Discussion and Application of FM Synchronous Broadcasting Network Technology (Postprint)

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Abstract

This paper discusses and analyzes the application of FM synchronous broadcasting network technology at Huangshan Radio and Television Station, focusing on system principles, system design, equipment composition, coverage design and performance analysis, and coherent zone analysis and adjustment.

Full Text

Introduction

With the rapid development of national economic construction and urban expansion, the number of in-vehicle listeners has increased continuously. The original coverage model of Huangshan Radio and Television Station, which primarily served urban areas, can no longer meet actual needs. There is an urgent requirement to expand FM broadcast coverage to achieve city-wide service. However, due to Huangshan' s location in the mountainous region of southern Anhui with complex terrain, limited transmitter tower positions and heights have resulted in poor broadcast frequency coverage for many years. Currently, signals can only reach the main urban area and surrounding townships, with many districts and counties still experiencing poor coverage or blind spots. To address this situation, station technicians conducted field research and analysis, and after consulting with experts and manufacturers, concluded that FM synchronous broadcasting network technology could be applied in this mountainous region.

FM synchronous networks offer several key advantages: (1) They employ advanced digital and network technologies, making their overall technical level superior to conventional FM networks. (2) Conventional FM networks consume more frequency resources than synchronous networks—new sites require additional frequency applications—whereas FM synchronous networks use a single frequency throughout, eliminating the need for new frequency resources when adding stations. (3) Conventional FM networks rely on single-site coverage capability with no mutual support between stations on the same frequency, reducing overall network coverage efficiency. FM synchronous networks provide extensive coverage with mutual support between stations on the same frequency, yielding high network coverage efficiency. (4) Conventional FM networks do not support continuous cross-regional program listening, whereas FM synchronous networks do, making them particularly suitable for long-distance mobile listening of the same program. (5) Network-based remote monitoring systems enable automated management of each transmitter, offering high automation and network reliability. (6) This establishes a solid foundation for system operations, creating economic benefits while ensuring social benefits.

1. System Principle of FM Synchronous Broadcasting Networks

FM synchronous broadcasting networks combine digital and network technologies, adhering to China's industry technical standard "GY/T154-2000 Technical Specifications for FM Synchronous Broadcasting Systems"to achieve "three samenesses" (same frequency, same phase, same modulation) and "one guarantee" (guaranteed minimum reception field strength), completely solving interference problems in broadcast transmission coherent zones and enabling seamless synchronous coverage across the entire system. Digital baseband synchronization technology, a universal single-frequency network synchronization method successfully applied in DVB-T, DAB, national standard terrestrial digital television DTMB, and CMMB systems, can be adopted for FM synchronous broadcasting networks. This technology uses 1PPS and 10MHz clock and frequency reference signals output by a GPS standard frequency generator as the reference for synchronous encoders and decoders, solving automatic delay adjustment issues in transmission with phase synchronization accuracy of less than 1 microsecond, meeting synchronous broadcast requirements. Simultaneously, digital FM technology ensures that all performance indicators of FM signals transmitted from each station are completely identical (synchronous), precisely achieving physical synchronization across the entire FM network.

The core equipment of FM synchronous broadcasting networks consists of synchronous encoders, synchronous decoders, and digital synchronous exciters (with pilot synchronization), whose collaborative operation accomplishes the synchronization technology. The synchronous encoder, installed in the signal front-end system, receives digital stereo audio signals from the audio distributor, encoding, compressing, and multiplexing them for transmission as a multiplexed stream carrying audio signals. Synchronization time identifiers are inserted into the stream to provide a time synchronization reference for synchronous decoders. The synchronous encoder outputs signals through E1 or ASI interfaces to digital transmission networks (such as cable television networks or fiber optics), which distribute signals to each transmitter station. Synchronous decoders installed at each transmitter station work in conjunction with the synchronous encoder, primarily receiving program transmission streams from the network, demultiplexing signals, measuring system delay based on received synchronization time identifiers, and automatically compensating for audio delays to ensure "time synchronization" across all transmitter stations before delivering digital audio signals to digital synchronous exciters. The performance of digital synchronous exciters directly relates to carrier and modulation stability and is key to achieving high-quality synchronous broadcasting. They must incorporate all functions of internationally common digital exciters while adding a "synchronization signaling" function to enable automatic synchronous adjustment. With high-quality digital synchronous exciters, FM signals from each station in the network can achieve the following "five samenesses" : same frequency—transmitter carriers locked to GPS frequency reference; same phase—identical audio transmission delay across stations; same pilot—strictly synchronized 19kHz pilot frequency and phase; same modulation—identical modulation across transmitters; and same pre-emphasis—strictly consistent pre-emphasis curves.

