: any value above this threshold shall be accepted*
- *Accept Below: any value below this threshold shall be accepted*
- *Reject Above: any value above this threshold shall be rejected*

As illustrated in Figure 10 and referred in previous notes, there may be an indeterminate zone between the 'Reject Below' and 'Accept Above' thresholds and between the 'Accept Below' and 'Reject Above' thresholds. Because of component tolerances in the CCO and dynamic influences during operation (such as variation in the pickup-coil height), it is not possible to specify a single threshold value above which a signal shall be accepted and below which it shall be rejected. Therefore a "buffer zone" is defined, on one side of which acceptance shall be mandatory and on the other side of which rejection shall be mandatory. In the "buffer zone" acceptance may due to circumstances not always happen, which could reduce availability. This is mitigated by defining CCT transmission tolerances narrower than the CCO reception thresholds.

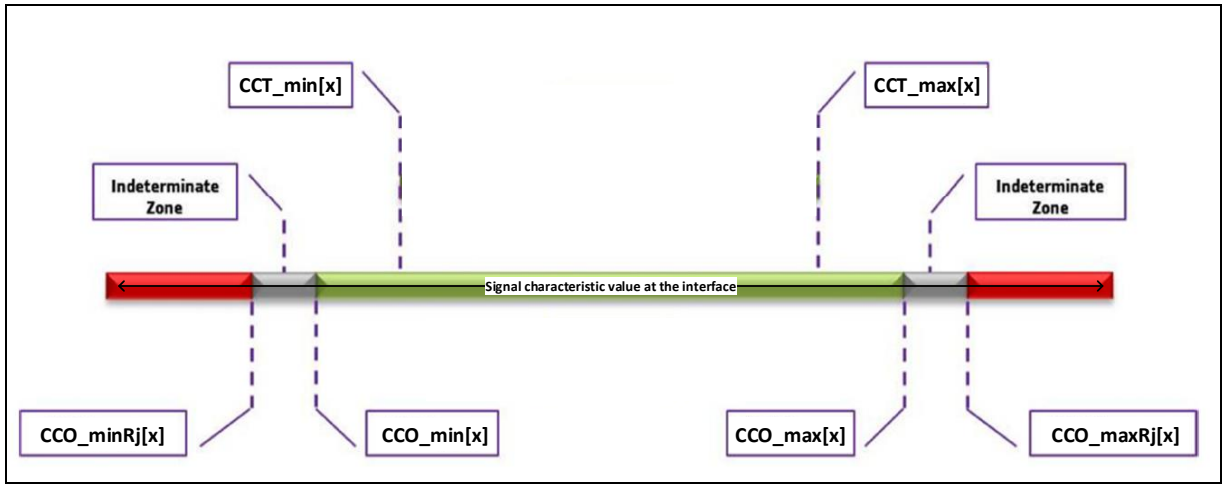


Figure 10 – CCT and CCO minimum and maximum signal characteristic values

6.2.2.1 Carrier frequency acceptance criteria

[REQ:IE-AIRGAP_00036];[Allocation:Onboard];[Type:Mandatory]
The CCO shall apply the following acceptance thresholds for the decoding of the carrier frequency

$CCO\_minRj_{[CFreq]}$	$CCO\_min_{[CFreq]}$	Nominal Frequency	$CCO\_max_{[CFreq]}$	$CCO\_maxRj_{[CFreq]}$
47 Hz	48 Hz	50 Hz [C1]	52 Hz	53 Hz
80.3 Hz	81.3 Hz	83.3 Hz [C2]	85.3 Hz	86.3 Hz

[END_REQ]

[REQ:IE-AIRGAP_00037];[Allocation:Onboard];[Type:Mandatory]
The CCO shall accept the 'carrier frequency' characteristic of the emitted signal if it is between or equal to $CCO\_min_{[CFreq]}$ and $CCO\_max_{[CFreq]}$.
[END_REQ]

[REQ:IE-AIRGAP_00038];[Allocation:Onboard];[Type:Mandatory]
The CCO shall reject the 'carrier frequency' characteristic of the emitted signal if it is below $CCO\_minRj_{[CFreq]}$ or above $CCO\_maxRj_{[CFreq]}$.
[END_REQ]

6.2.2.2 Signal amplitude acceptance criteria

Note: The acceptance threshold for the signal amplitude is not defined by magnetic field strength. It is defined indirectly by current thresholds in the CCT code transmission circuit.

