Electromagnetic Compatibility Testing and Rectification Analysis of Beidou Shipborne Terminal System

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Abstract: The Beidou shipborne terminal is mainly composed of two parts: the antenna and the chart display and control terminal. Its circuit includes both the transmitting part and the receiving part, which is prone to electromagnetic compatibility problems. Due to the increasingly complex electromagnetic environment of the actual working environment, the Beidou shipboard terminal must meet the electromagnetic compatibility requirements in order to ensure its safety and stability during work. This paper introduces the electromagnetic compatibility test standards and methods of Beidou shipborne terminals, and studies the path of rectification, which is of great significance and application value to the research of electromagnetic compatibility of Beidou navigation series products.

1 INTRODUCTION

With the globalization of the economy and the development of world trade, maritime shipping has become increasingly popular. In order to obtain the position information, shipping status information, route information, etc. of shipping ships in real time and effectively, large shipping companies have invested a lot of manpower and material resources to develop ship remote control systems, thereby improving the accuracy and efficiency of shipping logistics monitoring(Xie Dinglong, 2020).

The Beidou satellite navigation system is a satellite navigation system independently developed by my country. It has been applied in many fields and played an important role, including: communications, water, disaster reduction, maritime affairs, marine fisheries, transportation, exploration, forest fire prevention, etc.(Lao Ji-Ding Chen). The Beidou shipborne terminal system is a marine communication and navigation equipment that uses satellite positioning technology, wireless network technology and other real-time positioning, tracking, and remote dispatching of ships on the move (Wang Ershen, 2008). Its electromagnetic compatibility performance is closely related to the safe driving of the ship.

2 THE NECESSITY OF ELECTROMAGNETIC COMPATIBILITY TESTING OF BEIDOU SHIPBORNE TERMINAL SYSTEM

The electromagnetic compatibility design of the system means that each device in the same electromagnetic environment will not cause performance degradation due to electromagnetic emissions from other devices, and at the same time, it will not cause other devices in the same electromagnetic environment to suffer from electromagnetic emissions from this device. Use performance degradation, even can not be used (Ogunsola A, 2003). In order to ensure that the shipborne terminal system will neither affect the normal operation of other equipment on the ship nor reduce its performance due to external interference when in use, it is particularly important to conduct electromagnetic compatibility performance testing of the Beidou shipborne terminal system in the development stage.

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3 ELECTROMAGNETIC COMPATIBILITY TEST ITEMS

The IEC 60945 standard is a test method for general requirements for maritime navigation and radio communication equipment and systems. It involves ship electrical, navigation, integrated navigation equipment, navigation equipment, and ship communication equipment. Therefore, the test requirements of this standard are selected for the Beidou shipborne terminal system. EMC testing. The electromagnetic compatibility of the Beidou shipboard terminal system is divided into two parts: one is the self-compatibility of the Beidou shipboard terminal system; the other is the electromagnetic compatibility between the Beidou shipboard terminal system and other equipment in the same environment. The testing items should include the launch part and the immunity part of the Beidou shipborne terminal system (Wang Shuping, 2012).

3.1 Electromagnetic Emission Test Items

In order to examine whether the external radiation disturbance generated by the Beidou shipborne terminal system when it is working meets the test limit requirements, it is necessary to test the external emission value of the Beidou shipborne terminal system. This test differs from antenna emissions not interfering with other equipment on board. During normal use, the equipment will not affect other equipment or systems in the same environment., such as a radio receiver. When its emission value is within the limits specified in the standard, it means that the Beidou shipborne terminal system meets the requirements. The table 1 shows specific test limits.

Table 1: Beidou Shipborne Terminal System Radiated Emission Test Limits.

Frequency Range (MHz)	QP limit（dBμV/m）
0.15-0.3	80-52
0.3-30	52-34
30-2000	54
156-165	24(QP) or 32（PK）
The lower limit should apply at transition frequencies (0.3MHz and 30MHz) and in the frequency range 156 MHz -165 MHz.	

3.2 Conducted Disturbance Test Items

In order to test any signal generated by the Beidou shipboard terminal system, such as the signal appearing on its power port. The signal is conducted into the ship's power supply, potentially disturbing other equipment. It is necessary to test whether the conducted disturbance generated by the Beidou shipboard terminal system meets the test limit requirements. If the disturbance exceeds the limit value, it may be conducted in the ship power supply system, which may affect the normal operation of other equipment. The table 2 shows specific test limits.

Table 2: Beidou shipborne terminal system conducted emission test limits.

Frequency Range (MHz)	QP limit value（dBμV）
0.01-0.15	96-50
0.15-0.35	60-50
0.35-30	50
At the transition frequency (0.15MHz) a lower limit should be used	

Table 3: List of Beidou Shipborne Terminal System Immunity Test Projects.

