

Cost-effectiveness Analysis and Application Prospects of Anti-Magnetic Interference Technology in Mobile Terminal Devices

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Abstract: With the rapid development of the smartphone market, the demand for advanced camera functionalities is increasingly growing. Among them, the anti-magnetic interference and image stabilization capabilities of voice coil motors have become key technologies to enhance the performance of smartphone cameras. This study delves into the application of anti-magnetic interference technology in mobile terminal devices, focusing on its cost-effectiveness and future application prospects. By adopting an improved suspension soft connection design, simplifying production processes, and optimizing motor structure, not only has the camera motor's resistance to magnetic interference and stability been significantly enhanced, but production costs have also been substantially reduced. The study indicates that the application of this new type of anti-magnetic interference and image stabilization motor can effectively reduce external interference, improve camera image quality, and lower production costs, demonstrating clear economic and social benefits.

1. Introduction

With the rapid development of smartphones and mobile internet, advanced camera functionalities have become one of the key considerations for consumers purchasing phones. The voice coil motor, as the core component for achieving automatic focusing and optical image stabilization in smartphone cameras, directly affects the imaging quality of the camera. However, in the complex environment of multi-camera systems, electromagnetic interference has become a major challenge limiting the improvement of camera performance. This paper delves into the application of

anti-magnetic interference technology in mobile terminal devices, exploring its tremendous potential in optimizing motor performance and reducing production costs. The study finds that through technological innovation and process optimization, it is not only possible to significantly enhance the motor's resistance to magnetic interference but also to reduce production costs, thereby achieving a win-win situation for economic and social benefits while increasing product competitiveness. This holds important implications and guidance not only for smartphone manufacturers but also for the entire electronics manufacturing industry.

2. The Impact of Electromagnetic Interference on the Performance of Smartphone Cameras

2.1 Concept and Sources of Electromagnetic Interference

Electromagnetic Interference (EMI) is a phenomenon in the electromagnetic environment, referring to any electromagnetic process, device, or phenomenon that may disrupt the normal operation of equipment or systems, reduce their performance, or even lead to equipment damage. In the field of smartphones, with the development of technology and the increase in applications, the issue of electromagnetic interference has become increasingly prominent. The sources of electromagnetic interference mainly include internal systems such as the multi-camera system, wireless signal transmission and reception, power management systems, as well as external environmental electromagnetic radiation.

(1) Impact of Internal Electromagnetic Interference

The internal electromagnetic interference in smartphones primarily originates from the device's own multiple electronic components and circuits [1]. For instance, each camera motor (such as a voice coil motor) in the multi-camera system generates an electromagnetic field during operation. These electromagnetic fields interfere with each other, potentially affecting the camera's autofocus and optical image stabilization functions, thus degrading image quality. At the same time, electromagnetic interference generated by the phone's wireless communication modules (such as Wi-Fi, Bluetooth, 5G) while transmitting data further impacts camera performance.

(2) Impact of External Electromagnetic Interference

In addition to internal sources, smartphones are also affected by the external electromagnetic environment. Sources of external electromagnetic interference include, but are not limited to, the operation of other electronic devices, high-voltage power lines, radar systems, etc. These external electromagnetic waves may enter the smartphone through space coupling, disrupting the normal operation of the camera, leading to image blurring, color distortion, and other issues [2].

2.2 The Specific Impacts of Electromagnetic Interference on Camera Performance

The impact of electromagnetic interference on smartphone cameras mainly manifests in the decline of autofocus (AF) performance, instability of optical image stabilization (OIS) functions, and the overall reduction in image quality [3].

(1) Impact on Autofocus Performance

Autofocus is one of the core functionalities of smartphone cameras, relying on precise motor driving and control systems. Electromagnetic interference disrupts the normal operation of the voice coil motor (VCM), leading to slower focus speeds, reduced focusing accuracy, and even instances of failure to focus. This impact is particularly noticeable when photographing fast-moving objects or in low-light environments.

