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Simulation of Conductive and Radiated Emission for Off and On-Board Radio Receivers according to CISPR 12 and 25

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Abstract

Two of the most commonly exercised standards for electromagnetic compatibility (EMC) by automotive engineers are CISPR 12 and CISPR 25. While CISPR 12 is imposed as a regulation to ensure uninterrupted communication for off-board receivers, CISPR 25 is often applied to ensure the quality of services of on-board receivers. Performing these tests becomes challenging until the vehicle is prototyped which may prolong the production time in case of failure or need for modification. However, conducting these tests in a simulation environment can offer more time and cost-efficient ways of analyzing the electromagnetic environment of automotive vehicles. In this paper, a computational approach is proposed in order to predict electromagnetic disturbance from on-board electronics/electrical systems using 3D computational electromagnetic (CEM) tool; Altair Feko. The presented study elaborates on radiated and conductive emission simulations performed for both vehicular and component/module level EMI testing according to CISPR 12 and 25. A high-frequency dynamic circuit network of a DC wiper motor is considered as a source of emission while different receiving antennas have been used according to regulation. A study is also conducted by analyzing effects of different types of cable harness on radiated and conducted emission.

Introduction

Today's automotive vehicles are technologically more equipped and offer a lot more features than what they used to do in the past. However, all these new features that provide safety and comfort come with a cost; vehicles became a very complex collection of a large variety of electronic systems. The complexity of these systems along with very short design cycles result in the concern of Electromagnetic Compatibility (EMC). It is very much desirable to predict any EMC issues in the early stages of development. In many cases, it is not possible to rely on the measurements to resolve complex EMC issues. Simulation is one of the attractive solutions to this dilemma, both in the aspects of cost and time effectiveness.

CISPR 12 is a regulatory standard established to protect off-board receivers such as television/radio broadcast in residential or commercial areas from EMI created by different electronic/electrical systems in a vehicle [1]. On the other hand, CISPR 25 is a general engineering standard practiced for maintaining the quality of services of on-board receivers from conducted and radiated emissions in both component and vehicular levels [2]. Both of the standards were developed and established by EMC regulatory committee named CISPR (International Special Committee on Radio Interference) which is a part of International Electrotechnical Commission (IEC)[3].

This paper elaborates methodologies of using computational electromagnetics tool; Altair Feko [4] in performing such tests in a simulation environment. The paper is organized into two parts; CISPR 25 and 12. While CISPR 25 consists both component/module level emission and vehicular level emission test simulation, section on CISPR 12 lays out a methodology of vehicular radiated emission test simulation for protecting off-board receivers. Characteristics used for DC motor, different cable types and receiving antennas are also discussed in respective sections. While a study on performances for different types of cables was done for component-level test simulation, different antenna placement scenarios were investigated for vehicular level emission test simulation.

CISPR 25: Component/ Module and Vehicular Level Emission Test Simulation

CISPR 25 standard applies to any electrical/electronic component that is intended to be used in a vehicle. Limits are established to protect receivers installed in a vehicle from EMI caused by components/modules in the same vehicle. CISPR 25 lays out the limits and methods of measurement for such scenarios in the frequency range from 150kHz - 2.5GHz. CISPR 25 can be divided into two main parts; component/module level and vehicle level testing. There are several important sections of the standard that need to be considered; such as antennas to be used for different frequency bands, their performance characteristics, test setup, ALSE (absorber lined shielded enclosure) characteristics and limits of different cases. In this section, a methodology of simulating tests according to CISPR 25 will be discussed through an example of emission caused by a two speed DC wiper motor placed near to rear windshield.

Modeling of Two Speed DC Wiper Motor

To ensure perfect compatibility of simulations with measurements conducted in a chamber, getting the impedance data of the two speed DC wiper motor (source of the emissions) would be optimum. For this study, a high frequency equivalent electrical circuit is used to represent the DC wiper motor [5]. The impedance of the motor simulated by Feko for the frequency range from 100kHz - 1GHz along with the equivalent circuit used is shown in Figure 1.

