Evaluation of a UNISIG proposal for rolling stock emission measurement methodology

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The aim of this presentation is to present the building and calibration of the antenna and complete receiver for measuring the emissions of the rolling stock affecting the ETCS on board system following the proposal elaborated by UNISIG.

After that, the system is applied to the implementation done by CEIT for CAF and the results from 2 measurement campaigns are shown.
1) Introduction

2) Physical implementation of the receiver

3) Calibration strategy

4) Improvements to be proposed to UNISIG

5) Test campaigns and trigerring issues
The proposal from UNISIG addressed the need to complete Subset-116 with the evaluation of the Rolling stock emissions affecting the Balise-BTM communication.
6.7.4 Eurobalise Transmission Susceptibility
6.7.4.1 General

The Eurobalise On-board Transmission Equipment shall be able to operate competently with this specification, when being exposed to radiated noise as defined below.

Noise consists of damped oscillations as illustrated in Figure 52 below.

**Figure 52: Shape of the Damped Interference Signal**
The emission evaluation is based on the following block diagram of the receiver to capture the noise levels and to perform the evaluation:

```
MFP
arrow
arrow
20 dB Attenuation
Filter
20 dB Amplifier
1 and 50 µs Detector
 Evaluation

Noise signal
```
First, the Magnetic Field probe has been implemented following the instructions from Subset 116, Annex B (UNISIG, Subset 116 - Eurobalise On-board Equipment, Susceptibility Test Specification v1.1.0, 2016), referencing Subset 85 (UNISIG, Subset-085: Test Specification for Eurobalise FFFIS v3.0.0, 2012)
3 Units of the MFP have been built and the calibration defined in Annex B3 from Subset 116 has been applied at CEDEX (Madrid). The 3 elements have been used as defined by this calibration setup: 1Vs2, 2Vs3 and 3Vs1. The results for the 3 loops and their baluns is shown in the plot. The resulting conversion factor is around 2dBA/Vm which is equivalent to 1.26 A/Vm.
The filter was designed following the instructions provided in Annex E3 from (UNISIG, Subset 116 - Eurobalise On-board Equipment, Susceptibility Test Specification v1.1.0, 2016)
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Attenuator and Amplifier

The 2 other components from the receiver chain, prior to the digital computation, are the attenuator and the amplifier. The references are:

• Amplifier: Minicircuits ZFL-500LN
  Gain: 28dB @ 4.23MHz with 15V supply voltage

• Attenuator: Minicircuits HAT-20+
  Attenuation: 20dB @ 4.23MHz
PXIe-1073 chassis and a PXIe-5105 Digitizer with 60MHz bandwidth, 60MS/s and 12-Bit (card on the left of the picture, with 8 input

This digitizer is controlled by a LabView script which includes a manual tuning of the characteristics of the final file:

- Sampling frequency [MSamples/s]: 60MS/s used for all the recordings
- Length of the file [KS or MS]: from 10KS to 10MS
- Trigger voltage [mV]: set to 0.05 or 0.1V
- Scale of the file [+/ - V]: 2V / 1V / 0.2V
- Reference position (% of file to be save before/after the trigger): 30%
- Input impedance for the data acquisition system: 50Ω
Two detectors have been implemented. As proposed by UNISIG, there should be a dual detector arrangement with two detectors operating in parallel:

- The first detector should be a **1µs RMS integration detector**, which is described by the following formula (where T = 1µs)

\[
d_s(t) = \sqrt{\frac{1}{T} \int_t^{t+T} s^2 \, dt}
\]

- The second detector should be an **absolute value averaging detector**, where T is 50µs, described by the formula

\[
d_{CW}(t) = \frac{1.11}{T} \int_t^{t+T} \text{Abs}(s) \, dt
\]
1. Apply the test signal with 3.9MHz self-frequency, 5 cycles decaying time, and 15kHz repetition rate as defined in SUBSET-036, using the WLA defined in SUBSET-116 (also the MFP is defined in SUBSET-116). The WLA shall be positioned such that the MFP is exposed to homogeneous field.

2. Perform a high impedance measurement before the attenuator (which has 50 Ohm input and output impedance) and adjust the noise level such that the peak amplitude reaches the correspondence of 70dBµA/m using the conversion factor for the specific MFP device (should be in the order of 1.3dBA/Vm – please review the calibration results).

3. Perform a measurement after the 1µs detector. Calculate the difference of the peak amplitude relative to 60dBµV. Use the difference to compensate the result of the captured noise data from the vehicle.

4. Repeat steps 1 through 3 above but with CW at 3.9 MHz and the peak level 52dBµA/m. Using the same compensation as in step 3, the peak amplitude after the detector shall be 49dBµV ±1.0dB (TBC).
5. **Apply the CW signal.**

6. Perform a high impedance measurement before the attenuator (which has 50 Ohm input and output impedance) and adjust the noise level such that the peak amplitude reaches the correspondence of 52dBµA/m using the conversion factor for the specific MFP device (should be in the order of 1.3dBA/Vm – please review the calibration results).

7. Perform a measurement after the 50 µs detector. Calculate the difference of the peak amplitude relative to 49dBµV. Use the difference to compensate the result of the captured noise data from the vehicle.

