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A New EMI Test Method of Power Harness Used for HEV/FCEV : PHSA

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Abstract

Power harness used in HEV/FCEV may be a source of noise to other electric modules in the systems. EMI test specification for power harness has not been specified yet. Until now power harness is tested in accordance with low-voltage cable EMI test specification, such as IEC60096-1. But, the IEC specification may not be suitable for the high voltage power cables as it is designed for the low voltage cable. One of the major differences is signal direction and number of phases. In case of power harness, there is a possibility of radiation of noise to other units. But existing method only addresses single phase cable, whereas, in a real car 2 or 3-phase cables go together. Therefore there is a need of a new test method that can address the power harness test.

Accordingly, a new test method, PHSA(Power Harness Screening Attenuation) method is developed, that can be used for testing power harness and reflect real car conditions. To prove reliability of the PHSA method, effects of variables like cable length, cable bending and terminal impedance were tested. The specimens used for testing were 40A/600V power harness. Observing the results obtained from the experiment and theoretical analysis, it is concluded that PHSA method can be used to test any power harness.

Keywords: HEV, FCEV, EMI, power harness, shielding attenuation

1 Introduction

A lot of automotives have made problems such as global warming due to CO_2 gas and air pollution. Also that has led more and more consumptions of petroleum resources. This situation pushed car manufacturers to develop a new technology which can be alternative energy sources from the conventional one such as gasoline and diesel. One of the most realistic solutions is using electric energy instead of petroleum for energy source of vehicle. Hybrid Electric Vehicle (HEV) and Fuel Cell Electric Vehicle (FCEV) use electric energy. In HEV, both fuel and electric energy are used to drive depending on driving condition. In FCEV, electric energy made from hydrogen gas is used to drive. HEV and FCEV use high voltage because of its output power requirement and energy efficiency. This means there exist conventional low voltage system for the controller and electrical components, and extra high voltage system using the voltage ranging from 150V to 600V for power driving. This electrical difference in HEV/FCEV induces more various electromagnetic noise interference issues than former conventional vehicles. But, there is no evaluation method of shielding attenuation for high voltage system. Especially, it is impossible to evaluate noise radiation from passive component such as cable, connector, wiring harness. Hence in this paper, the new evaluation method for shielding attenuation of power harness was developed: PHSA (Power Harness Screening Attenuation) method. And to prove reliability of the PHSA method, it is performed that theoretical analysis and experiments on the variables of parameters such as cable length, bending, cable diameter and shield type.

1. The test is complete with different cable length.
2. Through bending variations of 3 angular types, those relations to screening attenuation based on a fixed average braided density can be found.
3. Screening attenuation is measured under variety terminal impedance.

2 PHSA Method

For developing the test method, first of all, it is required to be the reference specification. There are some test methods for cable shielding in the figure 1. But, most of them only focus on RF cable, not power cable. For developing shielding evaluation method, the former test method was analyzed, and classified as shown.

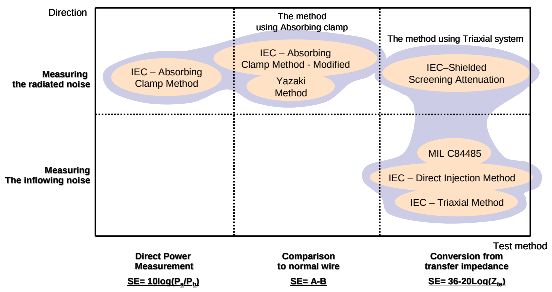


Figure 1: Analysis of other shielding evaluation method

The biggest difference between power harness and RF cable is the direction of noise signal. In case of power harness, it may interfere with other control lines, but because of much power it isn't hindered from other lines. In case of signal line, it is quite opposite.

And power harness includes several cables and connectors. To measure the shielding characteristic of not one wire and connector, but whole harness, it is required to include cables and connectors. But, any evaluation method can't be done like that. It is the most important objects of PHSA methods.

In Figure 1, the reference specification can be found. It is IEC shielded attenuation method. But, it is only for RF cable. Through the modification procedure of some variables and settings, PHSA is developed.

This method, PHSA, simulates the couplings, is applied on a determined length sample by injecting the current on the inner conductor of the cable and measures the induced voltage on the shield of the cable. The test result is calculated by using the following equation which is derived from the equivalent circuit shown in figure 2.