Component/Module Level Emission Test Simulation

CISPR 25 standard requires a test for both conducted emission and radiated emission for components/modules [2]. The standard also dictates the antenna types which should be used in radiated emission testing based on the frequency band. As this study is done for 30MHz-1GHz frequency range, Biconical antenna for 30MHz - 200MHz band and Log-periodic Dipole Array antenna for 200MHz - 1GHz frequency band were used as stipulated by CISPR 25.

FIGURE 1 Two speed DC Motor (a) Schematic (b) Impedance

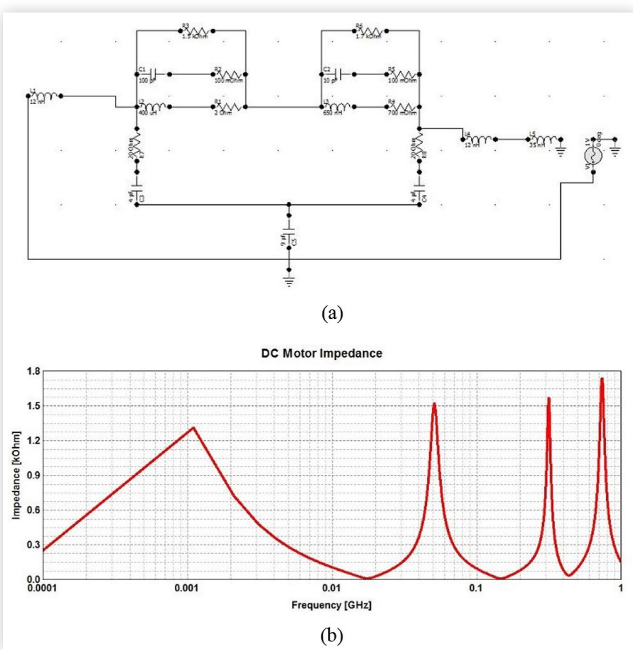
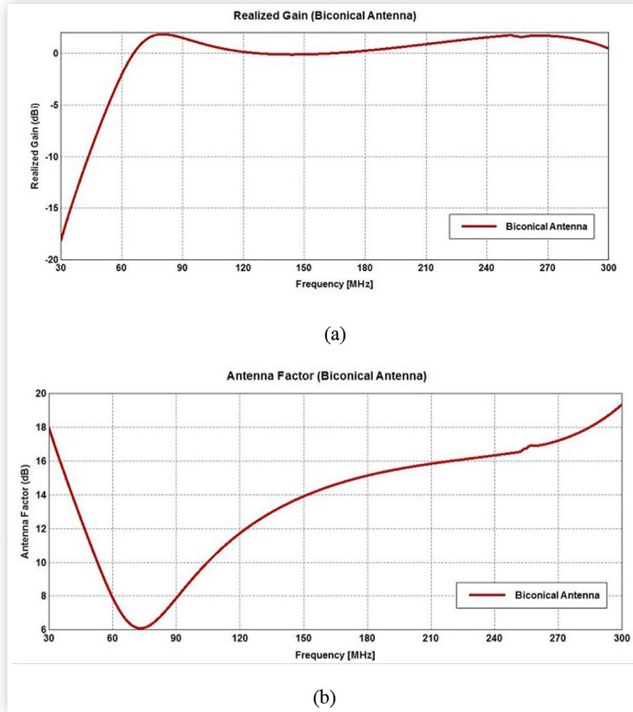


FIGURE 2 Biconical Antenna (a) Realized Gain (b) antenna factor



Antenna Types and Characteristics

A Biconical antenna was designed for the frequency band of 30MHz-300MHz and optimized to have 50Ω input impedance. Figures 2 shows the realized gain and antenna factor of the antenna. Antenna factor [7] was calculated by using the equation shown below,

$$FA = 20\log f - G_{dB} - 149.7 \qquad (7)$$

For the higher frequency band (200MHz - 1GHz), a log-periodic dipole array antenna with a square boom was designed. The input impedance for the designed antenna was optimized to 50Ω according to CISPR 25, while 54.51Ω was used as load impedance. The antenna performance realized gain characteristics and antenna factor are depicted in figure 3.