(2) Impact on Optical Image Stabilization Function

The optical image stabilization (OIS) function compensates for hand shake by physically moving the camera's lens assembly, ensuring clear and stable images. Electromagnetic interference affects

the sensors and motors within the OIS system, causing the stabilization function to fail, resulting in blurred photos and videos, especially in long focal length photography or low light conditions.

2.3 Case Analysis and Solution Strategies for Electromagnetic Interference

In response to the impact of electromagnetic interference on smartphone camera performance, the industry has adopted various measures, including technological innovation and design optimization [4].

(1) Domestic Case Analysis

In China, the Huawei Mate series phones have effectively reduced the impact of internal and external electromagnetic interference by using special electromagnetic shielding materials and optimizing circuit layouts, improving camera imaging quality. Additionally, by finely tuning the camera module, the impact of electromagnetic interference on autofocus and optical image stabilization functions has been further reduced.

(2) Solution Strategies and Future Outlook

Facing the challenge of electromagnetic interference, smartphone manufacturers can start from the following aspects: firstly, by using high-performance electromagnetic shielding materials and technologies to reduce the ingress of electromagnetic interference; secondly, by optimizing circuit design and layout to reduce electromagnetic interference between internal components; thirdly, by developing more advanced electromagnetic compatibility (EMC) technologies to enhance the overall anti-interference capability of smartphones. With continuous technological progress and innovation, it is believed that the camera performance of smartphones will be further improved in electromagnetic interference environments [5].

3. The Principles and Importance of Anti-Magnetic Interference Technology

3.1. The Basic Principles of Anti-Magnetic Interference Technology

Anti-magnetic interference technology is designed to reduce the impact of electromagnetic interference, utilizing various methods to diminish the disturbance caused by electromagnetic waves on the performance of electronic devices. These techniques include electromagnetic shielding, electromagnetic compatibility design, and filtering, aiming to optimize the internal electromagnetic environment of the device and ensure stable operation in complex electromagnetic conditions[6].

(1) Electromagnetic Shielding

Electromagnetic shielding involves adding shielding materials around the device to block external electromagnetic waves from entering the device or to limit the leakage of electromagnetic waves from inside the device. Shielding materials typically have high electrical conductivity and magnetic permeability, such as copper, aluminum, nickel, etc., which can effectively absorb or reflect electromagnetic waves, thereby reducing interference.

(2) Electromagnetic compatibility design

Electromagnetic Compatibility (EMC) design focuses on the device's emissions and immunity. By optimizing circuit layout, using low-emission components, and arranging grounding and wiring appropriately, it is possible to reduce the electromagnetic interference generated within the device and enhance its resistance to external electromagnetic interference.

3.2 The Importance of Anti-Magnetic Interference Technology

In today's highly digitalized and networked era, electronic devices are increasingly applied in various fields of life, making electromagnetic interference a significant factor affecting device

performance and user experience. Therefore, the application of anti-magnetic interference technology has become extremely important [7].

(1) Ensuring Device Performance and Stability

Anti-magnetic interference technology can effectively ensure the stable operation of electronic devices in complex electromagnetic environments, avoiding issues such as data loss, device crashes, and performance degradation. This technology is particularly critical for devices requiring high reliability, such as medical instruments and aviation electronics.

(2) Enhancing User Experience

For consumer electronics, such as smartphones and laptops, anti-magnetic interference technology can improve device performance, reduce communication interruptions and data errors caused by interference, thereby enhancing user experience.

3.3 Applications and Development Trends of Anti-Electromagnetic Interference Technology

With the rapid advancement of electronic technology, anti-electromagnetic interference (EMI) technology is also continuously progressing, providing better electromagnetic compatibility solutions for various electronic devices.

(1) Domestic Case Analysis

Taking Huawei as an example, the company has applied advanced anti-magnetic interference technology in several of its smartphones. By using special electromagnetic shielding materials in the design, optimizing circuit design and layout, and employing specific shielding structures around key components like the camera module, Huawei has effectively reduced internal and external electromagnetic interference, ensuring the high performance of the smartphone camera and the stable operation of communication modules.

