

Prediction Method for Automobile EMI Test Result in AM Frequency Band

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ABSTRACT

The EMI, electromagnetic interference, is tested for automobiles and components by the method defined in the international standard, CISPR 25. Regarding the automobile test, the EMI from the component installed in the automobile is measured by the antenna of an automobile. On the other hand on the component test, the EMI from the component is measured by a mono-pole antenna set forward of the component. However, components sometimes fail the automobile test even if its passed the component test due to the difference of the method. In this case, the component has to be designed again to pass the automobile test. Therefore, the prediction method of the automobile test result is required. In this paper, we tried to modify the standard component test configuration to predict the automobile test result for a fuel pump system in AM frequency band. At first, to show the noise propagation mechanism of the automobile test, the mechanism was modeled by an electrical circuit by focusing on the parasitic capacitances between the fuel pump system, the antenna and the chassis. Next, to realize the same electrical circuit as the automobile, the standard component test configuration was modified. For example, in the standard component test, the fuel pump should be set on the grounded ground plane. On the other hand, in the modified component test, the fuel pump was set between the floor and floating ground plane. As the result, the modified component test result agreed with the automobile test result, meaning automobile test result could be predicted.

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1. INTRODUCTION

In the international standard, CISPR 25, measuring methods of radiated electromagnetic noise for automobiles and components are defined. Regarding the automobile test, the radiated electromagnetic noise from the component installed in the automobile is measured by the antenna of the automobile. On the other hand on the component test, the radiated electromagnetic noise from the component is measured by the mono-pole antenna set forward of the component. The EMI of automobiles and the components are often evaluated referring to CISPR 25. However, the components sometimes fail the automobile test even if they passed the component test due to the difference of the method. In this case, the component has to be designed again. For example, power electronics components have some high power switching devices that the switching frequency is near the radio frequency band, called AM frequency band in Japan, from 526.5kHz to 1606.5kHz. The electromagnetic noise by switching will interfere with an AM radio receiver. The interference is sometimes found by the automobile test after the component test has been finished. Therefore, the prediction method for the automobile test result is required. In References [2], [3] and [4], the radiated electromagnetic noise propagation mechanism of the component test was investigated. And in References [4] and [5], radiated electromagnetic noise propagation mechanism of the automobile test was investigated. However, the difference of the mechanism between the automobile test and the component test was not discussed sufficiently. Moreover, the prediction method of the

automobile test result was not developed. In this paper, we tried to modify the standard component test configuration to predict the automobile test result. In this study, a fuel pump system whose component test results did not agree with the automobile test results was used. The fuel pump system consisted of a fuel pump, wire harnesses, and a controller.

This paper is organized as follows. In [Section 2](#), main investigation of this paper is shown. In [Section 3](#), the investigative study results for the radiated electromagnetic noise propagation in the automobile test system is discussed. In [Section 4](#), the investigative study results for the radiated electromagnetic noise propagation in the component test system is discussed. In [Section 5](#), the radiated electromagnetic noise propagation in the component test system is compared with that in the automobile test system. In [Section 6](#), the standard component test is modified to predict the automobile test result.

2. INVESTIGATION OF RADIATED ELECTROMAGNETIC NOISE PROPAGATION PATHS IN COMPONENT TEST SYSTEM AND AUTOMOBILE TEST SYSTEM

Reference [5] is an example of an earlier study on radiated electromagnetic noise propagation paths. This paper reported that the parasitic capacitance between the automobile body and the earth forms one of the radiated electromagnetic noise propagation paths.

The radiated electromagnetic noise from the fuel pump generates the voltage in the parasitic capacitance between the automobile body and the earth as discussed in Reference [5]. This voltage is divided by the parasitic capacitance between the antenna and the automobile body and the parasitic capacitance between the antenna and the earth. The voltage between the antenna and the automobile body interferes with the AM radio receiver. To further explore the above study results, the radiated electromagnetic noise propagation path was investigated with a focus on the difference of the location of parasitic capacitance between the component test system and the automobile test system.

