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Impact of the Measurement Methods on the Characterization of Transient Electromagnetic (EM) Interferences above 2 GHz in a Railway Environment

Grecia Romero(1), Virginie Deniau*(2), and Eric Simon(3)
(1) Institut de Recherche Technologique Railenium, France, (e-mail: grecia.romero@railenium.eu)
(2) IFSTTAR, France (e-mail: virginie.deniau@ifsttar.fr*)
(3) University of Lille, France (e-mail: eric.simon@univ-lille.fr)

Abstract

In order to offer Internet access on-board trains, Wi-Fi and LTE connections are required. These communication systems can be susceptible to electromagnetic (EM) interferences present in the railway environment at high frequency, produced by loss of contact between the catenary and the pantograph. We are mainly interested in the frequencies above 2 GHz, in which LTE and Wi-Fi operate. This paper presents measurements that were carried out to characterize transient interferences above 2 GHz. Two different measurement processes were carried out in order to analyse the impact of the measurement methods on the observed main characteristics of the transient interferences. The experimental results are analyzed in the time and frequency domains.

1 Introduction

Nowadays, Internet access has become a necessity for people, either for work or leisure purposes. Hence, more and more frequently transport systems offer on-board Wi-Fi service to their passengers to stay competitive. An on-board Wi-Fi solution for High-Speed Trains requires both a Wi-Fi and an LTE connection [1].

High-speed trains use an electric transmission system composed of pantograph and catenary (Figure 1). At high speed, the sliding contact between catenary and pantograph is regularly lost over very short periods of time, creating electrostatic discharges [2]. This phenomenon can affect the train operation and generates EM interferences [3]. These electrostatic discharges are transient EM interferences of very short duration and cover very wide frequency bands [4, 5].

To have a robust Internet access on trains it is necessary to take into account electromagnetic (EM) interferences present in the railway environment [6]. The railway environment is characterized by the presence of very high power low frequency signals from the drive system [7]. Due to the significant difference of powers between the low frequency and high frequency signals, higher frequency signals are generally undetectable in the measurement results.

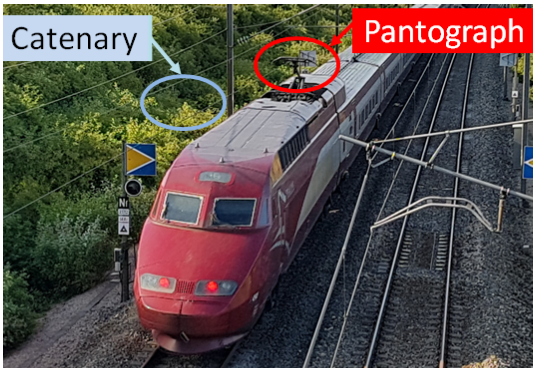

Figure 1. Pantograph catenary system.

Therefore, the main objective of this paper is to analyze the changes observed in the characteristics of transient EM interferences when the interference is measured by means of different measurement methods, in particular using different filters.

The rest of the paper is organized as follows. In Section 2, the whole experimental setup is detailed. In Section 3, the measurement results are presented and analyzed. Finally, conclusions are given in Section 4.

2 Experimetal method

In this section, we describe the two test setups employed to characterize the transient EM interferences produced by loss of contact between the catenary and the pantograph. The first setup is mainly focused on measuring above 2 GHz in order to center the attention on transient interferences. We focused on 2 GHz because it is the frequency band commonly used by LTE and Wi-Fi communications. The second setup used classic methods found in the literature that cover a wide frequency band, starting at 100 MHz.

To measure transient EM signals in a real environment, the experimental test setup was placed over a railroad line. In general, the acquisition in the time domain was carried out using an oscilloscope (LeCroy Wave Master 813Zi) connected to an antenna (horn antenna 700 MHz-18 GHz) through a filter (Figure 2). The antennas were oriented in the direction of the center of both railway lines (two directions).

Figure 2. Experimental setup.

In order to compare measurement methods employed to characterize transient EM signals, we used two setups by employing two different filters (Figure 3).

