EMC improvement of CAN bus in automotive bus

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Abstract. With the increase in the car above the electronic products, automotive interior complex and a wide range of electrical systems will produce all kinds of magnetic field, from the cause of EMC problems, from the perspective of traffic safety considerations, with the increase of automotive electronic components and lead to an increase in the complexity of the system, in order to eliminate all kinds of such electromagnetic fields, it will increase the cost of all kinds of unnecessary. The content of this paper is to improve the electromagnetic compatibility and working stability of the CAN bus in the automotive network system by improving the design of the system and routing rules.

1. Introduction

With the development of the times and the progress of science and technology, the objects that are closely related to our daily life have changed from the original single function to contain multiple scientific and technological functions. The same is true of cars, which are indispensable in People's Daily life. From the first steam locomotives to today's internal-combustion powered cars and electric cars powered by electricity. With the development of automobile technology and the increase of people's demands for various aspects of automobiles, for example: safety, comfort, functionality and so on[1]. It is these increasing demands that have led to the increasing number and complexity of electronic devices used in cars.

With the continuous update and development of computer technology, automation technology and electronic control technology, more and more electronic devices are used in automobiles[2]. Today, more than a third of the cost of a typical car is spent on electronic components. The development and large-scale application of automotive electronics technology to automobiles began in the 1970s, from the beginning of a low starting point, less technical content of the components to later with a certain amount of technical content and functional development, for example: anti-lock braking (ABS) technology and electronic gasoline injection technology, electronic technology used in the design of the car and became dominant control technology. But, the combination of the two technologies is not ideal at this stage.

Until later, the application of microcomputers on the car has become more mature, and has a certain level of intelligent automation, this time the car above the modules began to use the field bus communication and integrated into the driving computer (ECU), at this time, the car modules can communicate with each other, constitutes an on-board network system. There are many field buses used in automotive in-vehicle network systems, such as the famous CAN bus, LIN bus, FlexRay bus.
and so on, because of its transmission speed and good working stability, CAN bus is widely used in various control areas of automobile.

Based on the automotive electronic technology, this paper studies the electromagnetic compatibility of automotive CAN bus in the process of automobile operation, and discusses from the following aspects: firstly, it explains the relevant definitions and concepts of electromagnetic compatibility; Secondly, CAN bus signal simulation analysis is carried out to simulate various complex electromagnetic interference signals in the process of vehicle operation, and signal integrity analysis is carried out. Finally, based on the problem that can be interfered by automotive power frequency electromagnetic field, some methods are found to improve the end performance of the CAN bus. The main test contents include the analysis of the transmission signal integrity in the communication process of CAN bus, the superposition of on-board interference sources similar to those in the running process of cars onto CAN bus through simulation, and the use of oscilloscope to measure and compare the waveforms of transmitted data. Through the comparison of waveforms, the shortcomings are gradually improved. The test results show that the method proposed in this paper has very good effect and CAN bus anti-interference ability is improved obviously.

2. Introduction to relevant basic knowledge

2.1. Electromagnetic compatibility analysis

Electromagnetic compatibility, (English name: EMC) in the design of electronic products, electromagnetic compatibility is an important indicator of radio, electronic, electrical equipment or system.

The performance of the system is a direct result of the normal and stable operation. Electromagnetic compatibility for the system, is to achieve its performance index guarantee; for products, the eye test is the entry permit to the market. At present, various electronic industries have higher and higher requirements for EMC. Electromagnetic compatibility of electronic products has been the object of mandatory restrictions in the international community, making electromagnetic compatibility performance an important indicator of product performance[3]. This caused the designer to pay enough attention when the product designs. Electromagnetic compatibility (EMC) relates to the ability of a product and other products to coexist in a specific electromagnetic environment without causing degradation or damage to other products or their performance [8]. Second, anti-interference, namely electromagnetic harassment and electromagnetic sensitivity. Three elements of electromagnetic compatibility: (1) there is a certain noise source; (2) the existence of sensitive equipment susceptible to interference; (3) there are interference transmission routes, and none of the three is indispensable.

