Transmission and Application of Live Signals in CCTV 4K Ultra HD Broadcasting System (Post-print)

Authors: Pan Bingshun

Date: 2023-10-08T00:00:00+00:00

Abstract

With the advancement of live broadcasting technology, 4K ultra-high-definition online production and transmission technologies have developed rapidly. The ever-increasing demand from audiences for video clarity has brought about transformative changes to the entire video imaging industry. The launch of the CCTV-4K ultra-high-definition channel has fostered the integration of technological and cultural spheres. This paper analyzes the transmission application of the CCTV 4K ultra-high-definition broadcasting system, examining the signal backhaul scheduling of 4K live programs, the switching processing of live signals within the broadcasting system, as well as operational issues and emergency response methods in CCTV 4K live broadcasting, with a focus on analyzing the transmission technology of the CCTV 4K ultra-high-definition broadcasting system and the problems inherent in this system.

Full Text

Research on the Transmission and Application of Live Signals in CCTV' s 4K Ultra-High-Definition Broadcasting System

Author Affiliation: Tonglu County Media Convergence Center, Hangzhou, Zhejiang 311500

Abstract: With the advancement of live broadcasting technology, 4K ultra-high-definition (UHD) online production and transmission technologies have rapidly evolved. Increasing audience demand for video clarity has fundamentally transformed the entire video imaging industry. The launch of CCTV' s 4K UHD channel has fostered integration between technology and cultural sectors. This paper analyzes the transmission and application of CCTV' s 4K

UHD broadcasting system, examining signal backhaul scheduling for 4K live programs, switching and processing of live signals within the broadcasting system, and operational issues and emergency response methods during CCTV 4K live broadcasts. The analysis focuses on transmission technologies within CCTV' s 4K UHD broadcasting system and existing problems within the system.

Keywords: CCTV; 4K ultra-high-definition broadcasting system; transmission technology; live broadcast; live signal; 4K video

Classification Code: TI948.1
Document Code: A
Article ID: 1671-0134(2021)02-117-03
DOI: 10.19483/j.cnki.11-4653/n.2021.02.035

4K ultra-high-definition television features high resolution, high dynamic range, wide color gamut, high frame rate, and three-dimensional audio, delivering an immersive audiovisual experience to audiences. Moreover, 4K UHD represents a crucial development direction for broadcast television. With continuous advancements in information technology, television UHD broadcasting technology has undergone a tremendous evolution from traditional analog formats through digital, standard-definition, and high-definition modes to today' s ultra-high-definition paradigm. Television programs now employ two presentation methods: pre-recorded and live broadcasting. The pre-recorded approach involves pre-production planning, filming, editing, and post-production compilation before delivering the final program file to the broadcasting station. Conversely, live broadcasting utilizes UHD cameras to capture real-time scenes, transmitting live signals to the station' s studio for processing and broadcast. While the former lacks the authenticity of the latter, live broadcasting offers audiences superior interactivity and engagement, creating a sense of presence that authentically conveys the program' s content. However, live broadcasting presents significantly greater challenges and imposes substantially higher filming requirements than pre-recorded programs.

As CCTV' s 4K UHD video technology has been trialed in various sports events, it has proven capable of successfully completing live broadcasts even under challenging conditions. The following sections primarily address front-end signal backhaul scheduling, signal switching processing, live testing procedures, and emergency countermeasures during CCTV 4K UHD broadcasting system operations.

1. Construction of CCTV' s 4K UHD Video Broadcasting System

The construction of CCTV' s 4K UHD video broadcasting system must comply with relevant national technical standards to create an integrated platform combining management, monitoring, and broadcasting capabilities. The system

utilizes automated hard disk control software to manage broadcast operations, enabling sequential broadcasting of high-definition television programs while implementing video control. The system' s main advantages fall into three categories:

1.1 Application of New Technologies in CCTV' s 4K UHD Broadcasting System

CCTV' s 4K UHD video broadcasting system integrates 4K technology into file management and business processes. By employing virtual infrastructure, the system uniformly enhances 4K video file transcoding capabilities, bandwidth rates, and quality control computing power. It strengthens 4K UHD video playback through optimized allocation of basic resources for video data monitoring, fault diagnosis, and analytical processing. Finally, video baseband signals undergo IP-based transmission, encapsulated within the foundational audio-video architecture. Combined with IT switches or physical line interfaces, this provides high-frequency bandwidth support for 4K UHD video transmission, offering convenience to operational personnel.