3. RADIATED ELECTROMAGNETIC NOISE PROPAGATION IN AUTOMOBILE TEST SYSTEM

This section discusses investigative study results for the radiated electromagnetic noise propagation in the automobile test system. Radiated electromagnetic noise from radiation sources propagate to the antenna.

3.1. Radiation Sources

Radiation sources are described first. The fuel pump system mounted on an automobile is schematically illustrated in Figure 1. The fuel pump was installed in a plastic fuel tank mounted outside the automobile and soaked in gasoline. The controller was installed inside the automobile and connected to the fuel pump through wire harnesses. This means that wire harnesses were laid inside the automobile. The controller generated PWM signal to control the fuel pump. The harmonic of the PWM signal overlapped the AM radio frequency band and interfered with the AM radio receiver. In this system, three radiation sources, V_{wb_a} , V_{pb_a} and V_{cb_a} , existed as shown in Figure 2, which was a simplified form of Figure 1. Three radiation sources are explained below.

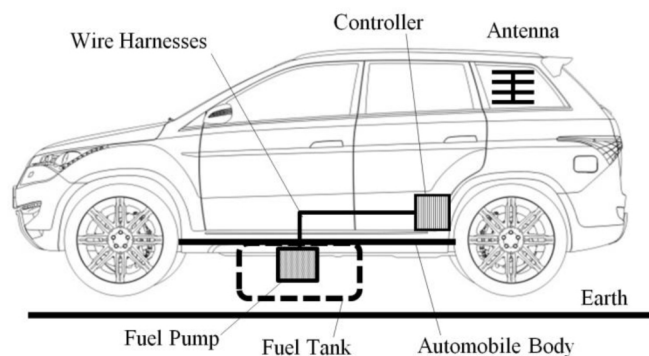


Figure 1. Mounting of the fuel pump system

The harmonic of the PWM signal transmitted from the controller partly leaked into wire harnesses as the noise current and propagated into the automobile body through the parasitic capacitance, C_{wb_a} , between wire harnesses and the automobile body. In this process, the voltage, V_{wb_a} , was generated in C_{wb_a} and acted as a radiation source. The remaining noise current reached the fuel pump through wire

harnesses propagated into the automobile body through the parasitic capacitance, C_{pb_a} , between the fuel pump enclosure and the automobile body. In this process, the voltage, V_{pb_a} , was generated in C_{pb_a} , and also acted as a radiation source. The noise current that had propagated into the automobile body returned to the controller through the parasitic capacitance, C_{cb_a} , between the controller and the automobile body. In this process, the voltage, V_{cb_a} , was generated in C_{cb_a} and also acted as a radiation source.

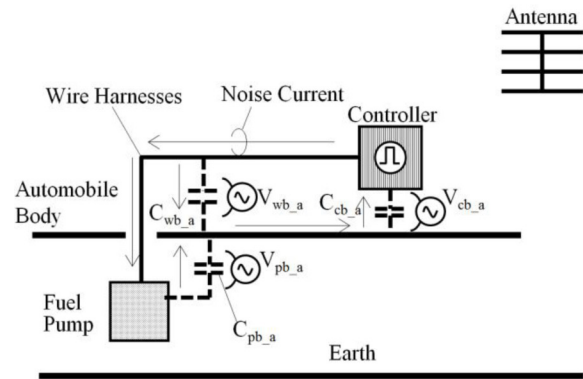


Figure 2. Electromagnetic noise radiation sources in the automobile test system

3.2. Radiated Electromagnetic Noise Propagation from the Fuel Pump

Next, the radiated electromagnetic noise propagation from radiation sources to the antenna are discussed. The radiated electromagnetic noise propagation path from the component to the parasitic capacitance between the automobile body and the earth, which is not discussed in Reference [5], was investigated. Based on the results, radiated electromagnetic noise propagation paths in the automobile test system are discussed. As an example, the radiation of the electromagnetic noise from the fuel pump, V_{pb_a} , was used.