Electromagnetic interference can be transmitted through wires, that is, it can directly invade sensitive devices through power lines, communication lines and signal lines of electronic devices, which are called conductive interference[9]. The electric and magnetic fields around the interference source will interfere with the sensitive devices near the electronic devices, which are called near-field coupling interference. At the same time, the interference will spread to the distant space in the form of electromagnetic wave. Thus affecting the work of the distant sensitive equipment. This way is known as far-field radiation interference. Essentially, electromagnetic interference can be coupled in two ways: by conducting through wires and by radiating through space. According to the coupling results, the interference is structured in common mode interference and differential mode interference. Interference current can be forwarded on a wire in two ways: common mode interference and differential mode interference[10]. Interference current forms an equal and opposite current on the wire, which is called the differential mode current, while the interference current forms an equal and opposite current on the wire, which is called the common mode current. Common-mode interference exists between all signal lines (including signal lines, data lines, power lines, etc.) and ground lines, while differential mode interference exists between signal lines.
Measures to improve electromagnetic compatibility commonly include filtering, shielding, and optimizing wiring. In addition, EMC performance of electronic equipment is improved, and filtering technology is adopted to suppress conduction coupling, etc. [10].

2.2. Can bus
In the late 1980s, CAN (Control Area Network) bus was jointly developed by German and American companies and became the international standard ISO11898 in 1993. It is designed to save a lot of on-board equipment cabling with multi-point, serial digital communication technology instead of conventional direct wire signal connection. Because of many advantages of the CAN bus, such as high cost performance, wide application (mainly reflected in the chip application), and protocol refinement, it has quickly gained favor in the field of industrial measurement and control and automotive electronics. However, electromagnetic interference has grown up to be a serious problem due to the harsh industrial environment in and around the operation of automobiles. Therefore, how to ensure the reliability of CAN bus communication is of particular importance.

2.3. Interference sources in automobiles
Automobile internal electromagnetic interference mainly from the following aspects: the power supply system, engine ignition system and instrument system of actuators, the control system of actuators, etc., the spectrum of interference signals is generally between 105 and 109Hz [3], and in the frequency signal of vehicle CAN bus communication produces because of the interference caused by engine ignition system. Generally, the ignition system is adopted in the state of pulse ignition. We can decompose the ignition pulse into multiple frequency components by using of Fourier series. Under the action of the higher frequency components in these harmonics, the ignition coil will generate high-frequency electromagnetic radiation. Thus forming interference [9]. We may make such equivalent: namely, the equivalent switching capacitors with shell, and the center of the spark plug electrode for high frequency pulse ignition are the inductor, capacitor and the overall form a LC circuit in parallel, so it will be a harmonic of ignition pulse forming high frequency oscillation (frequency values of L and C work together), external radiation of electromagnetic wave. In addition to the above analysis, from the engine ECU ignition pulse output to the ignition coil and ignition coil to the spark plug between the high voltage wires can radiate electromagnetic waves, the longer the connection wire spark duration is longer, the more automobile engine cylinder, the higher the engine speed, the more sparks there are, the stronger the emi.

Second, other factors can also develop varying degrees of electromagnetic interference, for example: automotive relays, solenoid valves, contacts and voltage regulators. The main source of interference is the relay, electromagnetic valve action produced by the spark. The interference caused by them will directly affect the normal operation of the ECU.

In addition to the interference mentioned above, there is another interference that can be overlooked is the interference of various motors inside the car. The function of motor in modern automobile is mainly to complete the execution of various electric functions, which are often said to be the actuator. Motor in the car includes: generator, starter, wiper motor, electric door and window motor, ventilation motor, warm air motor and so on [11]. These motors have their own functions, at the same time distributed in different parts of the car, some use silicon rectified ac motors, some use direct current motors with commutator, these motors will produce a strong spark between the carbon brush and commutator, can produce electromagnetic interference in a wide range of frequencies. If these motors have poor contact, damaged insulation layer and shaft deviation, etc., the generated electromagnetic interference will increase greatly [11].

2.4. Experimental simulation observation
By simulating the interference signal generated by the spectrum from 105 to 109Hz, it is applied to the CAN bus, and by observing and comparing the waveforms of the signal transmitted when there are interference sources and non-interference sources, the signal integrity analysis is done, As can be seen
from figures 1 to 6, we can see that Signals of different frequencies have different effects on our CAN bus data transmission. The figure 7 is a comparison diagram.