Note: The thresholds specified in this section are the thresholds for unmodulated carrier and for the ON-half-cycle of the modulated carrier.

[REQ:IE-AIRGAP_00039];[Allocation:Onboard];[Type:Mandatory]
The CCO shall apply the following acceptance thresholds for the signal amplitude characteristic:

Nominal Carrier frequency	$CCO\_minRj_{[Amp]}$	$CCO\_min_{[Amp]}$	$CCO\_max_{[Amp]}$
50 Hz [C1]	0.6 A_{rms}	0.8 A_{rms}	20.0 A_{rms}
83.3 Hz [C2]	1.4 A_{rms}	2.2 A_{rms}	20.0 A_{rms}

[END_REQ]

Note: 20 A_{rms} has been found to be a conservative value to prevent saturation of the pickup coils.

[REQ:IE-AIRGAP_00040];[Allocation:Onboard];[Type:Mandatory]
The CCO shall accept the 'signal amplitude' characteristic of the emitted signal if it is between or equal to $CCO\_min_{[Amp]}$ and $CCO\_max_{[Amp]}$.
[END_REQ]

[REQ:IE-AIRGAP_00041];[Allocation:Onboard];[Type:Mandatory]
The CCO shall reject the 'signal amplitude' characteristic of the emitted signal if it is below $CCO\_minRj_{[Amp]}$ value.
[END_REQ]

6.2.2.3 Modulation Frequency acceptance criteria

[REQ:IE-AIRGAP_00042];[Allocation:Onboard];[Type:Mandatory]
The CCO shall apply the following acceptance thresholds for the decoding of the modulation frequency

Code Name	CCO_minRj$_{[MFreq]}$	CCO_min$_{[MFreq]}$	Nominal Value $_{[MFreq]}$	CCO_max$_{[MFreq]}$	CCO_maxRj$_{[MFreq]}$
50 Code	43 ppm	45 ppm	48 ppm	52 ppm	54 ppm
75 Code	61 ppm	65 ppm	72 ppm	81 ppm	85 ppm
120 Code	106 ppm	114 ppm	123 ppm	130 ppm	140 ppm
180 Code	160 ppm	172 ppm	184 ppm	198 ppm	205 ppm
270 Code	244 ppm	255 ppm	276 ppm	292 ppm	315 ppm
420 Code	378 ppm	415 ppm	420 ppm	432 ppm	462 ppm

[END_REQ]

[REQ:IE-AIRGAP_00043];[Allocation:Onboard];[Type:Mandatory]
The CCO shall accept 'modulation frequency' characteristic of the emitted signal if it is between or equal to CCO_min$_{[MFreq]}$ and CCO_max$_{[MFreq]}$.
[END_REQ]

[REQ:IE-AIRGAP_00044];[Allocation:Onboard];[Type:Mandatory]
The CCO shall reject 'modulation frequency' characteristic of the emitted signal if it is below CCO_minRj$_{[MFreq]}$ or above CCO_maxRj$_{[MFreq]}$.
[END_REQ]

6.2.2.4 Duty Cycle of the modulation acceptance criteria

[REQ:IE-AIRGAP_00045];[Allocation:Onboard];[Type:Mandatory]
The CCO shall apply the following acceptance thresholds for the decoding of the modulation duty cycle.