Radiated Emission Test Simulation

The simulation was set up according to the regulation in CISPR 25. The DC motor was connected to a 1.7m long cable harness; the simulation model was set up so that the horizontal cable line from both EUT and source is 100mm each in length and the distance covered by the cable harness from EUT and Source is 1.5m which sums up to a total cable length of 1.7m as per CISPR 25). According to the standard, 13.5V was fed via 50Ω LISN (Line Impedance Stabilizing Network) [5].

FIGURE 3 LPDA antenna (a) Realized gain (b) Antenna factor

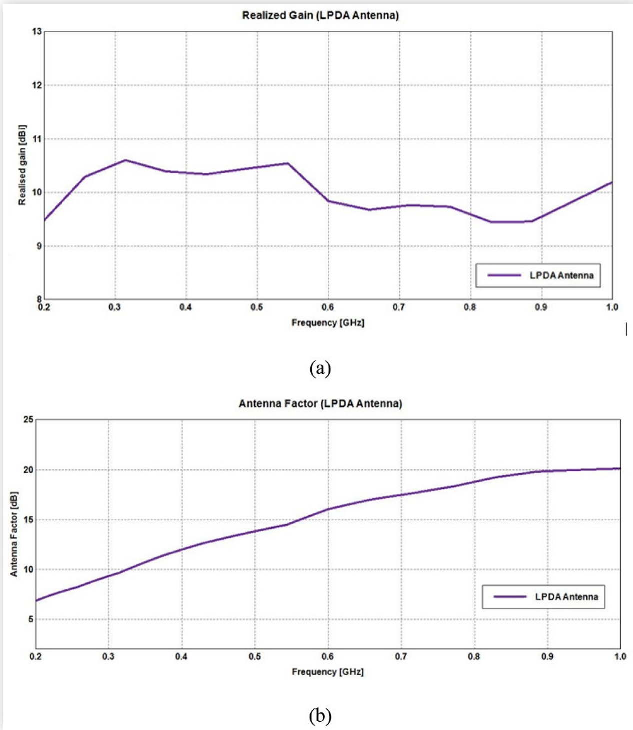
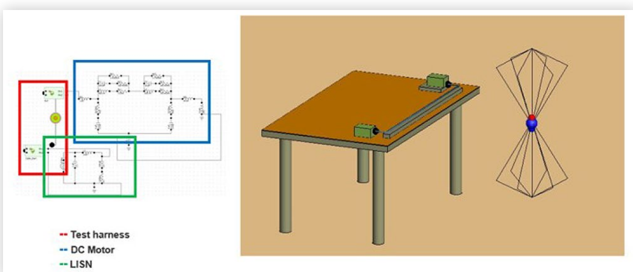


FIGURE 4 Simulation Setup for Radiate Emission (30MHz - 200MHz)



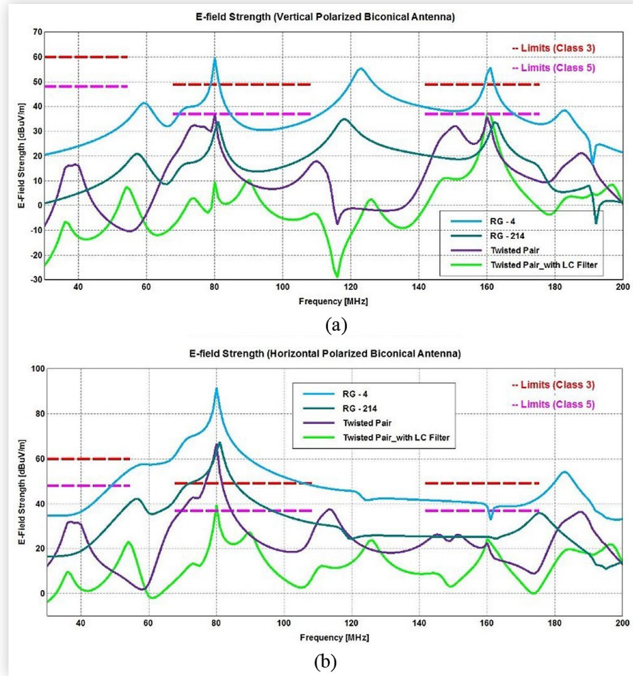
Antenna position and size of the ground plane were also modeled according to the standard.