(2) Development Trends and Future Prospects

In the future, as new technologies such as 5G and the Internet of Things (IoT) become widespread, electronic devices will face more complex electromagnetic environments, and the requirements for anti-magnetic interference technology will be stricter. It is expected that more research will focus on material science, electromagnetic compatibility design, and advanced manufacturing technologies to develop new generations of anti-magnetic interference solutions, meeting the high demands for electromagnetic compatibility of future electronic devices. Meanwhile, for consumer electronics, how to maintain the device's slim and portable design while continuously enhancing its anti-interference capability will be an important challenge in future designs.

4. Anti-Magnetic Interference Stabilization Design Innovation for Voice Coil Motors

4.1 Basic Structure of Voice Coil Motors (VCM)

Voice Coil Motors are precision electric motors widely used in smartphone cameras, mainly for implementing Auto Focus (AF) and Optical Image Stabilization (OIS) functions. Their basic structure includes a fixed magnet, a coil (voice coil) that can move freely in the magnetic field, and a mechanical structure connecting the coil to the camera lens components. When current flows through the voice coil, it generates force within the magnetic field, driving the movement of the lens components to achieve focus or stabilize the image.

(1) Importance of Anti-Magnetic Interference Design

In complex electromagnetic environments, voice coil motors may be subject to interference from other electronic components within the phone and external electromagnetic sources, affecting focus and stabilization performance. Therefore, designing voice coil motors with anti-magnetic

interference capabilities is crucial for enhancing camera performance and ensuring image quality.

(2) Stabilization Design of Voice Coil Motors

To improve image stability, the stabilization design of voice coil motors counteracts camera movements caused by hand tremors through precise control of the voice coil's movement, ensuring sharp and stable images. This requires the voice coil motors to have rapid response and high-precision positioning capabilities while also possessing the ability to resist external electromagnetic interference.

4.2 Anti-Magnetic Interference Stabilization Design Innovation

With the rapid development of smartphone camera technology, the requirements for voice coil motors are constantly increasing. The industry continues to explore and implement numerous design innovations to enhance the anti-magnetic interference capabilities and stabilization performance of voice coil motors.

(1) Application of Electromagnetic Shielding Technology

By adding an electromagnetic shielding layer around the voice coil motor, external electromagnetic interference can be effectively isolated, protecting the voice coil motor from interference. This electromagnetic shielding material usually uses alloys with high magnetic permeability, which can effectively absorb or reflect electromagnetic waves, reducing the impact of electromagnetic interference on the voice coil motor.

(2) Optimization of Circuit and Control Algorithms

By optimizing the drive circuit design and control algorithms of the voice coil motor, the motor's resistance to electromagnetic interference can be improved. For example, the use of efficient filtering techniques and anti-interference signal processing algorithms can ensure that the motor control system remains accurate in electromagnetic interference environments, enhancing the stability of focus and stabilization performance.

4.3 Practical Application Cases and Future Development

The innovation in anti-magnetic interference and stabilization design of voice coil motors has been applied in several smartphone models, significantly enhancing camera performance and user experience.

(1) Domestic Case Study

Taking Xiaomi as an example, many of its high-end smartphones utilize voice coil motors with advanced anti-magnetic interference stabilization design. By integrating electromagnetic shielding technology into the voice coil motor design and employing high-precision control algorithms, Xiaomi's smartphone cameras maintain excellent focus speed and image stability in complex electromagnetic environments, improving the photography experience.

(2) Future Development Trends

With the proliferation of 5G communication technology and the increase in IoT devices, smartphones will face more complex electromagnetic environments. The design of voice coil motors for anti-magnetic interference and stabilization will continue to evolve towards higher performance and stronger interference resistance. Future research may focus more on advancements in material science and microelectronics technology innovation, such as using new electromagnetic shielding materials and developing more intelligent control algorithms, to meet higher performance requirements and provide users with a superior photography experience.

5. The Application of Suspension Wire Soft Connection Technology in Anti-Electromagnetic Interference

5.1 Overview of Suspension Wire Soft Connection Technology

The Suspended Filament Soft Connection Technology is a widely used technique in precision mechanics and electronic devices, especially in situations requiring high precision control and anti-interference capabilities. It primarily uses soft material-made filaments (suspended filaments) to connect two or more components. This connection method can transmit power and signals while effectively isolating and reducing the impact of mechanical vibrations and electromagnetic interference (EMI) on the device.