Setup 1. This configuration comprises a horn antenna which was connected to channel 1 (C1) of the oscilloscope through filter 1. Filter 1 (Figure 3) is a high pass filter with a cutoff frequency of 1.8 GHz. With this configuration all low frequency signals are filtered out.

Setup 2. In order to assess the impact of low frequency signals on the characterization of transient EM interferences, we used a band pass filter whose frequency band was 100 MHz to 3 GHz.

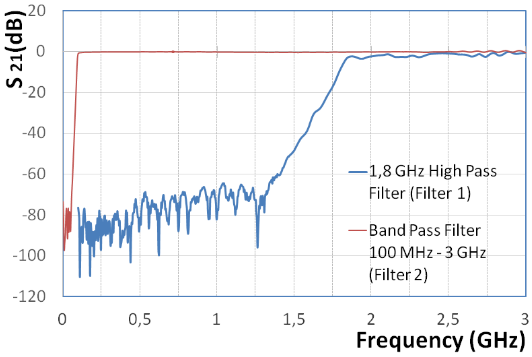

Figure 3. Frequency response of the High Pass Filter and the Pass Band Filter used in the experimental setups.

3 Measurement results

Figure 4 presents time domain representations of transient EM interferences measured by the oscilloscope, showing in channel 1 (C1) and channel 2 (C2) the interference that got through setup 1 and setup 2, respectively. The oscilloscope was configured with a sampling rate (Fs) of 20 Gsamples/s and triggered with channel 2.

We observed a transient EM interference in both channels. However, the interference amplitude measured with setup 2 (100 MHz -3 GHz band pass filter) is almost ten times bigger than the interference amplitude measured with setup 1 (1.8 GHz high pass filter). When the same interference is viewed in a zoomed-in time scale in Figure 5, a delay can be seen between both time domain representations. The delay is due to the fact that the cable used in setup 1 was longer than the cable in setup 2. Notice also how the waveshape of the interference in setup 2 is different from that of setup 1. Previous characterizations of the electrostatic discharge waveform [5, 8] resemble the interference waveforms we observed in setup 1.

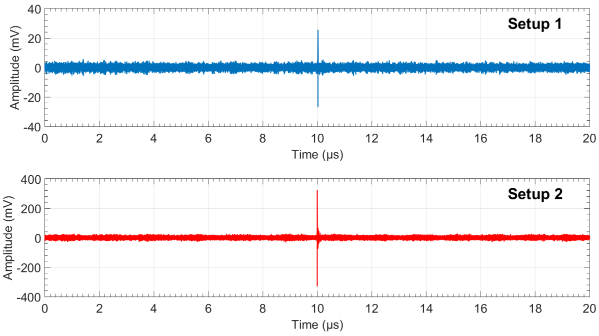

Figure 4. Time domain representations of transient EM interferences measured with setup 1 and setup 2, Fs of 20 GHz and triggered with channel 2 in 20 μs time window.

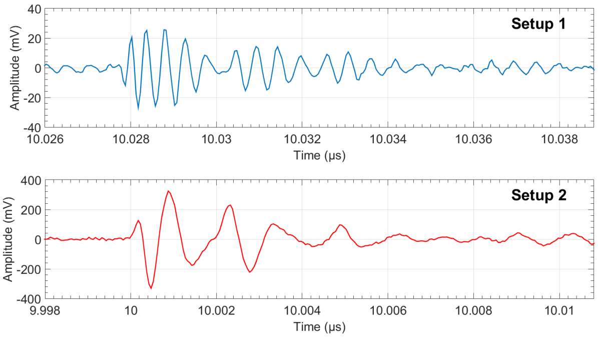

Figure 5. Time domain representations of transient EM interferences measured with setup 1 and setup 2 with Fs of 20 GHz and triggered with channel 2 in a 12.8 *ns* time window.

