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A Review of Ultra-High-Definition Broadcasting Development: Postprint

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Abstract

Broadcasting and television have experienced evolution from black-and-white to color, from analog to digital, and from standard definition to high definition, and are currently facing a new round of major technological innovation and development from high definition to ultra-high definition. With the application and development of ultra-high definition technology, the development environment, target audiences, and the scope and modalities of business promotion for broadcasting and television will undergo fundamental transformations. This paper first elaborates on the advantages of ultra-high definition technology and advancements in its key enabling technologies, then systematically reviews the relevant policies promoting the development of China' s ultra-high definition video industry, and finally explores the practical significance of developing ultra-high definition television.

Full Text

Preamble

A Review of Ultra-High-Definition Development in Radio and Television Broadcasting

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Abstract: Radio and television broadcasting has evolved from black-and-white to color, from analog to digital, and from standard-definition to high-definition. It now stands at the threshold of a new round of major technological innovation and development—from high-definition to ultra-high-definition. With the application and development of ultra-high-definition technology, the development environment, service objects, and business promotion scope and methods of radio and television will undergo fundamental changes. This paper first elaborates on the advantages of ultra-high-definition technology and improvements

in its key technologies, then reviews the relevant policies promoting the development of China' s ultra-high-definition video industry, and finally discusses the practical significance of developing ultra-high-definition television.

Keywords: 4K ultra-high-definition; encoding technology; broadcast television live satellite; 5G; radio and television

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Ultra-high-definition video represents the next evolution in video reproduction technology following analog, standard-definition, and high-definition reproduction, and represents the future direction of video technology. Developing ultra-high-definition television is the inevitable result of technological progress in radio and television broadcasting, and a necessary requirement to align with the latest trends in television development, better satisfying people' s new expectations for high-quality, diverse television programs and a better life. Ultra-high-definition video features 4K or 8K resolution and meets technical requirements for high frame rate, high bit depth, wide color gamut, and high dynamic range, making it a new generation of video technology.

In practice, the transition from standard-definition to high-definition only improved resolution, while the image' s color gamut and quantization bit depth (high bit depth) remained unchanged. Ultra-high-definition video, however, achieves comprehensive, multi-dimensional improvements in resolution (from $1920\times1080 to 3840\times2160 or 7680\times4320$), high bit depth (from 8-bit to 10–12-bit), high dynamic range (enhancing the representation of both highlight and low-light areas), scanning method (from interlaced to progressive scanning, improving vertical resolution), and color gamut, providing users with superior video services.

Internationally, the ultra-high-definition video industry started early, with increasingly mature development in technology research, standard formulation, and product promotion. Countries worldwide have developed unique advantages and characteristics in their broadcasting industries according to their national conditions. For instance, Japan' s NHK officially launched 4K $(3840\times2160 pixels) ultra-high-definition television with high dynamic range (HDR) imaging capabilities in 2018 and achieved 8K (7680\times4320$ pixels) satellite broadcasting during the PyeongChang Winter Olympics that same year. 4K and 8K ultra-high-definition television programs were widely promoted during the 2020 Tokyo Olympics. Japan' s Ministry of Internal Affairs and Communications plans to achieve full household television ultra-high-definition by 2025. South Korea launched 4K ultra-high-definition channels as early as 2014 (though without HDR capabilities) and has gradually achieved comprehensive 4K service provision. The United States promotes 4K broadcasting through satellite and streaming media. Several EU countries, along with the UK, Australia, and India, have also successively launched 4K channel broadcasting trials. In China, Guangdong Television Station took the lead in trial broadcasting 4K ultra-high-definition television programs in

Guangdong Province on December 23, 2017, and China Central Television (CCTV) officially launched 4K ultra-high-definition programming on October 1, 2018.

Currently, more than 70 4K ultra-high-definition channels have been launched globally, demonstrating enormous development potential and establishing itself as the direction for video field development. However, overall, global ultra-high-definition television development remains in its initial stages. The transition from high-definition to ultra-high-definition televisions presents both new opportunities and challenges for broadcasting institutions. Therefore, research and discussion on the development of ultra-high-definition broadcasting are necessary and provide valuable reference for the development of China' s ultra-high-definition technology.