Code Name	CCO_minRj$_{[Dut]}$	CCO_min$_{[Dut]}$	Nominal	CCO_max$_{[Dut]}$	CCO_maxRj$_{[Dut]}$
50, 75, 120, 180, and 270 Code	25%	30%	50%	68%	74%
420 Code	25%	30%	50%	65%	70%

[END_REQ]

[REQ:IE-AIRGAP_00046];[Allocation:Onboard];[Type:Mandatory]
The CCO shall accept the 'duty cycle' characteristic of the emitted signal if it is between or equal to CCO_min$_{[Dut]}$and CCO_max$_{[Dut]}$.
[END_REQ]

[REQ:IE-AIRGAP_00047];[Allocation:Onboard];[Type:Mandatory]
The CCO shall reject the 'duty cycle' characteristic of the emitted signal if it is below CCO_minRj$_{[Dut]}$ or above CCO_maxRj$_{[Dut]}$.
[END_REQ]

6.2.2.5 Modulation Depth Acceptance Criteria

[REQ:IE-AIRGAP_00048];[Allocation:Onboard];[Type:Mandatory]
The CCO shall apply the following acceptance thresholds for the decoding of the modulating signal.

Value	Modulation depth
CCO_minRj$_{[MDpth]}$	40%
CCO_min$_{[MDpth]}$	60%

[END_REQ]

Note: The modulation depth threshold sets a limit on the level of external noise at the carrier frequency which can be tolerated on the code signal.

Since noise is unlikely to emulate a valid combination of carrier frequency and modulation and is not expected to contain information which would allow it to be incorrectly interpreted as a valid code, the threshold value of 40% for modulation depth is therefore considered as appropriate.

[REQ:IE-AIRGAP_00049];[Allocation:Onboard];[Type:Mandatory]
The CCO shall accept the 'modulation depth' characteristic of the emitted signal if it is above or equal to CCO_min$_{[MDpth]}$.
[END_REQ]

[REQ:IE-AIRGAP_00050];[Allocation:Onboard];[Type:Mandatory]
The CCO shall reject the 'modulation depth' characteristic of the emitted signal if it is less than CCO_minRj$_{[MDpth]}$.
[END_REQ]

6.2.3 Performance Test for CCO signal reception

[REQ:IE-AIRGAP_00051];[Allocation:Onboard];[Type:Mandatory]
CCO signal reception shall be demonstrated, through generic product type testing, in a static environment, including the pickup coil installation boundaries and rolling stock movement boundaries specified in section6.2.1.1, i.e.

- Electrical centre 205 mm above top of and 230 mm to the side of the rail
- 5 degrees tilt in all three axis,

During the type test, the maximum installation cable length between pickup coils and Vital Computing Unit, as defined for the Generic CCO Application shall be used.
For each signal characteristic defined in subsection 6.2.2

- the defined minimum and maximum **acceptance thresholds** CCO_min$_{[x]}$ and CCO_max$_{[x]}$ and
- the defined minimum and maximum **rejection thresholds** CCO_minRj$_{[x]}$ and CCO_maxRj$_{[x]}$

shall be tested for conformity with the required threshold values.
[END_REQ]

[REQ:IE-AIRGAP_00052];[Allocation:Onboard];[Type:Mandatory]
CCO signal reception shall be demonstrated, through commissioning testing, in a static environment on straight track, representing nominal CCO installation conditions, and the nominal values of all signal characteristics where such nominal values are defined, and a signal amplitude between 0.8 and 1.2 A, for all code names.

[END_REQ]

[REQ:IE-AIRGAP_00053];[Allocation:Onboard];[Type:Mandatory]
Application specific Type tests and commissioning tests for CCO signal reception shall also include all activities required by the application specific safety cases.
[END_REQ]

7 Discontinuous Signal Transmission Requirements

7.1 CCT Requirements

7.1.1 Functional

[REQ:IE-AIRGAP_00054];[Allocation:Onboard];[Type:Mandatory]
CCT shall comply with the requirements defined in the [SUB-036].
[END_REQ]

[REQ:IE-AIRGAP_00055];[Allocation:Onboard];[Type:Mandatory]
CCT shall comply with the [SUB-026] requirements specifying the rules applicable for the use of packet 44.
[END_REQ]

[REQ:IE-AIRGAP_00056];[Allocation:Onboard];[Type:Mandatory]
CCT shall comply with the requirements defined in section 4.3.2. item x) of the [SUB-040].
[END_REQ]

Note: The functional description of packet 44 used for the Irish Class B CCS system will be developed in a further version of [IRS-CLASSB]

7.1.2 Installation

[REQ:IE-AIRGAP_00057];[Allocation: Application condition];[Type:Mandatory]
SRAC: An operating rule shall be established to ensure the absence of metallic objects on track in accordance with requirements defined in the [SUB-036] section 6.5.2.
[END_REQ]

Note: This section will be completed in a further version of the document to address rules related to the installation of balise groups on the track.