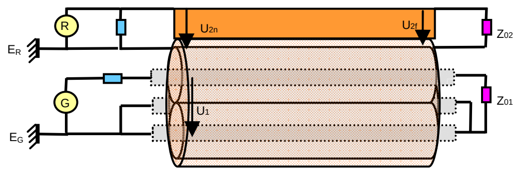


Figure 2: Equivalent circuit of line injection

Where,

- Z_{01} load impedance of circuit 1
- Z_{02} characteristic impedance of circuit 2
- U_1 the voltage wave in the primary circuit at the near-end, traveling to the far-end
- U_{2n} the voltage wave in the secondary circuit to the near-end and measure the near-end
- U_{2f} the voltage wave in the secondary circuit to the far-end and measure the far-end
- G Generator
- R Receiver
- E Earth
- T Coupling transfer function

With the reference to figure 2, there are the three wire cable setting and the current return path through the other cores. When the noise is generated to circuit one, then the radiated one is measured in the circuit two. The coupling transfer function T is the invariant quality with respect to the direction of feeding. It is showed that the normalized wave amplitudes for near-end and far-end coupling respectively as followed:

$$T_n = \frac{U_{2n}/\sqrt{Z_{02}}}{U_1/\sqrt{Z_{01}}} = \frac{I_{2n}/\sqrt{Z_{02}}}{I_1/\sqrt{Z_{01}}} \quad (1)$$

$$T_f = \frac{U_{2f}/\sqrt{Z_{02}}}{U_1/\sqrt{Z_{01}}} = \frac{I_{2f}/\sqrt{Z_{02}}}{I_1/\sqrt{Z_{01}}} \quad (2)$$

$$a_s = -20\log_{10}\left(\max\left|T_n, T_f\right|\right) \quad (3)$$

Where ,

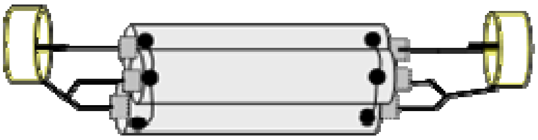
- a_s Screening attenuation

2.1 Preparation of the test specimen

Three phase power cables are experimented for screening attenuation by generating the noise in each individual core.(as shown in figure 2).

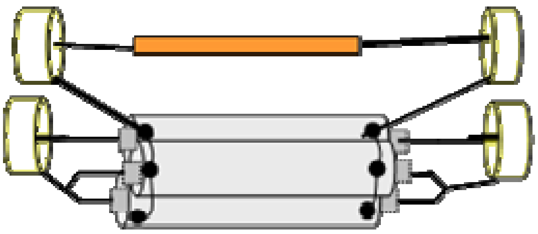
Figure 3 shows the procedure of preparing the test specimen.

STEP 1.



1. One core connected to inner of connector.
2. Other two cores connected to the outer of connector

STEP 2.



1. A copper tape is placed at the surface of cable & both the ends connected to the inner of connector on both the sides.
2. Shield of each cable is connected to the outer of the connector.

Figure 3: Preparation of the test specimen

2.2 Equipment suggestion

The signal generator and spectrum analyzer are the basic equipment in EMC test. In PHSA method, the network analyzer is recommended for it can measure the different frequency together automatically, meanwhile the signal generator can measure the frequency separately. If the measurement of characteristic impedance is needed, TDR (Time domain reflectometer) is a good choice.

2.3 Test set up and procedure

The instrument setting is shown in figure 4 and figure 5. In figure 4, noise is generated to one core and the current returning path is other two cores. At different steps of the test, the connection to measure the different values should be changed. For convenience, the letters to every possible connection points was designated in figure 4.

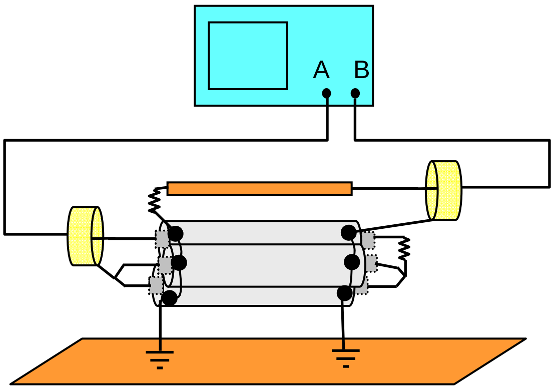


Figure 4: Noise source current path

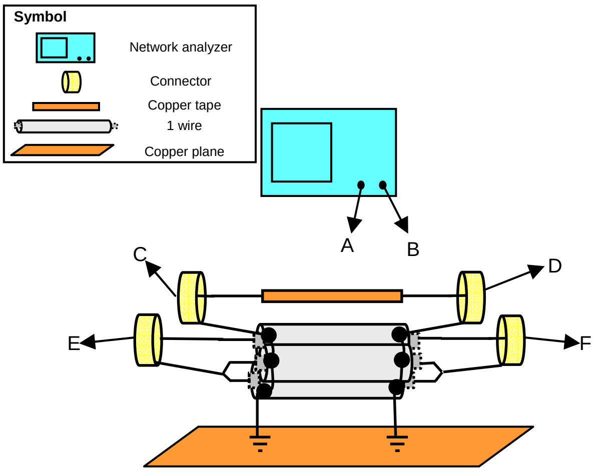


Figure 5: Test set up (to show procedure)

The procedure flow chart of PHSA method is shown in figure 6. Measuring the insertion losses to calibrate is the first step, for the insertion loss may be the same level with the noise itself. The second step is measuring transfer function. Then using the data to calculate the screening attenuation and transfer impedance. The procedure is composed of 7 steps during which five values are measured: reference data, insertion loss of injection circuit, insertion loss of CUT(Cable Under Test), near end transfer function and far end transfer function.