Test Items	Portable	Protected	Exposed	Underwater	Test purposes
Conducted RFI		150kHz-80MHz：3Vr.m.s. e.m.f. At a specific frequency point (refer to 6.4 requirement b)：10Vr.m.s. e.m.f. AC and DC power ports, signal and control ports, common mode performance criterion A			Evaluate the effect on equipment of conducted disturbance signals induced by electromagnetic radiation.
Radiation Interference	shell port：80MHz-2GHz 10V/m Performance criterion A			/	Evaluate the impact of radiated disturbance signals induced by electromagnetic radiation on equipment.
Fast transient (pulse group)		AC Port: 2kV Signal and control ports:1kV Performance criterion B			Evaluate the impact of fast transient pulse bursts (such as switching off inductive loads, relay shock bounce, etc.) on equipment.
Slow Transient (surge)		AC power port：Line to ground 1kV，Line to line 0.5kVPer formance criterion B			Assess the impact of equipment exposed to lightning surges.
Short term change in power supply		AC power port:±20%V 1.5s, ±10% Frequency 5s Performance criterion B			Evaluate the effects of equipment when subjected to short-term changes in power.
Power Outage		AC and DC power ports：60s Interrupt Performance criterion C			Assess the impact of equipment experiencing a power outage.
Electrostatic Discharge	6kV Contact Discharge 8kv Air Discharge Performance Criterion B			/	Evaluate the effects of equipment when subjected to electrostatic discharges directly from the operator and its operator to adjacent objects.

3.3 Electromagnetic Immunity Testing Project

The anti-interference ability of the Beidou shipborne terminal system to external emission values should be considered from the following aspects, including the radiation signal effect of the ship's transmitter antenna, direct or induced signals in the connecting cable, and sinusoidal and instantaneous signals caused by the ship's power supply or electrostatic discharge. State interference effect, etc. The different types of immunity test items and purposes that need to be completed by the Beidou shipborne terminal system are shown in Table 3.

4 ELECTROMAGNETIC COMPATIBILITY TEST RECTIFICATION ANALYSIS

The Beidou shipborne terminal system under development can find out through testing the parts of the electromagnetic compatibility performance of the designed product that need to be improved.

4.1 Analysis of the Generation and Transmission Pathways of Electromagnetic Interference

The generation of electromagnetic interference must have three elements, namely interference source, interference propagation path and sensitive equipment, as shown in Figure 1.

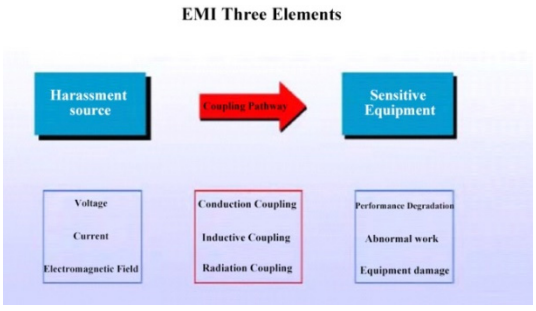

Figure 1: Electromagnetic Interference Propagation Path.

Interference sources are divided into natural interference sources and man-made interference sources according to the interference form. According to the source, it can be divided into internal interference and external interference. It can be seen that to improve the electromagnetic compatibility performance of the product, one of the three elements of electromagnetic interference must be eliminated, and the interference will be suppressed (James Colotti, 2006).

The Beidou shipborne terminal system has the following common interference sources:

1) Radio interference sources
2) Interference sources formed by circuit ports or interfaces, voltage or current changes
3) Interference of gas discharge on the system
4) Interference caused by external emissions from the internal modules of the Beidou shipborne terminal system

According to the above interference sources, the propagation paths of the analysis interference mainly include the following types:

1) radiation coupling
2) Conductive coupling
3) common impedance coupling
4) Line-to-line inductive coupling (Wang Ershen, 2008).

4.2 Analysis and Verification of Beidou Shipborne System Conducted Disturbance Test

In the working mode of the Beidou shipborne terminal system, the position data collected by the antenna is mainly transmitted to the signal receiving encoding module. The signal receiving encoding module decodes the received signal, and the decoded data is transmitted to the signal processing module. The final processed data is transmitted to the electronic chart display and control terminal and displayed to the user through the screen.

The Beidou shipborne terminal system was tested for the first time without any processing, as shown in Figure 2. The test chart is shown in Figure 3, (0.5 ~ 2) MHz range exceeds the standard seriously.

Figure 2: Beidou shipborne terminal system conducted disturbance test layout diagram.

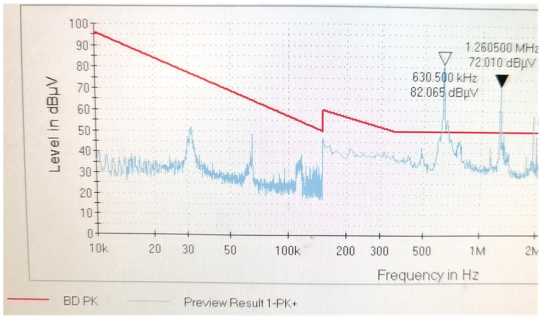

Figure 3: The frequency spectrum of the conducted disturbance test of the Beidou shipborne terminal system exceeding the standard

By observing the spectrum diagram, it is found that the signal frequency in the spectrum shows a certain pattern, which is manifested in the fundamental frequency of 0.63MHz and its multiples. After analysis, the antenna and electronic chart display and control terminal are potential sources of electromagnetic interference. A step-by-step investigation was carried out for further positioning.