To get an idea of how the type of cable impacts the emission, two types of cables (coaxial cable and twisted pair) were used, and the simulated results were compared for both vertical and horizontal antenna polarization. Additionally, a study was conducted to see how a change in the shielding of co-axial cable affects radiated emission. Also, to conclude the study a test was simulated using an LC filter connected to the motor along with twisted pair cable harness to reduce emissions.

Figure 4 shows the simulation set up and Figure 5 shows the simulated results for electric field strength received by a 50-Ω loaded Biconical antenna vertical and horizontal polarization.

From Figure 5, a comparison between different cable types can be realized. While using RG-4 coaxial cable which has less shielding does not pass the standard limits for class 3 in vertical polarization, using RG-214 with better shielding can easily pass the limits of class 5. Twisted pair cable can also be a better alternative as it caused a reduction in emission, slightly more than RG-214. However, for horizontal polarization, none of the choices seems to get through even class 3 limits. In that scenario, using an LC filter can be one of the options to suppress emissions.

FIGURE 5 Simulated E-field strength Received by Biconical Antenna (a) Vertical polarization (b) Horizontal Polarization



For a higher frequency band (200MHz - 1GHz), the same test set up and process were repeated with an LPDA antenna. E-field strengths received at a 50Ω antenna port were compared with each other and limits established by CISPR 25.

From Figure 6, a similar conclusion as that of the lower frequency band can be drawn. Better shielding for co-axial cable harness can reduce radiated emissions. However, for this band twisted pair does not suppress as much emission as it did for the lower frequency range. A further study can be conducted by importing different types of cable from Feko library. It is also possible to modify and/or configure cables and their shielding in Feko simulation environment to get better performance and meet the limits set by CISPR 25 standard. A similar simulation using untwisted unshielded pair cable will be presented at the conference.

Conducted Emission Test Simulation

The other part of the component/module level CISPR 25 establishes rules and limits for conducted emission. Such tests are conducted for lower frequency bands, 150kHz - 108MHz. Although both the current probe and voltage method can be simulated using Feko, in this paper, an example of

FIGURE 6 Simulated E-field Strength Received by LPDA Antenna (a) Vertical polarization (b) Horizontal Polarization