1. Technical Advantages of Ultra-High-Definition

Ultra-high-definition video can increase image resolution from 1080p high-definition (1920$\times$1080) to 4K, 8K, and beyond—a fourfold, sixteenfold, or even greater improvement that delivers more delicate picture quality and a more realistic viewing experience for users. Frame rates have also gradually increased from 25/30 frames per second to 50/60 fps, and even 100/120 fps, enabling more realistic representation of high-speed moving objects and reducing motion blur. This is particularly evident in live sports broadcasting, where dynamic images become smoother and avoid discontinuous visual perception. In China, frame rates of 50–100 fps are selected primarily because the national power grid frequency is 50 Hz. The color gamut standard meets the latest International Telecommunication Union standard BT.2020, substantially enhancing color representation.

2. Improvements in Key Ultra-High-Definition Technologies

During the analog television era, most equipment used by television stations was imported. However, entering the digital television era, with continuous ultra-high-definition technology development, domestic high-definition and ultra-high-definition equipment has been widely adopted, gradually breaking foreign monopolies. Ultra-high-definition technology primarily involves audio-video signal acquisition and editing, source audio-video encoding, network transmission, and terminal presentation technologies. The development of ultra-high-definition technology brings new opportunities for overall key technology improvements from broadcasting frontends to terminals and actively promotes the localization of video equipment.

2.1 Upgrades in Audio-Video Acquisition and Editing Technology

In audio-video signal acquisition, the basic requirements for ultra-high-definition cameras are high resolution, high frame rate, high bit depth, wide color gamut,

and high dynamic range. Internationally, high-end camera equipment is primarily monopolized by Japanese companies. However, with the promotion and application of ultra-high-definition television in China, although key modules such as CMOS remain under foreign control, Chinese technology companies including ZEUSELA, BOSMA, and BANSHOU have launched 4K ultra-high-definition camera products, demonstrating independent design and manufacturing capabilities for professional ultra-high-definition cameras. Furthermore, essential equipment for ultra-high-definition program production—monitors and switchers—have also achieved domestic breakthroughs. Companies like BOE and Konvision have launched 8K monitors, and NewAuto has successfully developed ultra-high-definition broadcasting systems.

In audio-video signal editing, breakthroughs in applied basic research such as audio-video signal processing, cloud terminal collaboration, and artificial intelligence (AI) are key to occupying the commanding heights in the ultra-high-definition field and determine the speed and level of China's ultra-high-definition video industry development. By the end of 2020, CCTV had completed 4,000 hours of ultra-high-definition television program production, while Guangdong Television had accumulated nearly 30,000 hours of 4K programming. Cable television, IPTV, and internet platforms have successively launched 4K on-demand ultra-high-definition film and television zones.

2.2 Localization of Video Encoding Standards

The international encoding standard H.264 remains the most popular video encoding format, widely used in standard-definition and high-definition program encoding and compression. However, its encoding efficiency and quality can no longer meet the actual needs of ultra-high-definition encoding and compression. In ultra-high-definition video transmission, most applications use the new-generation H.265 video encoding format. China' s AVS Working Group launched the first-generation national video encoding standard AVS in 2006, followed by an enhanced version AVS+. Currently, the video encoding standard AVS2 has been applied in China' s domestic ultra-high-definition broadcasting channels, saving approximately 40% bitrate compared to H.265 for scene video encoding. In March 2019, AVS3—the world' s first third-generation audio-video encoding and decoding technical standard for 8K and 5G industrial applications—completed its baseline profile formulation, achieving approximately 30% improvement in encoding performance over the previous AVS2 standard.

In terms of ultra-high-definition encoding and decoding equipment providers, domestic leading enterprises such as Digital Vision, AVS Technology, and Keweixin can generally support various audio-video encoding standards for the ultra-high-definition video industry. Chips and encoding/decoding applications are dominated by companies like HiSilicon, NTT, and Socionext, but these are limited to H.265 encoding applications. China' s independent intellectual property rights video encoding standard industry system has matured, yet most domestic terminal products support international encoding formats, requiring payment of high

patent licensing fees. Ultra-high-definition development facilitates the transition from international standards to domestic proprietary standards in China' s video encoding industry, ensuring long-term and healthy development of the nation' s video technology and industry.