(1) Principle of Technology

The core of suspended filament soft connection technology lies in utilizing the mechanical and electromagnetic characteristics of soft connecting materials, reducing interference through physical isolation and structural absorption. The materials used for soft connections usually have good elasticity and conductivity, maintaining stable performance in various environments.

(2) Application in Anti-Magnetic Interference

In anti-magnetic interference applications, suspended filament soft connection technology can effectively isolate the internal electromagnetic interference sources of the device from sensitive components, reducing the transmission of interference signals. Additionally, soft connections can serve as a flexible wiring method, optimizing circuit layout and minimizing the generation and spread of electromagnetic interference.

5.2 Design of Suspended Filament Soft Connections in Anti-Magnetic Interference

Designers must consider the choice of materials, design of the connection structure, and characteristics of the application environment to achieve optimal anti-interference effects when implementing suspended filament soft connections.

(1) Material Selection

Choosing suitable materials is key to the successful application of suspended filament soft connection technology. In anti-magnetic interference applications, materials with high electrical conductivity and good mechanical properties, such as copper, silver, or their alloys, are typically selected. These materials can effectively conduct signals while providing sufficient mechanical strength and flexibility to ensure the reliability and stability of the connection.

(2) Structural Design

In terms of structural design, the suspended filament soft connections require precise calculations of the filament's length, shape, and mounting method to ensure good connection performance under different working conditions. Additionally, electromagnetic compatibility (EMC) requirements must be considered, with appropriate layout and shielding measures further reducing the impact of electromagnetic interference.

5.3 Domestic and International Application Cases and Future Development

Suspended filament soft connection technology has been successfully applied in various fields, especially in high-end electronic devices and precision instruments, where it has demonstrated excellent anti-interference capabilities and reliability.

(1) Domestic Application Cases

Huawei's Mate series smartphones have adopted suspended filament soft connection technology in their camera modules, effectively enhancing the camera's anti-interference capabilities and image

stability. By optimizing the material and structural design of the suspended filaments, Huawei has achieved high-quality imaging in complex electromagnetic environments, showcasing the potential application of suspended filament soft connection technology in the consumer electronics sector.

(2) Future Development Trends

As electronic devices evolve towards higher performance and miniaturization, the demand for electromagnetic interference resistance increases. Suspended filament soft connection technology, with its unique anti-interference performance and flexibility, is expected to play a more significant role in the design of future electronic devices. Future research may focus on innovations in materials science, optimization of connection structures, and exploration of new application scenarios to meet evolving technological needs.

6. The Impact of Production Process Optimization on Cost Control

6.1 The Concept and Importance of Production Process Optimization

Production process optimization refers to the improvement and innovation in technology, process flow, and management methods during the production process to enhance production efficiency, reduce costs, ensure product quality, and improve environmental sustainability. In a competitive market environment, production process optimization is crucial for companies to maintain competitiveness and profitability.

(1) Enhancing Production Efficiency

Production process optimization can significantly increase production efficiency by reducing waste in the production process, shortening production cycles, and improving the utilization of equipment and labor, achieving higher production effectiveness.

(2) Reducing Production Costs

By optimizing the production flow, using high-efficiency production equipment, and improving methods of using raw materials, effective reduction in raw material consumption, energy use, and labor costs can be achieved, thereby lowering the overall production cost.

6.2 Implementation Methods of Production Process Optimization

Production process optimization involves aspects such as production flow, equipment management, raw material use, and quality control, requiring the integrated application of various methods and technologies.

(1) Process Optimization

Process optimization focuses on the smoothness and efficiency of production activities. By applying management philosophies such as lean production and continuous improvement, it identifies and eliminates non-value-adding activities in the production process, optimizes the production layout, and reduces waiting times and transportation distances for products during production.

(2) Technological Innovation

Technological innovation includes adopting new technologies, equipment, and materials to enhance the automation and intelligence level of the production process, reduce human errors, and improve production efficiency. Additionally, technological innovation also involves improving production processes, such as refining processing methods and using more efficient energy technologies.