1.2 Enhanced 4K Video Broadcasting Quality

The integration of new UHD 4K display technology has significantly improved television program broadcasting quality in the 4K UHD system. The 4K UHD advantages manifest in digital quantization, three-dimensional audio, resolution, and color gamut. Furthermore, since traditional multi-channel automated hard disk broadcasting systems can effectively meet the requirements of 4K UHD broadcasting, diverse program formats can be broadcast live. Programs can also be broadcast sequentially through the 4K UHD system in either automated or manual modes. The primary broadcasting methods include live signal backhaul and file-based playback from hard disks or optical media.

1.3 High Flexibility

The 4K UHD broadcasting system employs traditional single-driver broadcasting for program transmission. Through a universal broadcasting platform architecture, the existing 4K UHD system integrates IT switches to effectively merge data resources and modules, further facilitating flexible business expansion of the UHD broadcasting system. Simultaneously, the 4K UHD broadcasting system incorporates emerging scientific technologies and operational capabilities, receiving support from server and virtualization technologies in software architecture construction, thereby driving flexible expansion of CCTV' s 4K UHD broadcasting system in television programming.

2. Live Signal Backhaul and Scheduling

CCTV' s 4K UHD broadcasting system transmission utilizes 4K UHD cameras for real-time scene capture, transmitting footage directly via cables to 4K direc-

tor' s rooms or broadcast vans. The live signals are then converted and transmitted through fiber optic technology and satellite networks directly to the master control studio for processing. Finally, the signals are delivered to master control, where they undergo decoding analysis, distribution, and scheduling before being transmitted through the television broadcasting system into a compression encoding system and uploaded to the network. Although current live signals can be selectively decoded and processed through peripheral equipment to achieve transmission, the architecture of this peripheral equipment requires adjustment and optimization to ensure effective and stable scheduling and transmission of live signals.

3. Live Signal Switching and Processing

3.1 Overall Framework Design for 4K UHD Live Signal Processing Systems

To ensure stable transmission of live signals and smooth broadcasting of 4K UHD video, the video server must meet high performance requirements. The 4K UHD broadcasting system employs primary-backup link design and heterogeneous design during construction, utilizing traditional signal baseband links as the primary route while establishing new IP-based signal transmission links as backup routes. This configuration allows both routes to maintain independence while remaining interconnected, even when employing 4x1 switching switches as emergency switches for the 4K UHD video broadcasting system. When other live signals access CCTV' s 4K UHD broadcasting system, decoders convert compressed SDI signals into 4K signals, which after synchronization operations are transmitted to both primary and backup links.

3.2 Live Signal Link Analysis

The primary and backup links for live signals differ significantly. The primary route is formed through direct scheduling via baseband matrix, transmitting to production personnel through video servers for adding logos, subtitles, time stamps, and other graphics. The signal then passes through the primary broadcast video server to distribution cards for live signal distribution before being delivered to both the primary 4x1 switching switch and the backup route for emergency purposes. After adjustment, the final-stage video distribution cards distribute and transmit the signal to master control. The backup link operates differently, encapsulating signals directly through IP gateway baseband, then transmitting the live signal to broadcast servers via IP gateway matrix adjustment. After switching and IP gateway baseband decapsulation, the signal is distributed and transmitted to master control through final-stage video distribution cards.

3.3 IP-Based Equipment Links

Due to the unique transmission requirements of 4K live signals, CCTV' s 4K UHD broadcasting system has implemented key technologies and equipment. Utilizing general switches through IP gateways for data transmission and live signal regulation control enables multicast transmission of live signals from few-to-many points within the general switch, substantially reducing network load capacity.

3.4 Compatibility of CCTV' s 4K UHD Broadcasting System

As 4K UHD broadcasting systems remain in the development stage, differences between 4K UHD and HD systems primarily involve resolution, dynamic range, and color gamut. However, high dynamic range and wide color gamut impose complex compatibility requirements. While high dynamic range and wide color gamut are mature in program shooting, production, and broadcasting, their effects are not particularly noticeable on some television terminals. Consequently, the compatibility of high dynamic range and wide color gamut in CCTV' s 4K UHD broadcasting system remains an unresolved issue.

