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Electromagnetic fields radiated by high speed railway lines, application case: cover slab over the railway lines

***Abstract**. This study is focused on the evaluation of low frequency electromagnetic fields regarding human exposure. Low frequency electromagnetic fields radiated by railway lines are calculated with a bi-dimensional in-house tool based on transmission line theory [1]. The influence of parameters such as railway traffic is shown. A comparison to Public Recommendation 1999/519/CE [2] allows to determine risk situations, which is essential to implement the proper prevention solutions.*

***Streszczenie.** Niniejsze opracowanie koncentruje się na ocenie pól elektromagnetycznych małej częstotliwości pod kątem narażenia ludzi. Pola elektromagnetyczne małej częstotliwości emitowane przez linie kolejowe zostały obliczone za pomocą dwuwymiarowego modelu opartego na teorii linii transmisyjnej [1]. Opisano wpływ parametrów związanych z ruchem kolejowym. Porównanie z Zaleceniem Rady Europy 1999/519/EC [2] pozwala określić sytuacje ryzykowne, co jest niezbędne dla zastosowania właściwych rozwiązań profilaktycznych. (**Pola elektromagnetyczne emitowane przez linie kolejowe dużych prędkości, przykład zastosowania: płyta nakrywająca nad liniami kolejowymi**).*

Keywords: railway lines, low frequency electromagnetic fields, human exposure, electromagnetic compatibility.
Słowa kluczowe: linie kolejowe, pola elektromagnetyczne małej częstotliwości, narażenie ludzi, kompatybilność elektromagnetyczna.

Introduction

The increase of traffic density and speed contributes to an increase in electromagnetic fields produced by railway systems. Furthermore the development of urbanized areas reduces the available space in train stations, which contributes to place people and workers closer to electromagnetic field sources. An example is the construction of the Nîmes Montpellier railway bypass (Contournement Nîmes Montpellier, CNM), a 80 km High Speed Line (HSL or French TGV) project in the south of France. In the framework of this project, a new train station will be constructed in Montpellier. Due to the lack of space, a cover slab will be built over the railway lines allowing the possibility of installing future offices. Therefore, people and equipment that will be in this area will be very close to the catenaries of the railway lines. Exposure to low frequency electromagnetic fields is thus a subject of increasing questions regarding health effects that need to be treated [3].

The calculation of electromagnetic fields radiated by railway lines is one of the main objectives of the Electromagnetic Compatibility Section of the SNCF. It is very important to evaluate human exposure levels to radiated electromagnetic fields, as well as to guarantee the electromagnetic compatibility of the railway system with its environment. The evaluation of electromagnetic fields in the railway environment is a subject well described in several studies in the literature. Some are based on transmission line theory [4]. Certain numerical studies introduce in their calculation the complex geometry of the railway system and apply the finite element method [5], [6], [7]. The interest of our study is to obtain with a multiconductor model the low frequency electromagnetic fields generated at every point of the railway line, taking into account the feeding and traction return circuits as well as traffic conditions.

An in-house 2D software (MODALF 6) which is based on transmission line theory [1] allows the calculation of voltages and currents of all the conductors of the railway system at a given frequency (50 Hz and its harmonics). These parameters combined with the geometrical and electrical characteristics of the conductors allow the calculation of electromagnetic fields. Electric and magnetic fields maps can be obtained in any desired cross section of the railway line. The effect of a passing train on electromagnetic field levels can be examined, as well as the worst case regarding human exposure and sensitive neighbors (hospitals, schools, industries among others), which is the center of this work.

This tool was used in the context of CNM project to evaluate the electromagnetic fields radiated by the railway line and to analyze the possible risks linked to the installation of the cover slab over the railway lines.

Railway model

The SNCF in-house software MODALF 6 permits to model the electrification supply characteristics of the railway line, as well as the traction return circuit. The electrical characteristics of the substations and power transformers are thus taken into account, and the return of traction current by the return conductors (rails, protection wire, buried earth wire and the ground) is properly represented. MODALF 6 represents the conductors of the railway system with lumped elements at a given frequency. The impedances and the admittances of the system are thus determined with Carson's method [8] and with the complex image method [9], respectively. The ground is represented with its resistivity in the system's impedances. With these lumped elements the voltages and currents in every point of the system can be obtained. The electromagnetic fields of the system are calculated by means of the conductors' position and electrical parameters (permeability, resistivity) with the second order complex image method [10], [11]. This software permits also to add any modifications along the line, as short circuits, the presence of sources, etc.

The CNM high speed line under study is electrified in 2x25 kV, 50 Hz. Biscarrat substation supplies power to the railway line from kilometric point 26 to 51.5, and La Castelle substation feeds the line from kilometric point 51.5 to 87. The new train station that will be constructed has six railway tracks, and the cover slab will be placed between kilometric points 81.65 and 81.85 at a height of 6.2 m regarding the railway tracks. The cover slab width is 1 m.