In order to explain the reason behind the differences in the waveshapes between both representations, it is necessary to analyze their behavior in the frequency domain. Figure 6 shows their frequency domain representations obtained using the Fast Fourier Transform (FFT) with 256 points over each transient. As you can see, the transient EM interference obtained by way of setup 1 is mainly composed of high frequencies. For transient EM interference obtained using setup 2, in contrast, the high power frequency components are concentrated below 1 GHz. Indeed, in the 2.4 GHz frequency band, both representations have almost -23 dBV. However, in setup 2, these frequency components are hidden by lower frequency components with higher power. In view of the above, the shape is different.

Figure 7 displays three successive transients obtained with setup 1 and setup 2. The oscilloscope was configured with a sampling rate (Fs) of 10 Gsamples/s and triggered with

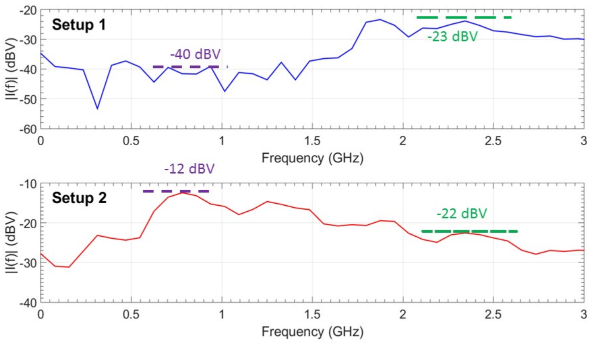

Figure 6. Frequency domain representations of transient EM interferences of Figure 5.

channel 2. For setup 1, transients show repetition intervals of 78 *ns* and 58 *ns*, and they have similar characteristics (shape and amplitude). In setup 2 too, there are three transients with the same repetition periods, although the duration of the transients looks larger than in setup 1.

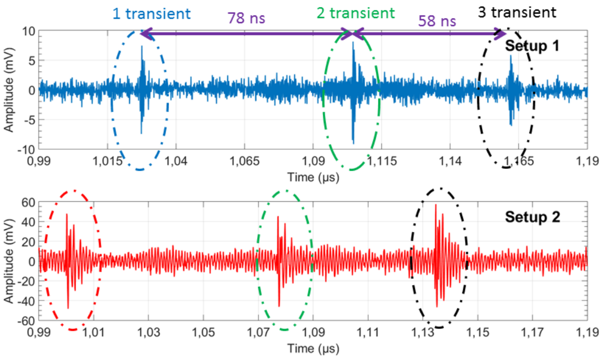

Figure 7. Time domain representations of three transient EM interferences measured with setup 1 and setup 2 with Fs of 10 GHz and triggered with channel 2 in 200 *ns* time window.

Frequency domain representations by the FFT with 128 points over each one of these transients are presented in Figure 8. Notice how for all cases, we got the same behavior we had observed earlier. Hence, in setup 1, high frequency components are the most important. On the other hand, in setup 2, higher power levels are concentrated in lower frequencies.

There were cases where we recorded interferences using trigger with setup 2 that are not presented in setup 1, as you can see in Figure 9. This is due to fact that the oscilloscope was triggered with channel 2 (setup 2), and with this configuration the oscilloscope recorded all environment noise. Figure 10 indicates that recovered signals correspond to environment noise.

However, when the oscilloscope was triggered with channel 1 (setup 1), all transient interferences recorded correspond to loss of contact between the catenary and pantograph,

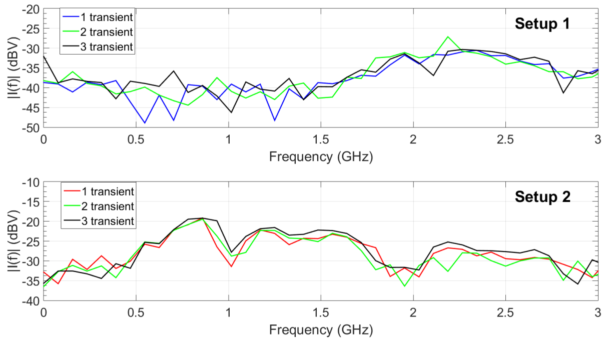

Figure 8. Frequency domain representations of three transient EM interferences of Figure 7.