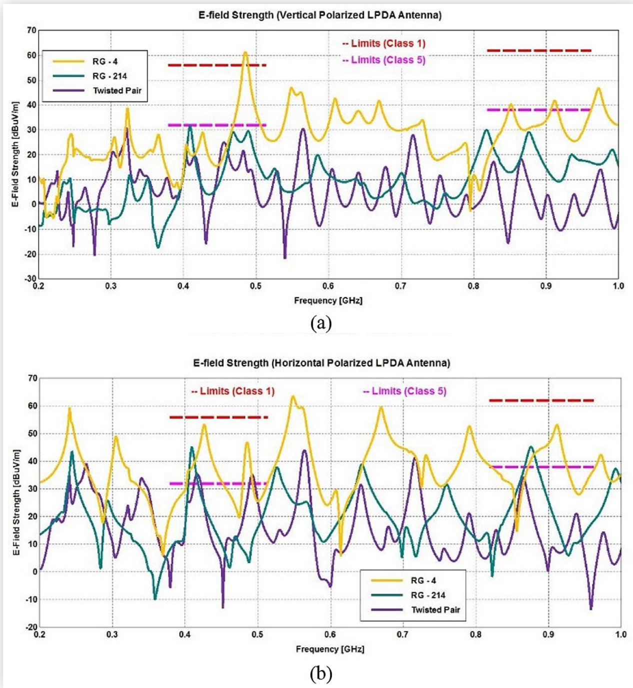
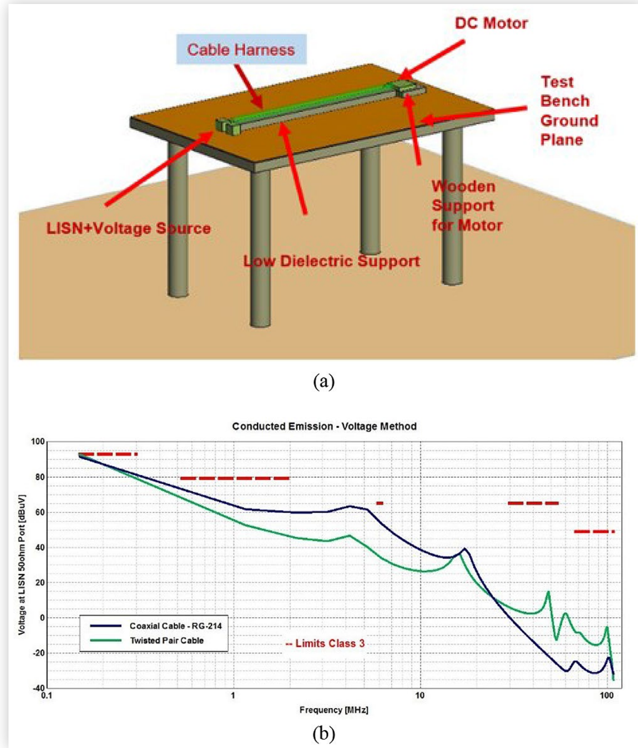


FIGURE 7 Conducted Emission Test Simulation (a) Simulation Setup (b) Received Voltage



conducted emission caused by DC motor using the Voltage method is demonstrated. 50Ω LISN was used to measure the voltage. The harness was placed 50mm above the ground plane and support was designed using low dielectric material (<1.4). Figure 10 shows the simulation set up and the received voltages at 50Ω LISN port.

It can be noticed from Figure 7 that twisted-pair cable caused fewer emissions below 25kHz. On the other hand, above 25kHz frequency, the coaxial cable (in this case RG - 214) seems to be a better fit. However, in both cases, the test passes through CISPR 25 Class 3 limits. Alternative options in the choice of cable can be simulated for further study to suppress emissions if needed.

Vehicular Radiated Emission

An automobile can have as much as 30 antennas mounted on its body and they are pivotal to ensure the quality of radio receptions. However, emissions from other on-board electronic/electrical systems can cause a high-level of electromagnetic interference by introducing noise into the antenna terminals. CISPR 25- Clause 5 establishes the rules, regulations, and limits to maintain acceptable quality from these radio receivers from on-board emissions [2]. For such vehicle level testing, it is highly recommended to use the supplied antenna with the vehicle as receiving terminal of emission. If no specific antenna is supplied, different types of monopole antennas can be used according to the specification requirements established by CISPR 25 [2].

For this study, 820 MHz - 960MHz UHF band has been considered and a quarter-wave monopole antenna (as listed in CISPR 25) was used as a measurement antenna [3]. Two different antenna placement scenarios have been considered to see how radiated emissions can affect the noise induced. An equivalent circuit of a 2-speed DC wiper motor was used as a source. Using Feko cable analysis tool [6], a cable harness was designed with a twisted pair cable to connect the voltage source located in the front side of the car to the wiper motor located near the rear windscreen. The test set up for both antenna placement scenarios is shown in Figure 8.