Fig. 1. Standard transmission signal                           Fig.2. 500KHz interference signal

Fig.3. 50Hz interference signal                           Fig.4. 500MHz interference signal

Fig.5. Yellow is a shield                                    Fig.6. Green is unshielded

Fig.7. Contrast figure

(Yellow is the data measured by the special transmission line, while green is the waveform measured by the general conductor)

Through these observations, attempts to add some shielding have improved the effect. Improvement method 1: metal shell is used as shielding cover for the circuit related to the CAN bus. After the shielding cover is applied, the observation of waveform shows that the interference is reduced a lot. Improvement method 2: replace the ordinary transmission line with a dedicated transmission line, after using the dedicated shielding line, the interference is reduced a lot. Improvement method 3: use special connector to connect at the connector to reduce interference.

3. Analysis of experimental results
Through the simulation experiment, we find that the interference of electromagnetic interference on vehicle electronic equipment, especially the interference of CAN bus, CAN not be ignored, no matter it is internal interference or external interference, and these electromagnetic interference will seriously affect the accuracy and reliability of the communication data transmission of the vehicle network system. If there is an error in the transmission of data, it will cause unnecessary trouble or even an accident. Therefore, in order to ensure the normal operation of automotive electronic devices, some technologies are more or less adopted in automobiles at present, that is, some anti-interference methods are adopted to ensure the data transmitted by CAN bus of automobiles are more accurate and have more guiding significance.

In order to make the system free from internal and external electromagnetic interference, anti-interference measures must be taken. The second is to cut off or destroy the coupling channel between the noise source and the disturbed equipment; The third is to strengthen the ability of the disturbed equipment to resist electromagnetic interference and reduce its sensitivity to interference.

3.1. Methods to prevent signal sentry

(1) The related circuit modules are shielded by metal shell.
(2) Replace the normal transmission line with a dedicated transmission line.
(3) Use a dedicated connector at the connector to connect.

3.2. Methods to eliminate interference sources

3.2.1. Modularization of circuit design
In the circuit board design, reasonable wiring is one of the important contents of anti-interference technology. According to the performance of the automobile circuit and its position and function, the most basic types of circuits in the automobile can be designed separately to form different circuit modules. The advantage of this method is that the power supply and connection of different modules can be separated, the lead can be shortened, the inductance value can be reduced, the undeserved coupling can be reduced, and the insulation impedance can be increased. The mounting position of circuit components on the circuit board is arranged in a straight line according to the transmission sequence of signals, that is, the order from input to output. Arrange them as neatly as possible and do not mix them so as to prevent parasitic coupling, mutual interference and self-excited oscillation.

3.2.2. Damping resistance
How to dilute the electromagnetic interference caused by the spark? In the high voltage circuit of the ignition device, the damping resistance can be serialized. The larger the damping resistance, the better the suppression effect. However, the damping resistance should not be infinite, which will bring another problem, that is, reducing the spark energy between spark plug electrodes, which will affect the ignition effect. Therefore, size of damping resistance should be reasonably selected, and the resistance value is about 10-20k. Add to the ignition coil end and spark plug connector end. Materials are generally made of carbonaceous materials.

3.2.3. Metal mask
Metal shield is another kind of more effective means to suppress interference, for the part of the automotive equipment that can produce electromagnetic wave to use metal shield, material can choose copper, aluminum, steel and other materials with high conductivity, can achieve the effect of anti-interference.

3.2.4. Reduce related interference in PCB wiring process
In the PCB wiring process, through reasonable wiring, can reduce a lot of interference. First, by using the ground wire to surround the crystal oscillator, the clock circuit can reduce the interference to the
surrounding signal. Second, avoid 90 degrees fold line when wiring, reduces high frequency noise emission.

4. Conclusion
In this paper, the electromagnetic performance of CAN bus in automotive network system under automotive power frequency electromagnetic field is studied. When data transmission and communication are conducted by CAN bus in simulated automobile, electromagnetic interference sources similar to those in automobile operation are generated through simulation to simulate the environment similar to that in automobile operation. Then, CAN bus is exposed to such an environment for communication, and the transmission waveform is monitored by oscilloscope. Several methods are proposed to increase the electromagnetic compatibility and anti-electromagnetic interference capability of CAN bus network under the automobile power frequency electromagnetic field. Experiments show that these methods are effective, CAN very good shielding electromagnetic interference in the working process of the automobile, effectively improve the CAN bus network of electromagnetic compatibility, by adding a small amount of hardware cost, achieve the goal of the CAN bus CAN increase the electromagnetic compatibility, makes the vehicle CAN bus communication more reliable, stable, greatly improve the safety performance of the car, These methods can also be applied to the situation with fieldbus.

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