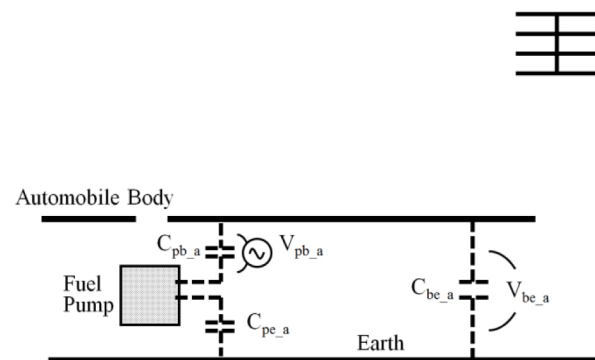


Figure 3. The radiated electromagnetic noise propagation from the fuel pump in the automobile test system

As shown in Figure 3, parasitic capacitances, C_{pe_a} and C_{be_a} , existed between the fuel pump and the earth, and between the automobile body and the earth, respectively. When taking the above fact into account, the radiated electromagnetic noise propagation from V_{pb_a} to C_{be_a} could be represented by the equivalent circuit shown in Figure 4. In this Figure, C_{pb_a} is omitted due to no relation with the radiated electromagnetic

noise propagation. C_{pe_a} and C_{be_a} were considered to act as radiated electromagnetic noise propagation paths. V_{pb_a} was divided by C_{pe_a} and C_{be_a} so that the voltage, V_{be_a} , was generated in C_{be_a} . Therefore, applying Ohm's law, V_{be_a} was calculated by Equation (1).

$$V_{be_a} = V_{pb_a} + 20\text{Log}_{10}\left(\frac{C_{pe_a}}{C_{pe_a} + C_{be_a}}\right) \quad (1)$$

Where, units of V_{be_a} and V_{pb_a} are dBuV. Moreover, considering that the equivalent circuit of Figure 5 in Reference [5], the electromagnetic noise propagation from the fuel pump to the antenna in the automobile test system could be represented by the equivalent circuit shown in Figure 6. Therefore, V_{ab_a} , the antenna inductive voltage as a measure to evaluate EMI of components in accordance with CISPR 25, was calculated by Equation (2).

$$V_{ab_a} = V_{pb_a} + 20\text{Log}_{10}\left(\frac{C_{pe_a}}{C_{pe_a} + C_{be_a}}\right) + 20\text{Log}_{10}\left(\frac{C_{ae_a}}{C_{ab_a} + C_{ae_a}}\right) \quad (2)$$

Where, a unit of V_{ab_a} is dBuV, and C_{ae_a} and C_{ab_a} are parasitic capacitances between the antenna and the earth, and between the antenna and the automobile body, respectively. The second term and the third term are propagation losses of the radiated electromagnetic noise. To check the validity of the equivalent circuit, V_{ab_a} calculated by Equation (2) was compared with V_{ab_a} actually measured. C_{pe_a} , C_{be_a} , C_{ae_a} and C_{ab_a} were determined from S_{11} , impedance, that was measured by a network analyzer. V_{pb_a} was measured by a high frequency probe and a spectrum analyzer. V_{ab_a} was measured by the spectrum analyzer as the output of the antenna. The comparison result is shown in Figure 7. In this figure, the solid line represents the measured values, while the broken line represents the values calculated by Equation (2). The calculated values agreed with the measured values within a tolerance of approximately 4dB, verifying the validity of the equivalent circuit shown in Figure 6.