Received voltages due to radiated emissions from the cable harness at antenna terminal were compared (shown in figure 9) to see the effects of antenna placement scenarios. As can be seen from Figure 9, the radiated emission when the quarter-wave QW monopole is located closer to the motor (Placement 1) is larger than the QW monopole is located away from the motor (Placement 2).

Using Feko, different antenna placements scenarios can be easily evaluated. Using various asymptotic and full-wave

FIGURE 8 Vehicular Emission Test Set-up

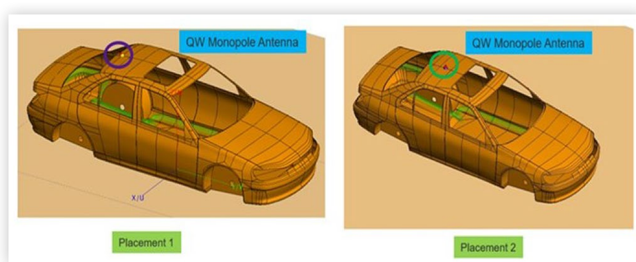
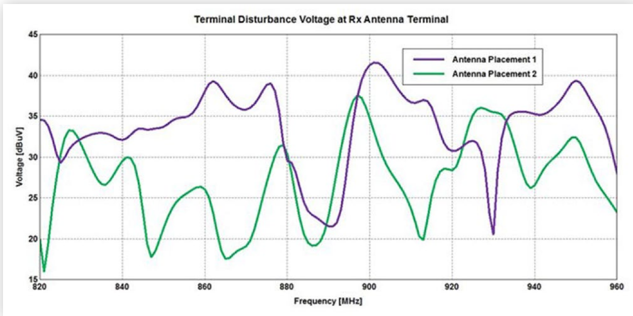


FIGURE 9 Emission Received by a QW Monopole Antenna on The Same Vehicle



solvers offered by Feko, an appropriate solver can be selected depending on simulation frequency and electrical size of the vehicle. The issue of vehicular emission for on-board receivers can be approached in two different ways. Further modifications in cable harness can be done using Feko cable analysis tool and the system can be modified to suppress radiated emission for the specific frequency band. On the other hand, antenna placement scenarios can be evaluated to get better radio reception. For a source, instead of an equivalent circuit, measured impedance can also be used in Feko to get realistic comparison to measurement results.

CISPR 12: Vehicular Radiated Emission Test Simulation to Protect Off-Board Receivers

As mentioned earlier, CISPR 12 is a regulatory standard established to protect off-board receivers such as television/radio broadcast in residential or commercial areas from EMI created by different electronic/electrical systems in a vehicle [1]. Several test methods have been elaborated in CISPR 12 for such testing; OTS (Open Test Site) and ALSE (Absorber Lines Shielded Enclosure) can be used as a test environment. In this study, ALSE method has been used to conduct emission test at 30MHz - 200MHz frequency band and a Biconical antenna was used as a receiving antenna according to CISPR 16 [2,5].

The simulation set up is shown in Figure 10, while the received E-field strengths for both vertical and horizontal polarizations of the biconical antenna are shown in Figure 11.

Two different methods can be followed for ALSE method; one where radiated emission will be measured at a 3m/10m distance by rotating the vehicle 360°, alternatively the measurement can be done by following the test set up depicted in Figure 10. An equivalent circuit of a 2-speed DC wiper motor was used as a source of emission [5].