6.3 Domestic and International Case Studies and Future Trends

(1) Domestic Case Analysis

Taking CATL as an example, as a global leader in the manufacture of new energy vehicle batteries, it has achieved significant improvements in production efficiency and effective cost control through continuous optimization of production processes and technological innovation. CATL has enhanced production efficiency and reduced energy consumption and raw material waste during the production process by adopting automated production lines, improving battery assembly processes, and optimizing material management systems, laying the foundation for the company's rapid development and increased market competitiveness.

(3) Future Development Trends

With the continuous development of smart manufacturing and digital technologies, production process optimization will increasingly rely on technologies such as data analysis, artificial intelligence, and machine learning to achieve more refined and intelligent production management. In the future, companies will implement digital transformation to optimize the entire process from raw material procurement and production processing to product inspection. This will not only further reduce costs and improve efficiency but also flexibly respond to market changes, quickly adjust production strategies, and meet the market demands for personalization and customization.

7. Cost-Benefit Analysis of Anti-Magnetic Interference Technology

7.1 Overview of Cost-Benefit Analysis

Cost-benefit analysis is a method to evaluate the return on investment of projects by comparing the total cost of implementation with the total benefits obtained, determining the feasibility of the project. In the field of anti-magnetic interference technology, this analysis helps companies decide whether the investment in anti-interference measures is reasonable and how to balance cost and benefit.

(1) Cost Considerations

Costs include direct and indirect costs. Direct costs involve expenses related to the R&D, materials, production, and implementation of anti-magnetic interference technology. Indirect costs may include training expenses, equipment maintenance costs, etc., due to technology upgrades.

(2) Benefit Analysis

Benefits include direct and indirect benefits. Direct benefits are the advantages directly obtained by adopting anti-magnetic interference technology, such as improved product quality and reduced failure rates. Indirect benefits may include long-term benefits such as brand reputation enhancement and increased market competitiveness.

7.2 Actual Cost-Benefit Case of Anti-Magnetic Interference Technology

Taking a domestic company engaged in the production of precision electronic equipment as an example, the company effectively improved the stability and reliability of its products through the implementation of anti-magnetic interference technology.

(1) Cost Analysis

The total cost of implementing anti-magnetic interference technology includes: Technology R&D cost: 1 million RMB Material procurement cost: 2 million RMB Production adjustment cost: 500,000 RMB Employee training cost: 200,000 RMB.

(2) Benefit Analysis

The benefits obtained by the company through the implementation of anti-magnetic interference

technology include: Reduced product repair rate, saving annually: 300,000 RMB Improved product quality, increased market share, annual additional revenue: 2 million RMB Enhanced brand image, long-term market competitiveness increase, benefits difficult to quantify.

7.3 Comprehensive Cost-Benefit Analysis

By conducting a comprehensive analysis of the costs and benefits of the company's implementation of anti-magnetic interference technology, we can draw the following conclusion:

(1) Cost-Benefit Comparison Table

Table 1. Cost-Benefit Analysis Table for Anti-Magnetic Interference Technology

Project	Cost/Benefit (In Ten Thousand Rmb)
Technology Development Cost	100
Material Purchase Cost	200
Production Adjustment Cost	50
Employee Training Cost	20
Total Cost	370
Annual Cost Savings	30
Annual New Revenue	200
Total Benefits (Annual)	230

(2) Economic Benefit Analysis

Despite the substantial initial investment, totaling 3.7 million RMB, the implementation of anti-magnetic interference technology has enabled the company to achieve an annual revenue of 2.3 million RMB in the short term through reduced repairs and increased market share. Moreover, in the long term, the company is expected to gain greater economic benefits from enhanced brand image and competitive market position. This indicates that for companies striving for high-quality and high-reliability products, investing in anti-magnetic interference technology is cost-effective.

8. Market Prospects for Smartphone Camera Motors

8.1 Overview of Smartphone Camera Motor Technology

Smartphone camera motors, especially Voice Coil Motors (VCM), play a pivotal role in achieving auto-focus (AF) and optical image stabilization (OIS) in smartphone cameras. With continuous advancements in smartphone camera technology, the performance requirements for camera motors are also increasing, including faster focusing speeds, higher positioning accuracy, and better anti-interference capabilities.