2.3 Upgrades and Transformation of Network Transmission Systems

In network transmission, cable television, IPTV, satellite broadcasting, and terrestrial broadcasting are the primary methods. Using H.265 or AVS2 encoding, 4K bitrate is approximately 30–50 Mbps, while 8K bitrate is about 100–150 Mbps, while ensuring ultra-high-definition video experience. Ultra-high-definition large video services impose higher requirements on IP-based networks and platforms. To guarantee ultra-high-definition video transmission and align with future development directions, broadcasting institutions should undertake system architecture optimization. With the arrival of the ultra-high-definition era, the number of live 4K programs will increase dramatically, and existing DVB platform frequency points can no longer support ultra-high-definition business development. Through IP-based transformation, ultra-high-definition programs can be operated on IP platforms. After gradually transitioning from DVB to IP, future live broadcasting, on-demand services, time-shifted playback, and intelligent services will all be transmitted via IP, ensuring 4K program viewing while rapidly developing IP-based intelligent services and providing smooth access to IoT services, truly enhancing user experience.

2.4 Integrated Application of Ultra-High-Definition + 5G + Cloud Services

In June 2019, China Mobile, China Unicom, China Telecom, and China Broadcasting Network obtained 5G commercial licenses, marking China' s official entry into the 5G commercial era. By the end of 2020, the nation had newly built and launched more than 600,000 5G base stations, with terminal connections exceeding 200 million, basically covering all cities at the prefecture level and above. The rapid advancement of 5G applications provides important momentum for China' s ultra-high-definition video industry development, giving rise to ultra-high-definition + 5G + cloud services. On one hand, 5G' s high speed and large bandwidth solve the problem of large bitrate transmission, promoting rapid development of ultra-high-definition video applications. Cloud services address needs such as on-demand and easy scalability. On the other hand, ultra-high-definition video accounts for the largest proportion of consumer network traffic and represents the most important driving force for 5G construction and promotion. As a central large-scale cultural enterprise and a new basic telecommunications operator, China Broadcasting Network not only has high-quality 700 MHz spectrum for wide 5G coverage but also possesses rich radio and television resources, giving it unique technical advantages for promoting ultra-high-definition + 5G integrated applications.

2.5 Ultra-High-Definition + Live Satellite Promoting UHD Application

Live broadcast satellites are important components of modern communication systems and public cultural service systems, serving as crucial means and channels for radio and television transmission coverage and representing an important method for promoting Chinese radio and television programs internationally. They offer advantages including non-geographic limitation, wide coverage, low cost, and high quality. Broadcasting ultra-high-definition programs via China' s radio and television live satellite platform—that is, using live satellites to broadcast ultra-high-definition television programs—enriches the content of the live satellite platform, further enhances the business carrying capacity and service quality of satellite radio and television, promotes transformation, upgrading, quality improvement, and efficiency enhancement of satellite radio and television, improves service quality and levels, drives ultra-high-definition television application and popularization, achieves high-quality and comprehensive development of satellite radio and television, satisfies people' s new demands for higher-quality satellite audio-visual services, and further enhances people' s sense of gain.

2.6 Terminal Product Demand Promoting Ultra-High-Definition Development

According to the *White Paper on Ultra-High-Definition Video Industry Development (2021)*, in terms of terminals, China' s 4K television sales and market share continue to grow. The penetration rate of 4K ultra-high-definition televisions in domestic retail exceeds 70%, reaching nearly 100% for screens 43 inches and above, with 8K televisions becoming flagship standard configurations for manufacturers. High resolution, high frame rate, high bit depth, wide color gamut, and high dynamic range have become new selling points for terminal performance. In 2020, China' s cable set-top box shipments exceeded 13 million units, of which 4K ultra-high-definition set-top boxes accounted for 61.9%, while high-definition set-top boxes accounted for 37.9%. The actual number of national high-definition and ultra-high-definition cable television users exceeded 100 million households. The rapid development of ultra-high-definition terminal products has created a situation of terminals leading the market. Since the launch of CCTV' s ultra-high-definition channel in October 2018, China' s ultra-high-definition industry has developed rapidly in response to enormous market demand.