In order to simplify the model, two railway tracks were represented. Railway traffic is modeled as a load of 1500 A, which represents the load of the high speed line in steady state. This load can be moved along the railway lines. Varying the position of this load permits to determine the worst case for a parameter under study, in this case for electromagnetic field levels in the train station. It is important to note that the electromagnetic fields generated by the railway line depend not only in traffic, but also in the connections along the railway line. This highlights the importance of modeling the feeding connections between the tracks and the connections between the return conductors with MODALF 6. Also, the scope of MODALF 6 is to represent any rectilinear conductor in the railway environment. Thus, it is not possible to include complex geometries as the cover slab. Therefore, the calculation is done by taking into account its height and knowing that the cover slab will have a reduction effect on the obtained electromagnetic field levels.

Figure 1 shows the cross section of the model. The conductors of the two railway tracks are clearly shown: the ca-tenaries (Contact wire 1, Messenger wire 1, Contact wire 2, Messenger wire 2), the feeders (Feeder 1 and Feeder 2), the protection wires (OPC 1 and OPC 2), the buried earth wires (BEC 1 and BEC 2) and the rails (Track 1 and Track 2).

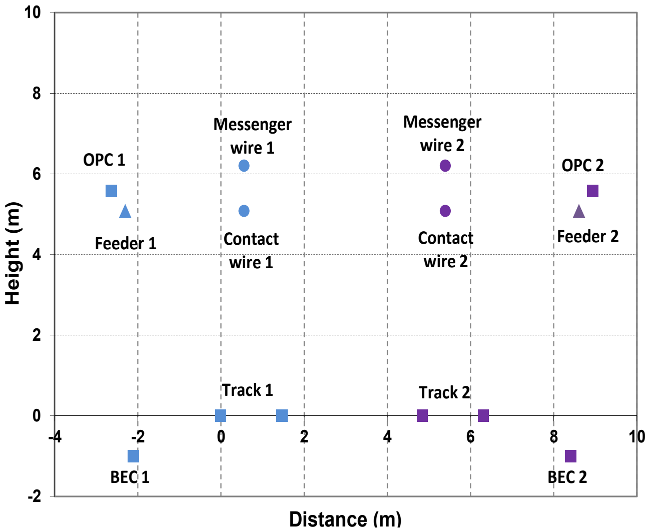

Fig.1. Cross section of the model for CNM high speed line for the evaluation of electromagnetic fields in the new train station. Two railway tracks are modeled with their respective conductors. The position of the conductors is shown.

Simulation results and recommendations

The evaluation of electromagnetic fields is performed only in steady state. In short circuit state the fault is eliminated in less than 200 ms, and according to standard EN 50121 the exposure to electromagnetic fields is too short to be taken into account [12].

In steady state the calculation of electric and magnetic fields radiated by the CNM high speed line can be obtained in any kilometric point and at any position in the cross section. In this case electromagnetic fields are observed in the kilometric point 81.75, which is inside the new train station. At this kilometric point and at the position of the cover slab, MODALF 6 permits to evaluate the maximum level of magnetic and electric fields regarding the position of the load.

A. Electric field

Electric fields depend on the voltage of the conductors, so they are present even if there is no load. Maximum electric field levels occur in the absence of the load because the voltage in the catenaries will be at its maximum (27.5 kV). At kilometric point 81.75 the maximum electric fields in the cover slab (at 6.2 m from the rails) is shown in Figure 2. The electric field value is higher around the catenary wires and decreases rapidly away from these wires. Electric field limits regarding public exposure (Public Recommendation 1999/519/CE) are also shown in this figure. It can be seen that these limits are exceeded in the cover slab.

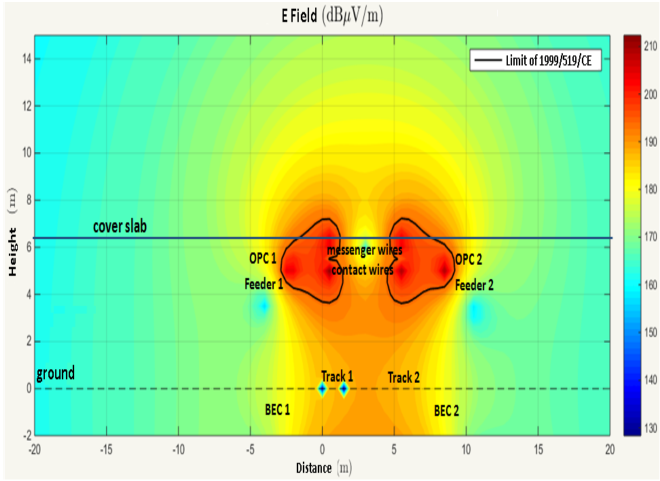

Fig.2. Electric field map [dBμV/m]. The contribution of the railway conductors and traffic in the field distribution is shown. The limit given by 1999/519/CE is exceeded in the cover slab in the region close to the messenger wires.