7.2 CCO Requirements

7.2.1 General

[REQ:IE-AIRGAP_00058];[Allocation:Onboard];[Type:Mandatory]
CCO shall comply with the requirements defined in the [Subset-036].
[END_REQ]

7.2.2 Installation

[REQ:IE-AIRGAP_00059];[Allocation:Onboard];[Type:Mandatory]
A DTP Balise Antenna shall be mounted on the underframe of the unit body.
[END_REQ]

[REQ:IE-AIRGAP_00060];[Allocation:Onboard];[Type:Mandatory]
A DTP Balise Antenna shall be mounted in front of the first axle of the unit, and as close as possible to that first axle.

Note: this is to ensure compatibility with CCT Balise Group installation rules and to reduce lateral deviation between antenna and balises when the unit is in a curve.

[END_REQ]

[REQ:IE-AIRGAP_00061];[Allocation:Onboard];[Type:Mandatory]
The distance from the electrical centre of a DTP Balise Antenna to the front of the unit shall not exceed 3 meters.
[END_REQ]

8 Further Clarification

Further clarification can be sought from the CRR by phone at +353 1 206 8110 or by email info@crr.ie.

9 List of Participants

The participants for each revision of this IRS are shown below in Table 1.

Table 1 List of Participants by Revision

Participant Name and Organisation		**Involved in Issue A**		
Francois Pignard	IÉ-IM	✓		
Maik Wuttke	CRR	✓		
Paraic O'Lochlainn	IÉ-IM	✓		

Appendices

Appendix A

Note: This appendix supports Section 6.1.2 in relation to the topic of directional sensitivity of the pickup coils.

Magnetic field calculations:

The ratio between

1) the magnetic field B_{OWN} at a pickup coil from current in its own track at the minimum current level and nominal distance (0.6A and 200 mm) and

2) the magnetic induction B_{ADJ} at a pickup coil from current in an adjacent track at the maximum current and nominal distance (20A and approximately 1900 mm),

is determined by four factors;

1. *The ratio of the currents B_{OWN} and B_{ADJ}*
2. *The difference in distance between the pickup coil and the respective code transmission circuit conductors*
3. *The orientation of the pickup coil in relation to the respective code transmission circuit conductors, and*
4. *A coupling factor, k, whose value depends on the electromagnetic characteristics of the area around the pickup coil and the respective code transmission circuit conductors, which describes the reduction in efficiency of the coupling between the conductors and the pickup coil due to their surroundings, and hence the reduction of the output of the pickup coil from the theoretical voltage to a lower actual voltage.*

Effect of Distance from conductor

As shown in the formula defining the magnetic field in Section 6.1.2 the magnetic field around a conductor decreases linearly as the distance from the conductor increases.

Effect of Orientation of the magnetic field

The pickup coil will receive a field, from the adjacent track, which is oriented at almost 90 degrees to the orientation of the field from its own track.
See Figure 11 and Figure 12 below.