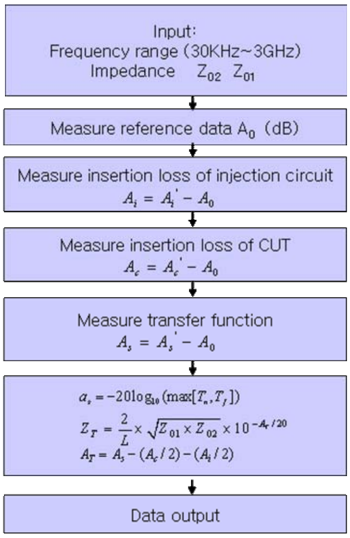


Figure 6: Flow chart of test procedure

The process is explained as following list:

1. Assemble the test setting in accordance with figure 4, and then input frequency range and measure the impedance.
2. Establish and store reference level by connecting the A and B
3. Measure and store the injection loss data of the injection circuit by connecting A to C and B to D
4. Measure and store the insertion loss data of the CUT by connecting A to E and B to F
5. Measure the near-end transfer function by connecting A to C and B to E; also connect D and F to terminations. Measure the far-end transfer function by connecting A to D and B to E; also connect C and F to terminations
6. Calculate the screening attenuation using the formula
7. Result obtained

A is generator port and B is receptor port in figure 4. The same procedures are repeated after changing the current path to core to shield.

3 Extraction of effective parameter

To extract effective parameters for evaluating screening attenuation, variety of parameter such as cable length, cable bending and terminal load were tested.

3.1 Cable length

At real cars, the length of power cable in real use is about 0.5~3 meters. Moreover it is various for the cars. Thus analyzing each length for design is very cumbersome with respect to time cost. An alternative solution to assist the design process of cable needs to save time and cost during designs for the HEV/FCEV power cable.

The test setting is shown in Figure 7. The specimens are changed by different lengths which are 0.5m, 1.0m, 3.3m.

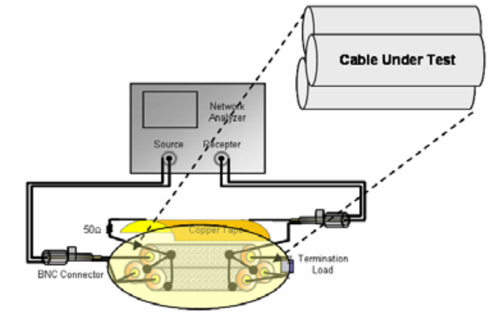


Figure 7: PHEV test setting for length variation

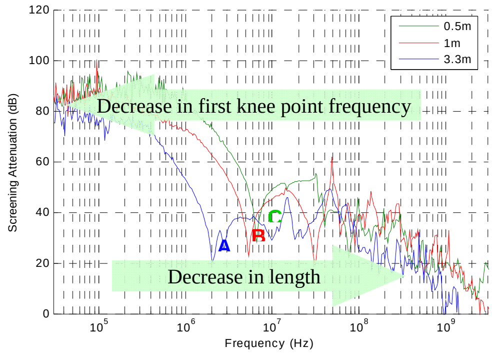


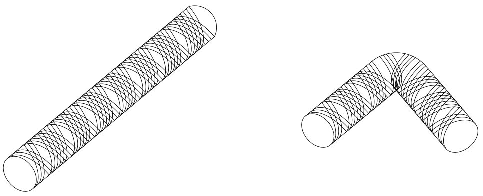
Figure 8: Screening attenuation graphs for different cable length

In figure 8, the cut-off frequency decreases related to increasing in length. Accordingly the recommended test cable length is 0.5m for avoiding the interference as frequency up to 3GHz.

3.2 Cable bending

In order to apply PHSA in the real car condition, important experiment on practical parameter bending was performed, because the bending of the cable may take place in real car situation. This factor of bending is very important as in Laboratory surroundings. In conventional test method, CUT was considered and experimented only in straight situations. However in actual car the case may be different as there could be bends in the cable due to limited wiring space as shown in the figure 9 which shows conceptual diagram of a car. Figure9 shows that the straight wire has an uniform shielding structure, on the other hand bended cable doesn't have an uniform shielding structure.