4.1 High Frame Rate Broadcasting Control Technology

High frame rate broadcasting control technology optimizes and enhances the traditional HD broadcasting system' s 25 fps foundation architecture for UHD broadcasting control. The most common frame rate for 4K video is 60 fps, meaning the same frame is displayed 60 times per second. Traditional HD broadcasting systems establish the basic requirements for 4K UHD broadcasting architecture while enabling 4K UHD broadcasting software to accurately identify and locate in/out points of broadcast playlist file materials.

4.2 4K UHD Broadcasting System Control Switching Technology

In live audio or video links, broadcast signals connect to primary and backup video broadcast servers or heterogeneous backup servers to provide broadcasting pathways for live video. Finally, through 4x1 primary-backup switches configured with synchronized frames, clean switching functionality is achieved, enabling clean switching of 4K UHD live video signals.

4.3 Uncompressed IP Streaming Broadcasting System Technology

Based on 4K UHD broadcasting system transmission, the IP broadcasting system backbone platform is established through uncompressed IP streaming architecture and virtualized broadcasting modes, utilizing 10Gb switches and network architectures for control data exchange. This provides IP distribution control and signal transmission scheduling for various broadcast channels.

5. Live Signal Testing and Emergency Measures for CCTV 4K UHD Broadcasting Operations

5.1 4K UHD Live Signal Line Testing

The security and stability testing of live signals is crucial to CCTV 4K UHD broadcasting system construction. Before broadcasting UHD live programs, comprehensive functional testing of live signal lines is conducted to ensure signals transmitted from studios display normally. The status of primary and backup lines can be analyzed using oscilloscope equipment to examine frequency waveforms during broadcasting, identifying and correcting any impacts on CCTV 4K UHD video live broadcasting. However, since the primary and backup line architectures differ in the UHD broadcasting system, switching and scheduling are required during live signal broadcasting. During pre-broadcast line testing, different oscilloscopes must be used to detect both primary route SDI output and backup route gateway output signals. If technical or configuration issues are discovered during testing, alternative methods can be employed to systematically identify which link exhibits abnormalities, allowing for step-by-step fault elimination.

5.2 Emergency Operations During 4K UHD Video Live Broadcasting

To ensure uninterrupted live video broadcasting, technical specialists monitor the security and stability of live signals during 4K UHD broadcasting system operation. If live signals or broadcasting system equipment issues are detected, rapid response and adjustment can be implemented. Typically, after live signals are transmitted to the master control room and inspected by master control, they are delivered to the primary live signals of the UHD broadcasting system and subsequently broadcast through the video server system. This synchronization between backup signals and primary signals enables immediate emergency response when issues arise in CCTV 4K UHD video broadcasting.

6.1 Conversion Issues

Traditional HD television broadcasting servers operate through file-based broadcasting. Their broadcast files use standard-definition modes with bitrates of only approximately 14 Mb/s, reaching 50 Mb/s for single-frequency channels. However, this is substantially lower than the bitrates of 4K UHD broadcast files. Currently, 4K UHD video broadcast files commonly employ 500 Mbps, approximately ten times higher than traditional single-frequency rates.

6.2 Transmission Issues

For upcoming programs, traditional network-based delivery methods transmit content through various backbone platforms to other networks. However, 4K UHD video files have large storage capacities and consequently require higher transmission rates. While traditional delivery methods can be used for 4K UHD

video files, they gradually increase the broadcasting system' s load capacity. Moreover, without changing transmission rates, live signal transmission can cause unnecessary program impacts.

6.3 Signal Transmission Issues

CCTV' s 4K UHD television signals require transmission rates up to 12 Gb/s, imposing relatively high demands on cable transmission capabilities. Within the same transmission line, the distance of live signal transmission affects the broadcasting system's ability to transmit 4K UHD signals. To address this issue, IP switch transmission methods can be employed for 4K signal transmission, or 10Gb switching networks/ports can be used with compression to ensure signal transmission meets CCTV 4K UHD video requirements.

7. Solutions for CCTV 4K UHD Broadcasting Issues

As CCTV 4K UHD video broadcasting has continuously developed over the past two years, UHD television has gradually entered millions of households, slowly replacing traditional broadcasting systems. Meanwhile, most television stations have begun transitioning to 4K UHD broadcasting systems. However, CCTV' s 4K UHD television broadcasting technology requires further system and equipment stability improvements during practical application. Solutions can be implemented through the following approaches:

7.1 4K UHD Broadcasting System Architecture

Despite requiring traditional television broadcasting architecture integrated with mainstream technologies to construct 4K UHD television broadcasting systems, the internal systems require interconnected platforms for cross-broadcasting of video file materials. After processing through the master control studio production system, IP gateways schedule and switch live signals, which following a series of reviews and conversions are delivered to the 4K UHD broadcasting system for distribution across all-media platforms. This UHD broadcasting system architecture not only supports 4K video file broadcasting but also effectively implements live and HD channel broadcasting requirements.