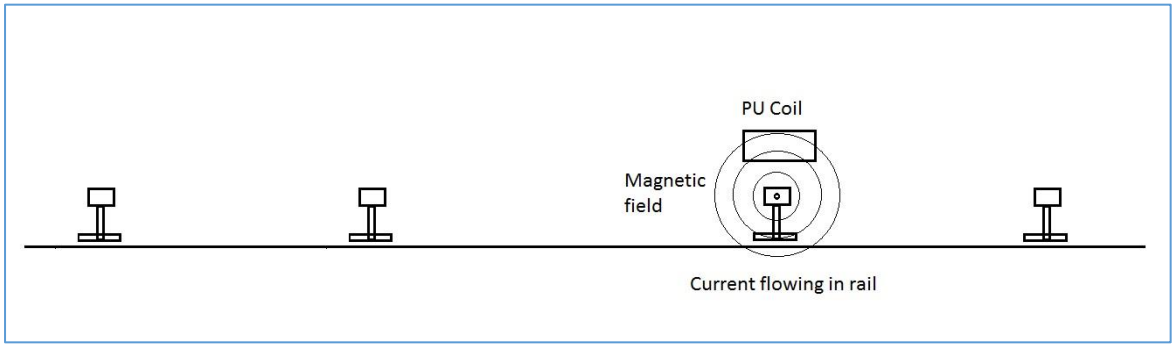


Figure 11 - Magnetic field from own track

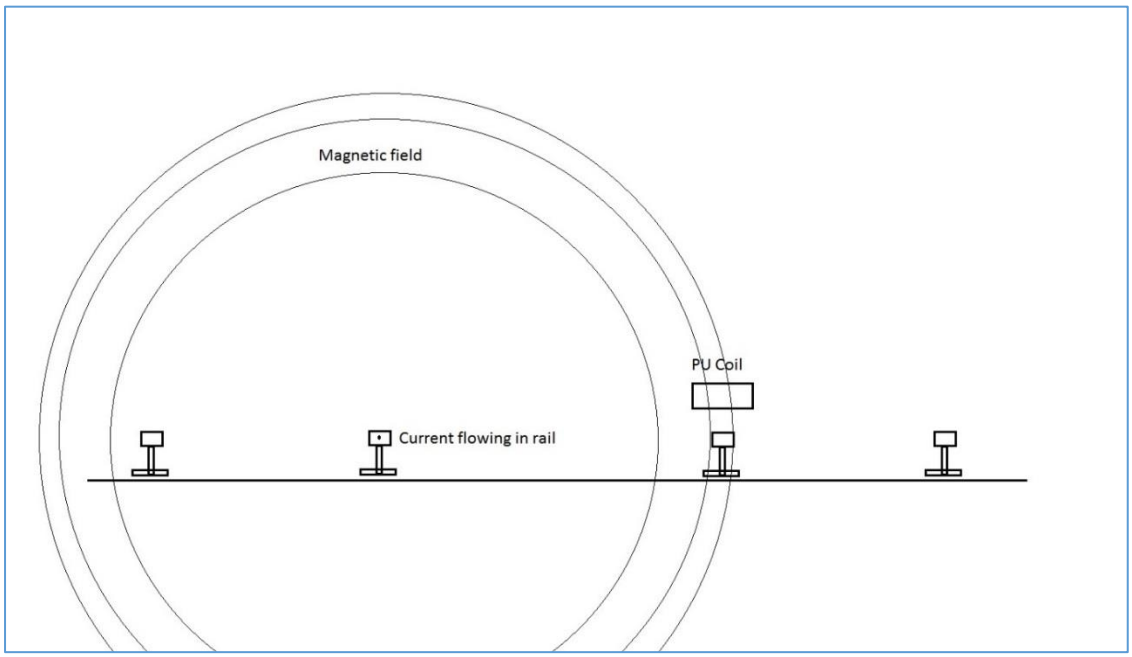


Figure 12 - Magnetic field from adjacent track

It can be seen that the field orientation at the pickup coil electrical centre, due to a current flowing in its own rail, is approximately horizontal, while the field orientation at the pickup coil electrical centre, due to a current flowing in the closer rail of the adjacent track, is close to vertical.

As the pickup coil design shall be such that its orientation with respect to the magnetic field affects the output, the resulting output from the adjacent track's field shall be lower than the output from the own track's field due to its orientation.

Effect of k factor

*The value of the **k** factor relates to the damping and distortion of the field in a real application when compared to a theoretical field around an infinite wire in vacuum. It cannot be easily determined other than by testing in typical reference situations. Its effect is significantly increased by the presence of large metallic structures such as track and rail vehicles within the magnetic field.*

Summary

The combination of these factors is such that the requirement for a 5-to-1 ratio between the pickup coil outputs in the two situations (pickup coil output due to own track's field vs. output due to adjacent track's field) is considered achievable.

In the possible case that a pair of pickup coils is subject to fields from adjacent tracks on both sides, this ratio could in theory reduce to a value of 2.5 to 1, which is considered an acceptable margin.