First, after turning off the electronic chart display and control terminal, we tried to reduce the external conduction disturbance of the electronic equipment. The excessive part of the disturbance changed slightly, but there was no significant improvement. After further investigation, the spectrum obtained after turning off the antenna power was shown in Figure 4.

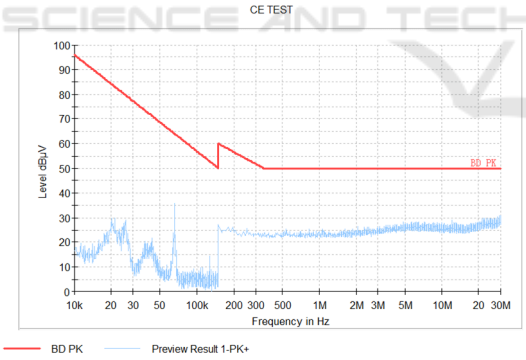

Figure 4: Spectrum diagram of the conducted disturbance test of the Beidou shipboard terminal system (turn off the antenna power supply).

After the antenna power is turned off, the portion exceeding the standard (0.5~2) MHz decreases significantly. After analysis, the antenna power supply is likely to generate (0.5-2) MHz frequency conduction disturbance. In order to reduce the disturbance and make the product meet the standard requirements, as shown in Figure 5, add magnetic rings at both ends of the power line to increase the impedance of the common-mode current and suppress the common-mode current. The effect of current and the conduction disturbance generated by it is obvious.

Figure 5: Electromagnetic compatibility rectification method-adding magnetic ring.

In order to more significantly reduce the disturbance value, a magnetic ring and filter are added to the antenna power supply. The test results are shown in Figures 6 and 7. It can be seen from the test chart that excessive conductive disturbance is well suppressed.

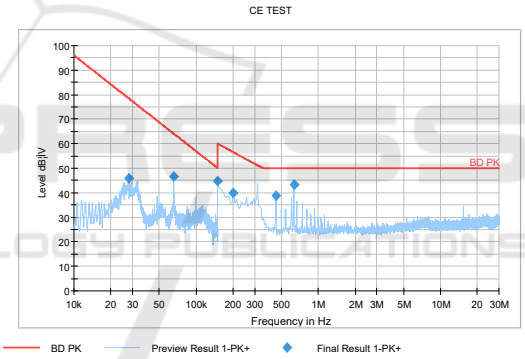

Figure 6: Conducted disturbance test power supply positive spectrum.

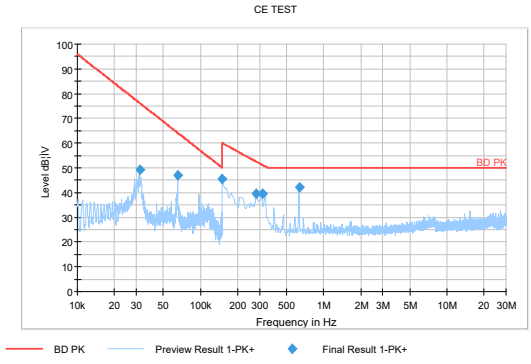

Figure 7: Negative spectrum diagram of conducted disturbance test power supply.

5 CONCLUSION

During the research and development stage of the Beidou shipborne terminal system, there are often phenomena that the products do not meet the standards. The conventional rectification methods include grounding, electromagnetic shielding and adding filters. When encountering the phenomenon that the electromagnetic compatibility test of the product does not meet the standards, such as conductive harassment exceeding the standard, you can check the addition or deletion of the components one by one through the on/off status of the plugged and unplugged components. Combined with the circuit characteristics and device characteristics of the system, the spectrum can be analyzed and rectified. , gradually find the emission source and rectification path. With the rapid development of the shipbuilding industry, more and more electrical and electronic devices are equipped on modern ships, and they are becoming more and more intelligent and complex. The space where the PCB is located is relatively small, and these devices will interact with each other. Cause electromagnetic interference (Rajeshwar K, 2005). Practice has shown that the electromagnetic compatibility design and PCB design issues of the Beidou shipborne terminal system circuit are also very important for system performance. It not only affects the operating performance of the equipment, but also causes serious accidents (Wang Bingqie, 2006), and the wiring strategy, integrated chip decoupling, Shielding, software anti-interference and other methods can improve the anti-interference ability of the system. The electromagnetic compatibility detection and rectification of the Beidou shipborne terminal system studied in this article is of great significance to the improvement of the quality of Beidou marine equipment developed with independent intellectual property rights and the development of the marine electronics industry.

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