3. Policy Implementation Driving the Ultra-High-Definition Video Field

Although China' s ultra-high-definition video research and utilization started relatively late, it has developed rapidly under policy-driven support, relying on a huge market space and industrial foundation. In recent years, the Chinese gov-

ernment has attached great importance to ultra-high-definition industry development, formulating a series of ultra-high-definition standards and action plans that have effectively advanced the industry' s development and application in related fields. In 2017, the National Radio and Television Administration released the industry standard *Technical Parameters for 4K Ultra-High-Definition Television Program Production and Exchange*. In September 2018, it issued the *Implementation Guide for 4K Ultra-High-Definition Television Technology Application (2018 Edition)*. In October of the same year, CCTV launched China' s first ultra-high-definition channel. Additionally, China formally promulgated the Ultra-High-Definition Video Industry Alliance standards *Ultra-High-Definition Television Technical Specifications* and *Ultra-High-Definition Television Measurement Methods*. These standards regulated the technical formats, content production, transmission methods, and terminal display equipment technologies for China' s 4K ultra-high-definition television programs, effectively guiding the development of China' s ultra-high-definition video industry.

In February 2019, the Ministry of Industry and Information Technology, the National Radio and Television Administration, and CCTV jointly issued the *Action Plan for Ultra-High-Definition Video Industry Development (2019–2022)*, which clearly proposed that China's technical route for developing ultra-high-definition video is "4K first, with consideration for 8K," greatly promoting ultra-high-definition video industry development and applications in related fields. Subsequently, eight provinces also released their own industrial action plans. To further standardize and promote China' s 4K ultra-high-definition development and improve 4K ultra-high-definition television program quality and production efficiency, the National Radio and Television Administration successively issued the *Technical Implementation Guide for 4K Ultra-High-Definition Television Program Production (2020 Edition)* and the *Radio and Television Technology Iteration Implementation Plan (2020–2022)*. The plan aims to basically achieve simultaneous high-definition broadcasting of central and provincial satellite programs via live satellite by the end of 2022. The comprehensive high-definition upgrade in the transmission and broadcasting field will further boost China' s ultra-high-definition video industry development. In May 2021, the China Center for Information Industry Development led the compilation and release of the *White Paper on Ultra-High-Definition Video Industry Development (2021)*. The implementation of these policies in the ultra-high-definition video field has greatly promoted the development of China' s ultra-high-definition television. As of March 2021, seven 4K ultra-high-definition channels had been approved and launched by the National Radio and Television Administration, bringing excellent visual experiences to users and satisfying people' s demands for high-quality, diverse television programs.

4. Practical Significance of Developing Ultra-High-Definition Technology

4.1 Meeting People' s New Needs for a Better Life

After more than a decade of technological innovation, radio and television broadcasting has evolved from standard-definition to high-definition and now pursues ultra-high-definition picture quality improvements, allowing people to experience increasingly clear visual enjoyment. It is predicted that in the future, more than 80% of mass network traffic and over 70% of industrial application data will be video data. People' s pursuit of high picture quality, low latency, and large screens has also catalyzed ultra-high-definition development.

When users watch ultra-high-definition television programs, they can experience richer picture layers, smoother and more delicate color transitions, better true color reproduction, and more fluid motion, resulting in a realistic viewing experience that enhances visual perception. This improvement is particularly evident when watching sports programs, where images become clearer and action details more delicate. China conducted ultra-high-definition live broadcasting during the 2019 FIBA Basketball World Cup, where hundreds of viewers watched 8K television signal live trial broadcasts transmitted in real-time via 5G on outdoor large screens at Wukesong Basketball Park. Remote audiences experienced firsthand the charm of combining ultra-high-speed and ultra-high-definition technologies, producing good demonstration application effects. Many viewers reported that the live broadcast images were clear, with athletes' action details visible in sharp detail. In sports broadcasting, CCTV' s 4K Olympic Channel and Beijing Winter Olympics Documentary 4K Channel have already been launched, and the 2022 Beijing Winter Olympics will feature 8K live broadcasting, which will further boost China' s ultra-high-definition video industry development. Under national policy guidance and strong industry promotion, coupled with 5G promotion and application solving the large-bandwidth, low-latency transmission challenges for ultra-high-definition video, ultra-high-definition video will undoubtedly usher in new development opportunities.