The different angle is shown in Figure 10 which is 45˚, 90˚, 180˚.



(a) uniform shielding structure of straight wire (b) widening of holes and concentration of braid

Figure 9: effect of cable bending

Figure 10: different angles setting

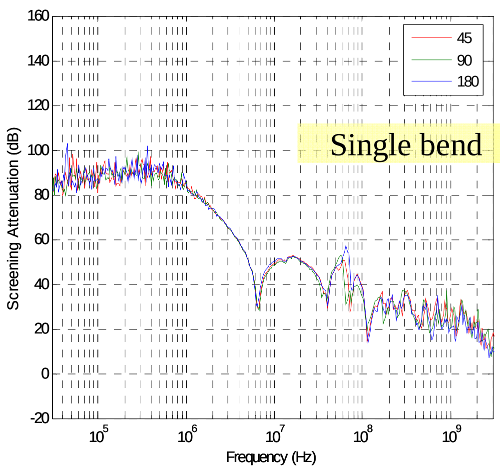


Figure 11: effect of different angles

If cable braided density is less than 60%, then there may be change in the result of screening attenuation under the same settings. On the basis of experimental results and logical consideration, however, there isn't the effect of cable compared to other factors when the cable has high braided density more than 60%.

3.3 Load variation

It shows that the different terminations induce different results. In the RF cable case, the 50ohm terminal resistance is used to test because it is fixed with circuit impedance, so it is good for use because there is no reflection. But in practical case, three phase power cables are connected to motor which has high impedance. Consequently there must be a high impedance termination. When the terminal impedance is low, the noise is made in magnetic field. Also when the termination is high impedance, the noise is chiefly made in electric field. This situation shows that it is needed to find out whether there is a difference in each terminations or not.

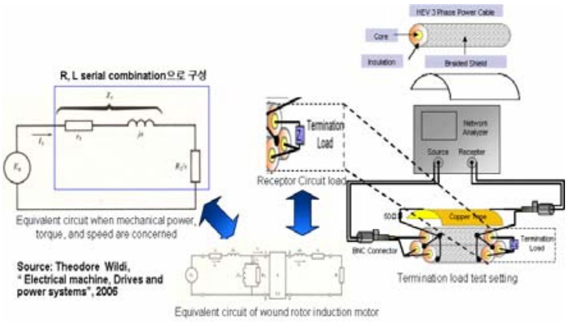


Figure 12: Comparison between termination load and motor impedance

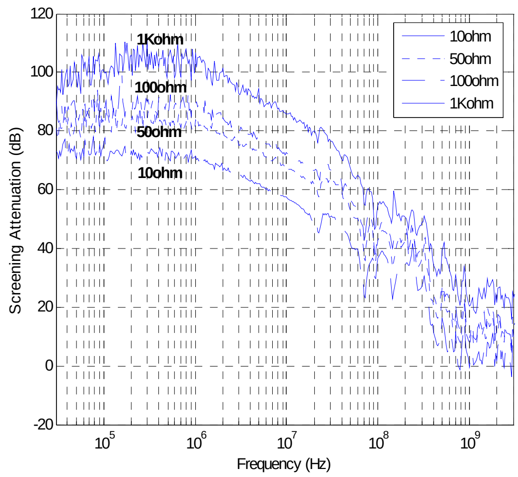


Figure 13: Different terminal loads

The result is showed in figure 13. The dotted line graph is for 50 ohm which is fixed with circuit impedance and other results are compared with it. And then it is easy to find that at the same frequency and the same terminal impedance. Therefore Larger the terminal impedance can make larger screening attenuation. Different load termination can be resulted differently more than 10dB in 30MHz region. Various loads experiments are important for three phase wire cable and it is also one of the advantages of PHSA method.

4 Conclusion

A new method for evaluating screening attenuation of power harness for HEV/FCEV which is called as PHSA is developed. The set-up, test procedure and effective variables are also introduced in this paper.

The followings are strong points of PHSA method.

1. It is available that the screening attenuation of the 3-phase power harness is evaluated using PHSA.
2. PHSA reflects real car conditions through testing effects of variables like a cable length, cable bending and terminal impedance.

The objective of PHSA method is measuring the shielding characteristic of not one wire and connector, but whole harness against magnetic and electric field. The experiment result shows the difference between one wire cable and three phase wire cable. It proves that PHSA method is corresponded with the purpose of this paper.

As the next steps of this research, to examine PHSA method, the test at real cars will be performed.

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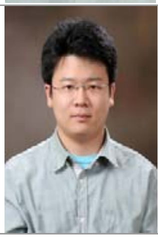

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