2. System Design of FM Synchronous Broadcasting Networks

The system employs digital baseband synchronization principles with standardized design, fully complying with the FM synchronous industry standard "GY/T154-2000 Technical Specifications for FM Synchronous Broadcasting Systems." The designed system should be easily integrated, highly universal, strongly scalable, and have a long lifecycle. The entire system is a "networked" project comprising four components: (1) Synchronous network front-end system (primarily implementing synchronous encoding, distribution, and transmission of broadcast program signals, as well as centralized monitoring of equipment at each transmitter site, mainly consisting of audio synchronous encoders, GPS receiving antennas, GPS standard frequency generators, digital audio distributors, and multiplexers); (2) Decoding and FM synchronous transmission unit (primarily implementing synchronous decoding of broadcast program signals and wireless transmission of FM synchronous signals, mainly consisting of synchronous decoders, GPS receiving antennas, GPS standard frequency generators, digital synchronous exciters, multiplexers, distributors, FM transmitters, and antenna-feeder systems); (3) Remote monitoring and management center (primarily implementing monitoring and management of transmission systems and working environments at each site, requiring bidirectional transmission of remote monitoring signals, which can utilize the bidirectional links of program distribution networks or mobile communication 4G/5G data services); and (4) Program transmission network (primarily implementing distribution of broadcast program signals to each site in the synchronous network while completing bidirectional communication of monitoring information, requiring digital interfaces in ASI or E1 form, with topology that can use point-to-point links, existing digital cable television networks, SDH networks, or their combinations). FM synchronous network transmission requires reliable, stable, low-jitter links; otherwise, unreliable transmission will cause loss of synchronization and network disruption, affecting safe broadcast operations, making the transmission network a critical component of the system.

3.1 Front-End System

The front-end synchronous encoder adopts a 1+1 hot backup structure with automatic/manual switching capability. Input signals use digital audio interfaces in AES format, with one synchronous encoder capable of processing synchronous encoding for one program' s digital audio signals. Program signals can be sourced from the front-end audio signal processor, distributed through an AES stream distributor to input identical program streams into primary and backup synchronous encoders. If the audio source only provides L/R analog audio signals, an AES encoder must be added. The GPS standard frequency generator provides a precise clock reference signal for the synchronous encoder, with two GPS generators forming a 1+1 backup structure. The synchronous encoder outputs in ASI format, enabling utilization of existing municipal cable television networks to transport synchronous audio streams to each transmitter station. The front-end audio synchronous encoder outputs one program' s TS stream with adjustable bit rates between 64-1024 kbps, which can be multiplexed with current television program streams, saving network investment and improving utilization of existing infrastructure.

3.2 Program Transmission

The synchronous encoder' s ASI output can fully leverage existing cable television transmission systems, equipment, and network resources. ASI synchronous audio streams can be conveniently interfaced with local cable television networks and multiplexed with current television programs for transmission over the same cable, conserving network investment and enhancing existing network utilization. Once program streams enter the cable television network, signals can be accessed at all nodes and interfaces throughout Huangshan' s cable network, facilitating expansion of the FM synchronous network and future new site construction. If county-level cable television rooms lack existing links to county transmitter stations, the synchronous audio stream can be relayed via existing microwave or fiber optic links, or a new short-range microwave link can be established to complete the last-mile program transmission.

3.3 Back-End (Decoding and FM Synchronous Transmission)

The back-end primarily consists of synchronous decoders, GPS standard frequency generators, GPS antennas, digital synchronous exciters, FM transmitters, and antenna-feeder systems. Synchronous digital audio signals are transmitted via cable television networks in DVB-C/QAM carrier form to transmitter rooms and enter the synchronous decoder. The synchronous decoder demodulates the multiplexed TS stream from the QAM carrier and demultiplexes it to restore the original audio AES program stream, which then enters digital synchronous exciters for different transmitters. The synchronous decoder uses clock signals provided by the GPS generator as a reference to coordinate with the front-end synchronous encoder, achieving time synchronization for FM broadcasting. The digital synchronous exciter uses GPS generator clock signals as a reference to ensure unified frequency and phase across all transmitters, while also guaranteeing consistent modulation and pre-emphasis curves.