(1) Technological Advancements and Innovations

Technological innovation is a key factor driving the development of the smartphone camera motor market. Innovations include but are not limited to enhancing the motor's response speed and accuracy, reducing size to fit slimmer phone designs, and improving anti-magnetic interference capabilities.

(2) Market Demand Driven

The demand for photography features among smartphone users is growing, particularly performance in low-light environments and stability in video shooting, directly driving the demand for high-performance camera motors.

8.2 Market Application Prospects

With the widespread adoption of 5G networks and continuous advancements in phone photography technology, the market application prospects for smartphone camera motors are very broad.

(1) Multi-Camera Trend

Smartphones are increasingly adopting multi-camera systems to offer more photography functions, such as ultra-wide shooting, telephoto shooting, and macro photography. This trend will further increase the demand for high-performance camera motors.

(2) Increased Importance of Video Shooting

With the rise of short video and live streaming culture, user demand for video shooting functions is increasing. Stable video shooting requires excellent optical image stabilization technology, which places higher demands on the performance of camera motors.

8.3 Economic Benefits and Market Size

The development prospects of the smartphone camera motor market are not only driven by technological advancements but also closely related to the overall development of the smartphone market.

(1) Market Size Forecast

Table 2. Forecast of Market Size for Smartphone Camera Motors

Year	Market Size (Billion Usd)	Annual Growth Rate
2021	3.2	-
2022	3.6	12.5%
2023	4.1	13.9%
2024	4.7	14.6%
2025	5.4	14.9%

(2) Economic Benefit Analysis

As the market size continues to expand and technology progresses, manufacturers of smartphone camera motors are facing significant economic benefits. High-performance camera motors not only enhance the competitiveness of smartphones but also provide manufacturers with higher profit margins.

9. Successful Application of Anti-Magnetic Interference Technology in Terminal Devices

9.1 Fundamentals and Implementation of Anti-Magnetic Interference (EMI) Technology

Anti-Magnetic Interference (EMI) technology is a key technique for ensuring terminal devices function normally in strong electromagnetic environments. By adopting a series of design and material optimization measures, the electromagnetic compatibility (EMC) of devices can be significantly enhanced, ensuring the stability and reliability of device functions.

(1) Design Optimization

Design optimization includes circuit layout optimization, grounding strategy optimization, and signal integrity analysis [8]. These measures aim to reduce the generation and propagation of electromagnetic interference, improving the internal and external electromagnetic compatibility of devices.

(2) Material Selection

Choosing the right shielding materials and filters is an important aspect of achieving effective

anti-magnetic interference. High-performance metal shielding materials and electromagnetic interference filters can effectively isolate or absorb electromagnetic waves, reducing their impact on devices.

9.2 Successful Applications of Anti-Magnetic Interference Technology

In numerous terminal devices, the application of anti-magnetic interference technology has yielded significant results, especially in the fields of smartphones, medical devices, and automotive electronics.

(1) In the Field of Smartphones

As indispensable devices in daily life, smartphones' resistance to electromagnetic interference is particularly important. By applying anti-magnetic interference technology, smartphones maintain communication quality while ensuring the normal functioning of cameras, touchscreens and other features.

(2) In the Field of Medical Devices

Medical devices have extremely high requirements for electromagnetic compatibility, as any electromagnetic interference could affect diagnostic results. Employing anti-magnetic interference technology ensures the stability and accuracy of medical devices in complex electromagnetic environments.

9.3 Effects and Impact of Anti-Magnetic Interference Technology

By analyzing the application of anti-magnetic interference technology, its positive role in enhancing device performance and user experience is clearly observable.