4.2 Seeking Rapid Transformation and Upgrading of the Broadcasting Industry

Ultra-high-definition video technology is accelerating its penetration into various fields of the economy and society, increasingly becoming an important engine for building a modern economic system and cultivating new development momentum, as well as an important support for developing smart radio and television and building a culturally strong nation. In recent years, impacted by internet video, traditional radio and television' s user base has gradually shrunk, and the upgrade from standard-definition has been unsatisfactory. In the new era and under new circumstances, the development environment, service objects, and business promotion scope and methods of radio and television have fundamen-

tally changed, making it increasingly urgent for broadcasting institutions to seek new business models and new growth points. Developing ultra-high-definition television can serve as a starting point for deepening supply-side structural reform in radio and television and seeking industry transformation and upgrading, representing an important strategic opportunity to regain initiative in the video industry.

First, the current shortage of total content services and insufficient content supply to meet consumer demand has long been a major pain point in ultra-high-definition industry development, while simultaneously representing a starting point for transformation and upgrading in the radio and television industry. Broadcasting institutions need to provide high-quality ultra-high-definition content, bringing users comfortable video experiences through new content and new experiences to regain user favor. Second, ultra-high-definition development helps broadcasting institutions explore a sustainable business model for the new era, focusing on content copyright and value-added services, learning from internet television experiences, and building their own brands and services to achieve long-term and healthy industry development. Meanwhile, ultra-high-definition television not only enriches television program content but also enriches television service functions, enhancing the added value of "content + services" and building smart homes.

4.3 Promoting Digital Integration Development of the Ultra-High-Definition Industry

The ultra-high-definition video industry encompasses economic activities related to ultra-high-definition video acquisition, production, transmission, and presentation. Its industrial chain is long, broad, and spans large domains. Future development will no longer be limited to the radio and television field but will extend to medical health, cultural education and entertainment, security monitoring, intelligent transportation, industrial manufacturing, and other fields. Since the outbreak of COVID-19 in 2020, the advocated contactless model has further promoted the implementation of ultra-high-definition industry applications. In medical health, 5G' s low latency enables ultra-high-definition remote medical diagnosis and treatment of COVID-19. In cultural education and entertainment, applications of 5G+4K/8K+VR+multi-view technologies have filled the void in entertainment activities during the pandemic, enriching people' s cultural life. In security monitoring, AI+5G+ultra-high-definition has opened a new development trend for the security monitoring industry. In maritime early warning, ultra-high-definition technology can address environmental factors such as low illumination and adverse weather to achieve clear restoration of monitoring details, enabling visual capabilities to discern facial and body details and ship numbers. In intelligent transportation, AI+ultra-high-definition can better analyze urban traffic conditions and achieve precise scheduling, thereby helping cities reduce traffic accident rates, alleviate congestion, and improve traffic operation efficiency. In industrial manufacturing, ultra-high-definition

technology is widely applied in industrial visualization, defect detection, robot inspection, and human-machine collaborative interaction scenarios.

5. Conclusion

This paper reviews the development of China' s ultra-high-definition video industry from the perspectives of ultra-high-definition technology advantages, key technology improvements, relevant policies promoting industry development, and the practical significance of developing ultra-high-definition technology, providing certain references for China' s ultra-high-definition technology development. Ultra-high-definition video technology features better resolution, picture quality, and viewing experience. In recent years, with the development of high-definition and ultra-high-definition technologies, China' s ultra-high-definition video industry has developed rapidly. It is estimated that by 2022, China's total ultra-high-definition video industry scale will exceed 4 trillion yuan. The accelerated development of the ultra-high-definition video industry not only drives the overall upgrading of the ultra-high-definition video industry chain but also stimulates the construction of "dual gigabit" new infrastructure and promotes content prosperity. Driven by government promotion and the 5G development trend, ultra-high-definition video has broad application prospects and important practical significance for meeting people's new needs for a better life, promoting rapid transformation and upgrading of the radio and television industry, and fostering digital integration development of the ultra-high-definition industry.

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