3.4 Remote Monitoring and Management System

FM synchronous transmission system monitoring differs from conventional FM transmitter monitoring, requiring not only remote transmitter monitoring but also system synchronization equipment monitoring. For transmitters in a synchronous network, "broadcasting in non-synchronous state" creates severe co-channel interference in coherent overlap zones, necessitating a comprehensive remote monitoring and management system. This system monitors equipment and working environments at each synchronous network site, enabling technical operators to observe equipment status in real time and address issues promptly, improving system reliability and availability—essential for safe broadcasting in FM synchronous networks. Functions include: (1) Remote transmitter monitoring of operational status parameters and alarm information; (2) Remote synchronization equipment monitoring of GPS reference sources, synchronous decoders, and other devices' operational parameters and alarm information. Controlled equipment at each site transmits status parameters and alarm information via 4G wireless internet to a monitoring server on the public cloud. Operators can log in to the public cloud from computers to access real-time equipment status and alarm information from all stations. The monitoring server automatically records equipment status and alarm information from each transmitter station, accepts access from authorized digital terminals (computers, mobile phones, tablets, etc.), and provides data query, organization, and printing functions.

4. Coverage Design and Effect Prediction

Located in a mountainous region, achieving seamless city-wide FM synchronous coverage for Huangshan requires substantial investment. Therefore, a step-by-step strategy can be implemented: first ensuring seamless synchronous coverage of all urban areas, townships, highways, and scenic spots, with subsequent infill based on funding and requirements. Through preliminary survey and research, a network can be formed with Huangshan Radio and Television Station' s main Huishan transmitter as the center, utilizing existing wireless transmitter stations in Shexian, Qimen, and Huangshan District to achieve effective city-wide broadcast coverage.

Except for the relatively close distance between Huangshan transmitter station and Shexian transmitter station (18 km), Qimen and Huangshan District transmitter stations are over 50 km from other stations with high mountains blocking signals between them. Signals from Huangshan and Shexian transmitter stations can create strong signal coverage overlap, enabling synchronous coverage through synchronization control technology adjustment of coherent zones. Qimen County transmitter station is distant from other sites and cannot achieve strong signal overlap coverage. However, a straight valley facing Huangshan facilitates electromagnetic wave propagation, allowing Qimen' s transmitting antenna maximum radiation direction to be oriented accordingly to extend coverage. Huangshan District transmitter station is also distant from other stations, with surrounding mountains blocking signals and preventing overlap with other stations.

5. Coherent Zone Analysis and Adjustment

Coherent zones generally occur in areas where signals from adjacent transmitter stations overlap at equal field strength. The most likely location for equal field strength meeting between signals from Huangshan transmitter station and Shexian transmitter station is between Wang' an Town and Yansi Town, representing the highest probability coherent zone. Huangshan transmitter station' s antenna maximum radiation direction should point toward Xiuning to satisfy coverage of Xiuning' s urban area while extending electromagnetic waves toward Qimen. With Huangshan transmitter station operating at full power, Shexian' s antenna direction can be reasonably adjusted or its transmitter output power appropriately reduced to create proper partial overlap between Shexian' s and Huangshan' s signals. Simultaneously, by adjusting independent delay parameters of exciters, signals from different transmitters can arrive simultaneously at the coherent zone' s central area. Well-adjusted synchronous FM coverage enables vehicles traveling between Huangshan and Shexian to continuously receive the same broadcast program normally.

Through the above analysis, adopting FM synchronous broadcasting network technology in Huangshan can efficiently utilize spectrum resources, further expand broadcast service coverage, improve user reception quality, broaden market prospects for broadcast services, and achieve excellent social and economic benefits.

[1] 魏方园. 调频同步广播技术的最新发展及应用 [J]. 卫星电视与宽带多媒体, 2020, (07): 60-61.

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