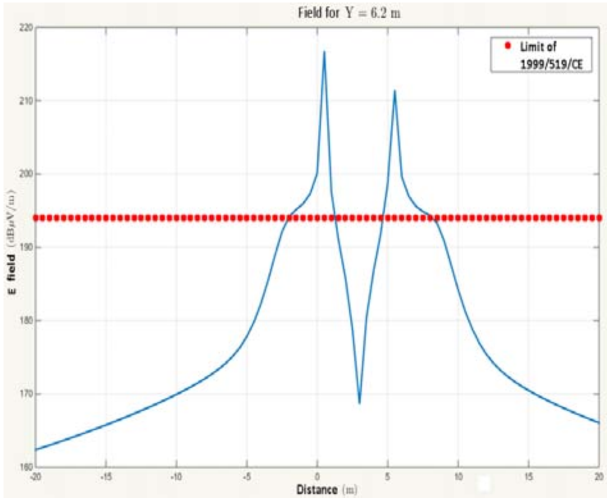

Fig.3. Electric field values [dBμV/m] at a height of 6.2 m, which corresponds to the height of the cover slab. It is shown that the limit of Public Recommendation 1999/519/CE is exceeded in some regions.

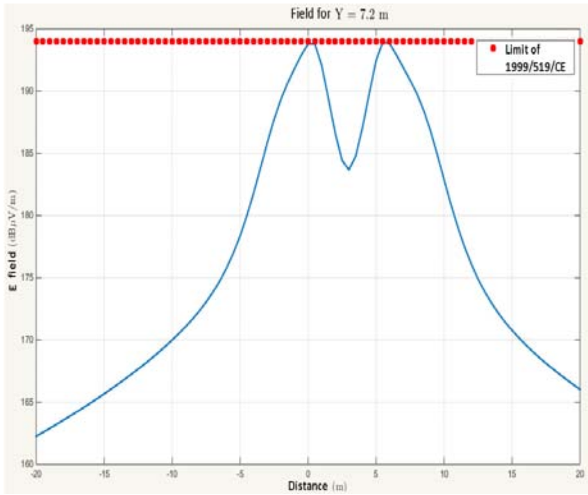

Fig.4. Electric field values [dBμV/m] at a height of 7.2 m, which takes into account the height and width of the cover slab. It is shown that the limit of Public Recommendation 1999/519/CE is respected.

Electric field levels can also be obtained in a horizontal line placed at a desired height. Figure 3 shows the results for a line at the height of the cover slab. It is clearly shown that the electric field exceeds the limit given by 1999/519/CE.

Electric fields were also calculated at a height of 7.2 m, which takes into account the width of the cover slab. At this height Figure 4 shows that electric fields do not exceed the limit given by 1999/519/CE.

Electric fields are rapidly attenuated with obstacles. The concrete reinforcement of the cover slab will highly contribute to reduce them; consequently they are not a concern.

B. Magnetic field

At kilometric point 81.75 the maximum magnetic field in the cover slab is when the load is in kilometric point 81.65. This is the point in which the contribution of all the railway conductors is higher regarding the current they carry.

The magnetic induction field map is presented in Figure 5. It can be observed that the magnetic induction field is higher around each railway conductor. Limits regarding public exposure (Public Recommendation 1999/519/CE) can be exceeded inside the region of railway track 1. Regarding the cover slab, it is shown that the limits are also exceeded.

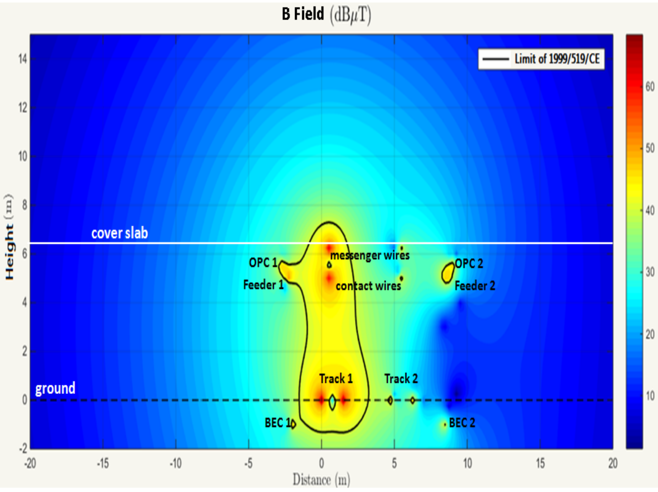

Fig. 5. Magnetic induction field map [dBμT]. The contribution of the railway conductors and the train in the field distribution is shown. The limit given by 1999/519/CE is exceeded in the cover slab in the region close to the messenger wire.