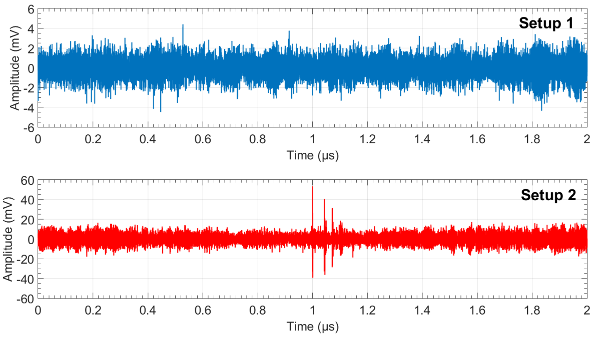

Figure 9. Time domain representations of transient EM interferences measured with setup 1 and setup 2 with Fs of 10 GHz and triggered with channel 2 in 2 μs time window.

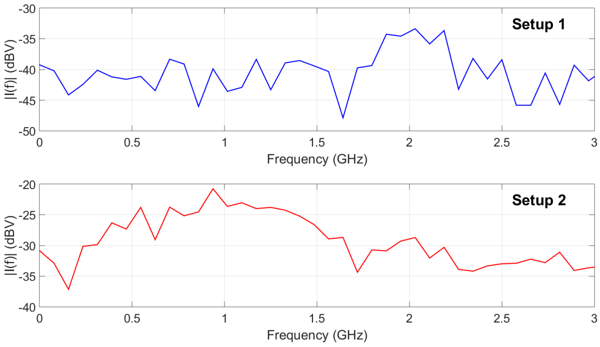

Figure 10. Frequency domain representations of Figure 9.

even in cases where transient interference was not visible in the time domain representation (Figure 11) in setup 2. In frequency domain representations (Figure 12), the interference is there. It was just hidden by environment noise.

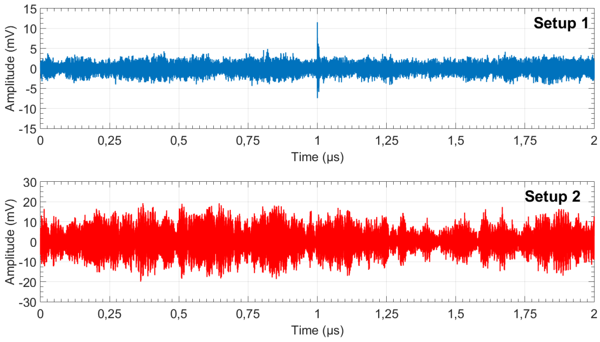

Figure 11. Time domain representations of transient EM interferences signals measured with setup 1 and setup 2 with Fs of 10 GHz and triggered with channel 1.

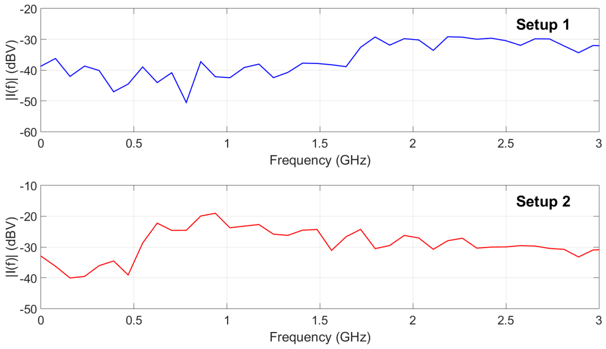

Figure 12. Frequency domain representations of transient EM interferences of Figure 11.

4 Conclusion

This paper presents a series of tests that were carried out to analyze the impact of measurement methods over the characterization of transient electromagnetic (EM) interferences above 2 GHz in a railway environment. Two different setups were analyzed in the time and frequency domains. The first setup was focused on measuring transient interferences above 2 GHz, while the second setup by means of the classic method by measuring since VHF frequency band. Experimental results highlight that transient EM interference above 2 GHz can be hidden by lower frequency interferences and environment noise.

In view of the above, we recommend to employ the setup 1 to do a statistical analysis of characteristics of transient EM interferences and to trigger with setup 1 the record automatically.

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