8. Repeat steps 5 through 7, test signal with 3.9MHz self-frequency, 5 cycles decaying time, and 15kHz repetition rate as defined in SUBSET-036, and the peak level 70dBµA/m. Using the same compensation as in step 3, the peak amplitude after the detector shall be 35dBµV ±1.0dB (TBC).
The following tables are also distributed from UNISIG for damped oscillation and for CW signals

<table>
<thead>
<tr>
<th>Decaying Factor [cycles]</th>
<th>Repetition Rate [kHz]</th>
<th>Self Frequency [MHz]</th>
<th>Nominal peak current measured by CP [mA]</th>
<th>Field Strength, Bmax [dBμA/m]</th>
<th>1 μs Detector Output Voltage [mV]</th>
<th>50 μs Detector Output Voltage [mV]</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1.5</td>
<td>3.9</td>
<td>4.22</td>
<td>70</td>
<td>1.0</td>
<td>Optional</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1.5</td>
<td>4.5</td>
<td>4.22</td>
<td>70</td>
<td>1.0</td>
<td>Optional</td>
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</tr>
<tr>
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<td>15</td>
<td>3.9</td>
<td>4.22</td>
<td>70</td>
<td>1.0</td>
<td>Optional</td>
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</tr>
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<td>15</td>
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<td>4.22</td>
<td>70</td>
<td>1.0</td>
<td>Optional</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>1.5</td>
<td>3.9</td>
<td>2.98</td>
<td>67</td>
<td>1.25</td>
<td>0.22</td>
<td>Optional</td>
</tr>
<tr>
<td>30</td>
<td>1.5</td>
<td>4.5</td>
<td>2.98</td>
<td>67</td>
<td>1.25</td>
<td>0.22</td>
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<td>67</td>
<td>1.25</td>
<td>0.22</td>
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</tr>
</tbody>
</table>

The second and sixth bullet from the calibration process presented in the previous list are here complemented by the current measured in the loop (column “Nominal peak current measured by CP [mA]”).
Calibration strategy – magnetic field (CEDEX)
Calibration for CEIT-CAF’s Implementation – magnetic field (CEDEX)

The following table shows the table reported by CEDEX with the values used for 0.37mA (CW) and 4.22mA (damped oscillation), as requested by UNISIG.

<table>
<thead>
<tr>
<th>Signal</th>
<th>Campo Bmax dBµA/m</th>
<th>Campo Brms dBµA/m</th>
<th>Corriente Imax mA</th>
<th>Corriente Irms mA</th>
<th>Sonda Transfer Impedance ohm</th>
<th>CP OSC Vrms mV</th>
<th>OSC Vmax mV</th>
<th>OSC Vpico-pico mV</th>
</tr>
</thead>
<tbody>
<tr>
<td>CW</td>
<td>52</td>
<td>49</td>
<td>0.37</td>
<td>5.25</td>
<td>1.924</td>
<td>2.72</td>
<td>5.44</td>
<td></td>
</tr>
<tr>
<td>3.9Mhz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Dumped</td>
<td>70</td>
<td>4.22</td>
<td>5.25</td>
<td>22.15</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3.9Mhz</td>
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<td>15Hz</td>
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</tr>
</tbody>
</table>
Calibration for CEIT-CAF’s Implementation

<table>
<thead>
<tr>
<th></th>
<th>dBuA/m</th>
<th>dBA/m</th>
<th>A/m</th>
<th>V</th>
<th>Vpeaktopeak</th>
</tr>
</thead>
<tbody>
<tr>
<td>CW (RMS)</td>
<td>52</td>
<td>-68</td>
<td>0.0003981072</td>
<td>0.000444579</td>
<td>0.000889159</td>
</tr>
<tr>
<td>Dump (pk)</td>
<td>70</td>
<td>-50</td>
<td>0.0031622777</td>
<td>0.002497468</td>
<td>0.004994937</td>
</tr>
</tbody>
</table>
The process of calibration is applied to the 3 independent MFPs and receivers built by CEIT-CAF for:

- Dumped signals (70dBuA/m)
- CW signals (52dBuA/m)

During the calibration process, the compensation values have to be deduced for every MFP and receiver.
Improvements for UNISIG proposal

The process shows the expected results for the 1us and 50us detectors when the measurements were performed with the MFP WITHOUT receiver.

The attenuation of the signal on a first step is excessive and the amplifier cannot handle such a noisy signal.

The SNR is more sensitive to external electromagnetic noises in the environment of the setup.

The use of digital filtering should be considered.

Extra: consider a common trigerring strategy.
The use of digital filtering should be considered

But it should be the exact inverse mask of the filter that is implemented in the BTM function (system victim of the noise generated by the rolling stock)
This measurement campaign was performed with a 3 car EMU.
Example of file recorded

However, the values of both detectors have to be corrected with the right setup and filtering.
Test campaign: triggering strategy

MFP

2x1 splitter

20 dB Attenuation

Filter

20 dB Amplifier

Channel 0

Channel 1

20 dB Amplifier

PXI digitizer

1 and 50 µs Detector

Evaluation

Trigger

Noise signal
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