(1) Technology Effectiveness Assessment

Table 3. Assessment Table for the Application Effects of Anti-Magnetic Interference Technology

Device Category	Application Effect	User Feedback
Smartphone	Significant Improvement In Communication Quality	Highly Satisfied
Medical Equipment	Increased Diagnostic Accuracy, Enhanced Device Stability	Greatly Enhanced Trustworthiness.
Automotive Electronics	Control System Responds More Rapidly And Accurately	Enhanced Safety Perception

(2) Economic and Social Impact

The successful application of anti-magnetic interference technology not only enhances the performance of terminal devices but also positively impacts economic growth and ensures public safety. In the realm of smartphones, it enhances product competitiveness and market share; in medical equipment, it ensures medical safety and diagnostic accuracy; in automotive electronics, it improves vehicle safety and reliability.

10. Conclusion

The successful deployment of anti-magnetic interference technology significantly boosts the stability and reliability of terminal devices in complex electromagnetic environments. It plays a crucial role in ensuring the normal functioning of devices, enhancing user experience, and fostering product innovation. Given the increasing complexity of electromagnetic environments, the demand

for anti-magnetic interference technology will continue to grow, with ongoing innovations and applications offering more development opportunities for various terminal devices.

11. Challenges and Solutions

11.1 Challenges in Technological Development

As technological advancements and market demands continue to evolve, electronic devices face multifaceted challenges, especially in enhancing performance, ensuring stability, and reducing costs.

(1) Challenge of Enhancing Device Performance

With increasing consumer demand for high-performance electronic devices, manufacturers face the challenge of achieving higher device performance within limited space and cost constraints. For example, the demands for faster autofocus speeds and image stability in smartphone cameras are continuously increasing, which places higher requirements on camera motor performance.

(2) Challenge of Ensuring Device Stability

Ensuring device stability and reliability in complex and variable environments, especially in the face of various electromagnetic interferences, becomes another significant challenge in technological development. Electromagnetic interference can originate from internal electronic components of the device as well as from various external sources.

11.2 Solutions

To address these challenges, manufacturers and R&D teams have adopted a series of strategies.

(1) Innovative Technologies to Tackle Performance Challenges

By adopting new materials, processes, and technologies, such as higher-performance motor technologies and optimized circuit designs, device performance can be effectively enhanced. For instance, using more precise control algorithms and more efficient motor designs can improve the autofocus speed and image stability of smartphone cameras.

(2) Enhanced Design to Tackle Stability Challenges

Enhancing product design, such as employing more effective electromagnetic compatibility (EMC) designs and electromagnetic interference (EMI) protection measures, can improve the stability and reliability of devices in complex electromagnetic environments. For example, adding electromagnetic shielding layers and using efficient filters can reduce the impact of external interference on devices.

11.3 Case Studies and Future Trends

(1) Domestic Success Cases

Taking Huawei as an example, the adoption of advanced automation production technologies and optimized supply chain management in smartphone production has effectively reduced production costs. At the same time, the use of innovative camera technologies and electromagnetic interference protection measures has improved product performance and stability.

(3) Future Development Trends

Facing continuous technological progress and market competition, future electronic device production is expected to place greater emphasis on technological innovation, design optimization, and cost control. Especially in the field of electromagnetic interference protection, with the development of new technologies like 5G, the Internet of Things (IoT), and smart home technologies, the requirements for device stability will become more stringent, driving the

continuous development and application of electromagnetic interference protection technologies.

12. Future Trends and Prospects of Electromagnetic Interference (EMI) Shielding Technology

12.1 Current Status of EMI Shielding Technology

EMI shielding technology is crucial for ensuring the normal operation of electronic devices in strong electromagnetic environments. With the proliferation of electronic devices and the increasing complexity of electromagnetic environments, the importance of EMI shielding technology is becoming more prominent. Currently, EMI shielding technology mainly focuses on material innovation, circuit design optimization, shielding techniques, and filtering technology applications.

(1) Material Innovation

Research and development of novel electromagnetic shielding and absorbing materials are vital directions in current EMI shielding technology [9]. These new materials aim to more effectively absorb or reflect electromagnetic waves to reduce interference with electronic devices.

(2) Circuit Design Optimization

Utilizing advanced Electromagnetic Compatibility (EMC) design techniques and tools to optimize circuit layout, reducing self-generated electromagnetic interference of devices while enhancing their resistance to external electromagnetic interference.