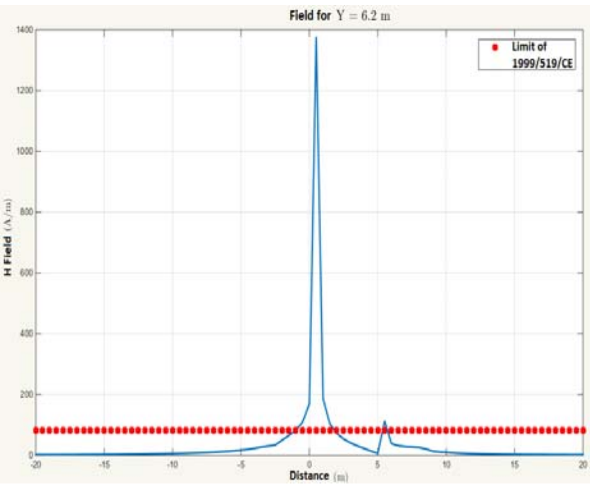

Fig.6. Magnetic field values [A/m] at a height of 6.2 m, which corresponds to the height of the cover slab. It is shown that the limit of Public Recommendation 1999/519/CE is exceeded in some regions.

Figure 6 shows the magnetic field obtained in a horizontal line placed at the height of the cover slab. Magnetic fields highly exceed the limit given by 1999/519/CE. A new calculation was performed taking into account the height and the width of the cover slab (7.2 m). At this position the limits are again exceeded. Table 1 shows the maximum magnetic field obtained for different heights.

Table 1. Magnetic field calculated at different heights from the tracks

y[m]	Maximum H field [A/m]
5.9	187
6.2	1377
6.5	275
7.2	88
7.3	80.5

From Table 1 it can be seen that magnetic fields exceed the limit given by 1999/519/CE (80 A/m) for several heights, which include the height and the width of the cover slab. At a height of 7.2 m, which takes into account the width of the cover slab, the levels are lightly exceeded.

The easiest way to reduce magnetic fields is to reduce the current source that generates them. This solution is not an option since the current driven by the railway conductors is already determined by the required traffic and operation conditions of the railway line. Another option can be to install highly permeable metallic screens, which can be very expensive. A feasible solution is to increase the width of the cover slab. This will contribute to increasing the distance to the messenger wire. At 7.3 m the maximum magnetic field is 80.5 A/m (Table 1), so a cover slab having a width of 1.1 m or more is adequate to have acceptable magnetic field levels. It is also very important to verify the susceptibility of sensitive equipment that may be installed on the cover slab. This depends on each equipment and may need additional solutions.

Conclusions

The electromagnetic fields generated by CNM high speed railway line were calculated and analyzed regarding human exposure. A new train station will be built with a cover slab over the railway lines in order to install future offices. Thus, human exposure to electromagnetic fields is a subject of great concern in this project.

A multiconductor model of the whole railway line was constructed with an in-house tool based in transmission line theory. This model takes into account the feeding connections between the railway tracks, the connections between the return conductors and traffic. This allows us to accurately obtain voltages, currents, and electromagnetic fields at any given point of the railway line.

Electromagnetic fields are calculated at the train station and at the position of the cover slab. The maximum level of electric fields is obtained when there is no load along the railway line, since this corresponds to the maximum voltage in the catenaries. For magnetic fields, the maximum level is analyzed regarding the position of the load (traffic). Thus, the load is moved along the railway line. Maximum levels are obtained between the connections of the return conductors. In this point the current driven by all the railway conductors is the worst regarding the magnetic field produced at the cover slab.

A comparison to Public Recommendation 1999/519/CE showed that electromagnetic fields exceed the recommended limits at the height of the cover slab. However, if the width of the cover slab is taken into account, electric fields are under the normative limit. For magnetic fields a slight excess is observed. In this case increasing the width of the cover slab allows to reduce the observed levels. Nonetheless, it is recommended to verify the susceptibility of electronic and sensitive equipment that may be installed on the cover slab.

This study constitutes a base for future studies regarding human exposure to electromagnetic fields in the railway environment. In the future, a measurement campaign will verify the magnitude of electromagnetic fields levels on the cover slab. Also a model taking into account real traffic and the concrete reinforcement of the cover slab would allow us to increase the prediction level of the in-house tool.

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