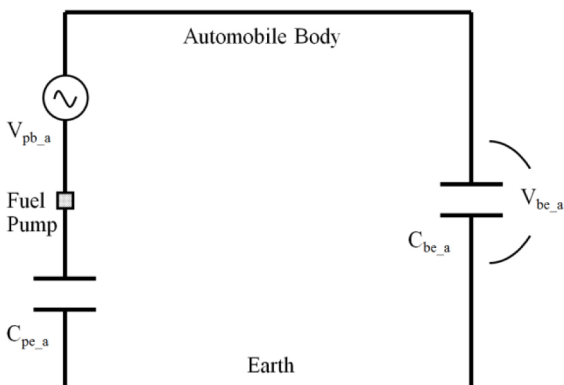


Figure 4. The equivalent circuit of the radiated electromagnetic noise propagation from the fuel pump

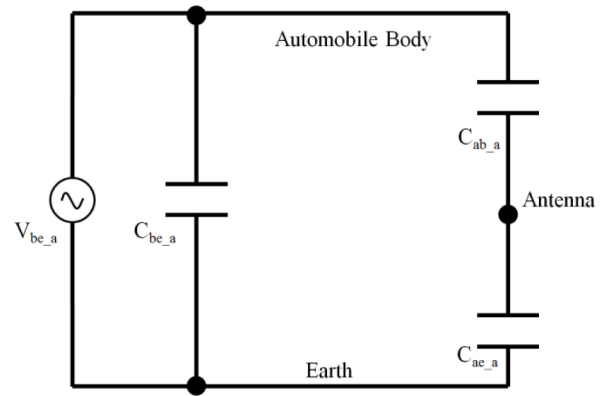


Figure 5. The equivalent circuit of the radiated electromagnetic noise propagation discussed in Reference[5]

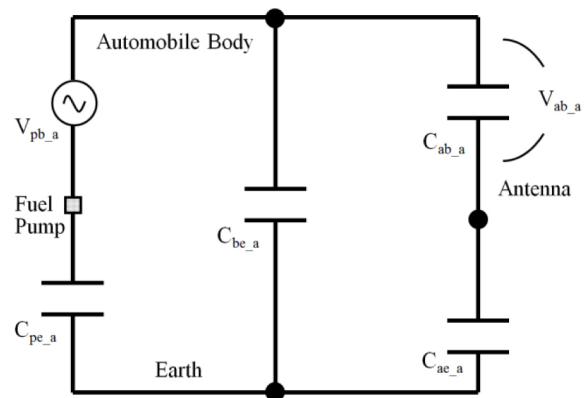


Figure 6. The equivalent circuit of the radiated electromagnetic noise propagation from the fuel pump to the antenna

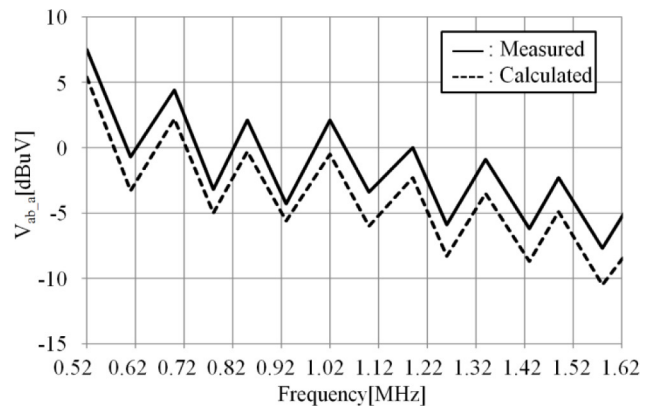


Figure 7. The comparison result of measured V_{ab_a} and calculated V_{ab_a}

3.3. Radiated Electromagnetic Noise Propagation from Wire Harnesses and the Controller

With regard to the electromagnetic noise radiation from wire harnesses and the controller, parasitic capacitances, C_{wa_a} and C_{ca_a} , also existed between wire harnesses and the antenna, and between the controller and the antenna as shown in Figure 8, respectively. The above-described V_{wb_a} and V_{cb_a} were generated at the positions shown in Figure 8. The electric circuit equivalent to Figure 8 is shown in Figure 9. This figure represents the radiated electromagnetic