7.2 Signal Broadcasting

Through the established CCTV 4K UHD broadcasting system, superior programs can be presented to audiences. However, this broadcasting system imposes high requirements on signal transmission, bandwidth, and storage. Considering the numerous issues in 4K UHD broadcasting system television program broadcasting—such as live signal collection, program data production and storage, and distribution to various signal terminals—the most critical issue is signal transmission. Although 4K UHD video can be transmitted in original code under normal conditions, its transmission rate reaches approximately 12 GB/s,

while China' s current common signal transmission rates are less than 2 Gb/s. Therefore, to enable efficient and stable 4K UHD video signal transmission, IP encapsulation must be utilized. Another adjustment involves compressing signals before bandwidth-based transmission.

7.3 All-Media Platform Distribution

The construction of 4K UHD broadcasting systems can be realized through all-media network platform distribution, utilizing common social software, apps, portal websites, and other platforms for unified distribution. This approach effectively combines content recommendation broadcasting based on audience preferences while allowing users to select on-demand or live content according to their needs, enabling precise push delivery.

7.4 Transition to IP-Based Architecture

Transmission can be implemented through wired networks or WiFi. Currently, some traditional audio-video equipment manufacturers have gradually begun transitioning to IP-based architecture, constructing IP matrix models suited to their development. As relevant specifications and standards continue to improve, the construction of 4K UHD broadcasting systems not only accelerates IP-based transformation but also deconstructs traditional network broadcasting architecture, providing more signal transmission channels for audio-video content and ensuring quality in 4K UHD video signal transmission.

The transmission scheduling of live signals in CCTV' s 4K UHD broadcasting system, combined with advanced technologies such as IP encapsulation/decapsulation and virtualization applications, represents a breakthrough in China' s television industry technology and indicates the future development direction for traditional television technology. The 4K UHD broadcasting system operates relatively smoothly, with efficient signal scheduling and transmission and excellent coordination across all components. Against the backdrop of rising consumer demand, the future 4K UHD video industry will continue to develop and update, making television live program production and broadcasting increasingly convenient and efficient.

References

[1] Xu Bin. Transmission and Application of Live Signals in CCTV' s 4K Ultra-High-Definition Broadcasting System [J]. Modern Television Technology, 2019(5): 134-137.
[2] Tang Ke. Design and Innovation of the Audio System for China' s First Satellite CCTV-4K Ultra-High-Definition Channel Studio [J]. Modern Television Technology, 2019(6): 60.
[3] Gao Haizhu. Application of TICO Codec in 4K Ultra-High-Definition Broadcasting System [J]. Digital Communication World, 2020(9): 31-35.

[4] Li Tianxiao. Construction and Implementation of OTT and 4K Broadcasting System Platform [J]. China Cable Television, 2019(3): 266-269.
[5] Zhou Xuedong. Analysis of IP Links in CCTV' s 4K Ultra-High-Definition Broadcasting System [J]. Modern Television Technology, 2019(9): 46-50.
[6] Wang Lei. Research on Issues Faced by 4K Ultra-High-Definition Television in Traditional Broadcasting and System Construction [J]. Media Forum, 2020(6): 51.
[7] Yang Kaihong. Analysis and Research of 4K Ultra-High-Definition Television Broadcasting System [J]. China Cable Television, 2020(6): 610-612.
[8] Gao Haizhu. Design of Network Security Architecture and Intelligent Security Early Warning Platform for 4K Ultra-High-Definition Broadcasting System [J]. Modern Television Technology, 2020(7): 120-124.
[9] Zhang Juan. Discussion on Key Points of 4K Ultra-High-Definition Broadcasting System [J]. Modern Television Technology, 2018(6): 68-73.

Author Biography: Pan Bingshun (1983-), male, from Tonglu, Zhejiang, Engineer. Research direction: Radio and television.

(Editor in charge: Hu Yang)

Note: Figure translations are in progress. See original paper for figures.