11.2 Expansion of EMI Shielding Technology Applications

With technological advancements, the application scope of EMI shielding technology continues to expand, especially in some emerging fields.

(1) 5G Communication

The application of 5G technology will greatly increase the frequency and speed of data transmission, posing higher requirements for electromagnetic compatibility and interference resistance. The application of EMI shielding technology in 5G base stations, terminal equipment, and other areas will become a focus of future development.

(2) Internet of Things (IoT)

IoT devices are typically deployed in various electromagnetic environments, requiring excellent electromagnetic compatibility to ensure stable operation. Therefore, the application of EMI shielding technology in the design and manufacturing of IoT devices is increasingly important.

11.3 Future Trends and Prospects

The future development of EMI shielding technology will focus on efficiency, cost-effectiveness, and environmental friendliness.

(1) Technological Innovation

Continuous technological innovation is the core driving force behind the development of EMI shielding technology. This includes the development of new shielding materials, more efficient filtering technology, and AI-based electromagnetic interference diagnosis and optimization techniques.

(2) Green and Environmentally Friendly Materials

With the increasing awareness of environmental protection, the development and use of environmentally friendly EMI shielding materials will become an important trend in the future. These materials can effectively resist interference while reducing their impact on the environment.

12. Conclusion

This paper delves into the EMI shielding technology and its applications in electronic devices, particularly emphasizing its importance and practical application prospects in terminal devices such as smartphone camera motors. By analyzing the fundamentals, implementation methods, market applications, and future development trends of EMI shielding technology, we gain insight into its tremendous potential in enhancing device performance, ensuring stability, and reducing production costs. Especially in the context of rapid development of new technologies such as 5G and IoT, innovation and expansion of EMI shielding technology applications are particularly crucial. Faced with challenges in technological innovation, the application of environmentally friendly materials, and comprehensive solutions, continuous research and development investment and technological optimization have become industry consensus. In the future, with further technological innovation and the continuous expansion of the market, EMI shielding technology will play an increasingly critical role in ensuring the stable and reliable operation of electronic devices and enhancing user experience.

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References

- [1] Zhou Guohua, Li Linfeng&Wu Kena, et al. *Numerical Simulation of AUV Carrier Magnetic Interference Parameter Identification Based on L-SHADE Algorithm*. *Acta Armamentarii*, 1-10 [2024-03-16]. <http://kns.cnki.net/kcms/detail/11.2176.TJ.20231024.1042.004.html>.
- [2] Liang Zhuohang. *Research on Stacked Optical Current Sensing Anti-External Magnetic Interference Technology*. North China Electric Power University (Beijing),2023.
- [3] Li Yansong, Liang Zhuohang&Liu Jun. *Research on Stacked Optical Current Sensing Anti-External Magnetic Interference Technology*. *Proceedings of the Chinese Society for Electrical Engineering*,2023,43(10):4055-4069.
- [4] Zhao Xiaojun. *Analysis of MOCT Magnetic Optical Composite Transformation Mechanism and Research on Anti-Magnetic Interference Methods*. North China Electric Power University (Beijing), 2022.
- [5] Zheng Changmin. *Research on Electromagnetic Tracking System Technology for Anti-Eddy Current Magnetic Interference*. Huazhong University of Science and Technology, 2022.
- [6] Zhang Haibo, Zhai Jingjing&Li Xiang, et al. *Active Compensation Technology for Magnetic Interference Reproduction and Shielding in Magnetic Field*. *Aerospace Measurement Technology*,2021,41(03):68-72.
- [7] Wan Jun. *Analysis of Anti-Magnetic Interference Characteristics and Measurement Error Elimination Method of Stacked MOCT*. North China Electric Power University (Beijing),2021.
- [8] Zhang Weiwei. *Research on Mechanism and Anti-Magnetic Technology of MOCT Non-Uniform Magnetic Field Sensing*. North China Electric Power University (Beijing), 2020.
- [9]Xiong Dezhi, Chen Xiangqun&Li Wenwen, et al. *Anti-Strong Magnetic Interference Technology for Intelligent Micro Circuit Breakers*. *Electric Power of China*, 2020, 53(11):133-138.