E-field strengths were calculated at 50Ω Biconical antenna port located at 1.8m above the ground at 3m distance from the skin of the vehicle [1]. Further study can be conducted by changing cable types or introducing more insulators inside the vehicle. Considering different scenarios involving different

FIGURE 10 Simulation setup for CISPR 12- ALSE Method (a) Vertical polarization (b) Horizontal polarization

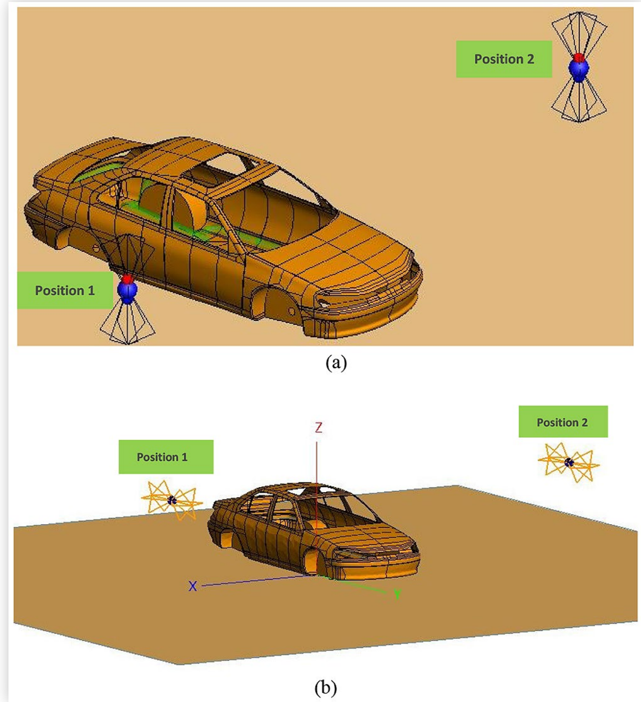
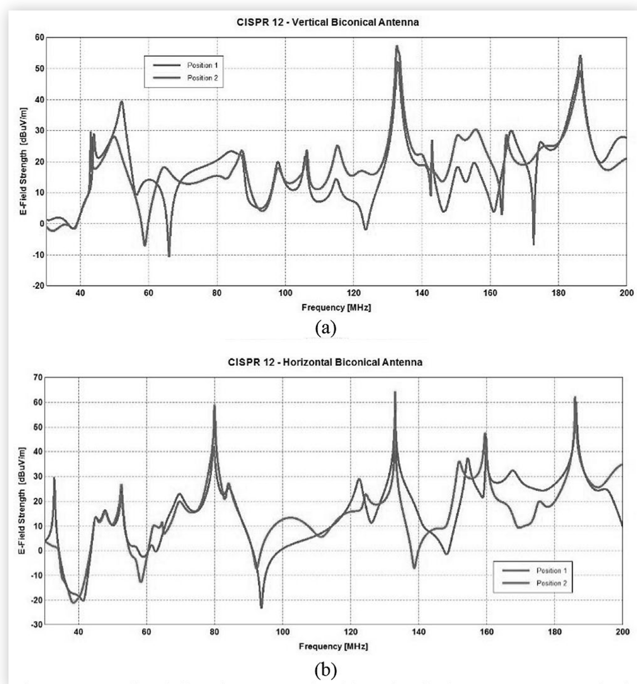


FIGURE 11 Radiated disturbances received by Biconical Antennas (a) Vertical polarization (b) Horizontal polarization



cable types, shielding material, and insulation, an efficient approach can be followed to choose the right type of cable taking into account the price, feasibility and of course anticipated radiation characteristics. Also, the vehicle can be rotated 360° using a parametric study to simulate such a test

Conclusions

In this paper, CISPR 12 and 25 regulated vehicular and component level emission test has been simulated for a two-speed wiper DC motor to demonstrate the advantage of using 3D CEM tools. A complete solution of such testing can be simulated using a 3D CEM tool, in here Altair Feko, starting from antenna designs, meeting requirements for such testing environment, etc. Although an equivalent circuit of DC motor was used in this study, measured impedance data of any type of component can be imported and used as a source. Examples have been used to demonstrate these test methods using simulations. A study on how the shielding and cable type can be a prominent aspect of emission suppression was also discussed. Different types of cables were imported from Feko cable library to study the effect of cable type and shielding on radiated and conducted emission. On the other hand, different antenna placement scenarios were also evaluated in order to explore the effects of antenna placement not only for better antenna performance, also for compliance testing.

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