Key Technologies and Optimization for Single Frequency Network Formation in Terrestrial Digital Television Broadcasting: Postprint

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Abstract

With the rapid development of contemporary society, people' s dependence on technology has significantly increased, and society has essentially entered a technological era, bringing great convenience to people' s lives. Terrestrial digital television broadcasting has developed based on modern technology, possesses distinct advantages compared to traditional analog television, and has been widely applied in present-day society. As an important networking form in terrestrial digital television broadcasting, the single-frequency network' s application has brought considerable benefits to society and demonstrates certain technical advancement, yet still exhibits deficiencies requiring further adjustments in the future. This paper will, in conjunction with actual conditions, conduct a detailed analysis of the key technologies and optimization paths for terrestrial digital television broadcasting single-frequency network networking, with the aim of providing reference and guidance for related work to be carried out in the future.

Full Text

Preamble

Digital terrestrial television broadcasting has emerged and evolved based on modern technology, offering robust capabilities for information dissemination. In China, a significant amount of information and news is transmitted through digital terrestrial television broadcasting, with single-frequency networks (SFN) serving as the primary technical foundation for this development. Current terrestrial digital television transmission in China primarily adheres to the DTMB national standard (GB20600-200), which offers distinct advantages and has gradually matured into the DTMB-A system with complete independent intellectual property rights. By leveraging SFN broadcasting systems, television broadcasting has achieved intelligent development. To further accelerate network construction technology, continuous optimization and innovation are essential.

The "digital microwave + SDH" program transmission network offers considerable convenience in construction, with straightforward operations and relatively low costs. Compared to "fiber optic + SDH," this transmission network can be effectively deployed in challenging geographical environments such as hilly and mountainous areas, regions with poor environmental conditions, and island locations, demonstrating strong adaptability. In the current technological landscape, "digital microwave + SDH" has gained widespread application, though it differs significantly from alternative approaches in aspects such as program output methods. In this architecture, digital microwave serves as the equipment carrier, with the generated carrier stored in SDH and converted into microwave RF signals for transmission to equipment. To ensure rational application and leverage the respective advantages of different architectures, scientific design during the construction phase is essential to ensure compatibility with regional and environmental characteristics.

2.1 SFN Networking Technology

In practical applications, SFN networking technology employs multiplexers to perform source encoding and compression of program streams and information data streams, outputting TS source code streams that are then fed into SFN adapters to complete TS/ASI code rate adaptation. ASI (Asynchronous Serial Interface) maintains a fixed code rate of 270 Mb/s, which satisfies transmission requirements for TS signals at various code rates. To achieve frequency synchronization across SFN sites, program bit synchronization, and exciter clock synchronization, GPS technology is integrated into adapters to leverage their clock reception capabilities. Based on ASI/DS3 adapters supporting ASI stream output, DS3 stream signals are output through nonlinear encoding and ultimately transmitted through STM-1 channels. Throughout this process, adapters function according to specific network transmission requirements, enabling conversion between low-order and high-order code streams (or vice versa) to adapt to network transmission environments. It is important to note that ensuring complete consistency of code streams across all transmission processes requires implementing 100% transparent transmission to maximize transmission effectiveness.

2.2 SDH Network Transmission

The information structure hierarchy employed by SDH transmission networks is referred to as Synchronous Transport Module level N (STM-N, where N = 1, 4, 16, 64). In practical applications, the frame structure carries information in a block format, with STM-1 (block-structured unit frame) serving as the basic synchronous transport module, achieving transmission rates of 155.520

Mb/s. Based on current network transmission capacity requirements, 4, 16, or 64 STM-1 modules can be multiplexed into STM-4, STM-16, and STM-64 transport modules, respectively, corresponding to their respective peak rates. Two primary program transmission network types exist: fiber optic + SDH and digital microwave + SDH. In fiber optic + SDH program transmission networks, transmitted program ASI streams and management unit pointer information are first multiplexed into DS3 signals, then further multiplexed into the functional area corresponding to STM-1, forming STM-1 transport modules to create baseband signals for transmission over fiber optic networks. To enable transparent transmission of TS code streams in terrestrial digital television broadcasting SFN program transmission systems, ASI-DS3 adapters must be properly applied, with TS null packets and null packets inherent to TS streams used for padding to facilitate final restoration of TS streams to their initial values.

2.3 SFN Transmission System

The SFN transmission system represents a critical component of terrestrial digital television broadcasting, characterized by distinct functional features. After TS stream signals are demodulated by the receiving system, they undergo synchronous encoding and carrier modulation at transmission points, with signals transmitted in-phase within a controllable time frame. This approach maximally ensures effective signal transmission and stability.

3. Optimization Paths for Terrestrial Digital Television Broadcasting SFN

Based on the above analysis, it is evident that current terrestrial digital television broadcasting SFN implementation relies on numerous technical supports to ensure normal operation. However, with societal development, original networking advantages struggle to adapt to rapid social progress. Optimization of SFN networking must therefore incorporate specific characteristics of the new era to satisfy holistic societal development demands.

3.1 Scientific Selection of Systems

A stable, high-performance, and highly reliable SFN broadcasting system provides a solid foundation for improving the overall operational efficiency of terrestrial digital television broadcasting. To better adapt to modern society, scientific selection and configuration of SFN systems and parameters are essential. Key components include channel transmission systems, source encoding systems, and network parameter facilities. Through scientific selection and configuration, the receiving system can be ensured to possess robust anti-echo interference capabilities under long-term echo delay conditions, minimizing bit error probability and guaranteeing signal transmission stability. Additionally, SFN networking design and optimization must incorporate regional characteristics, as modern building complexes and special terrain can significantly impact network construction and optimization. Therefore, following the principle of adapting measures to local conditions, transmitter antenna gain must be rationally designed to ultimately achieve a "petal diagram" pattern, ensuring comprehensive improvement in multipath signal processing capabilities for all receivers while increasing transmission point spacing, which promotes simplification of SFN systems and overall performance adjustment and optimization.

3.2 Emphasis on Signal Coverage Overlap Area Configuration

Successful SFN networking in terrestrial digital television broadcasting is primarily marked by signal coverage overlap, which accompanies successful regional source structure reception. Overlap areas generally refer to regions receiving coverage signals from two or more sites in different directions—that is, multipath signals. However, the presence of multipath signals directly impacts receiver decoding, while SFN network performance and adjustment are fully manifested in signal coverage overlap areas, making multipath signal delay adjustment a crucial means for network performance optimization. During construction, emphasis must be placed on configuring signal coverage overlap areas by selecting naturally protected back-to-back positions to reduce co-channel interference while avoiding complex multipath signal conditions in overlap regions. This approach enables gap-filling for blind spots and ensures comprehensive coverage. For example, during SFN construction for terrestrial digital television broadcasting in Zhuhai, single coverage transmission points proved insufficient. To ensure construction quality, planning proposed leveraging the Phoenix Mountain viewing point along the Hong Kong-Zhuhai-Macao Bridge for implementation. With Phoenix Mountain exceeding 400 meters in elevation, it provides convenient and ideal environmental conditions for transmission. To ensure successful transmission, transmitter antenna structures must be precisely selected, with specifications of 1 kW transmission power providing accurate coverage of main urban areas and partial western regions. Regarding SFN selection, SDH channel transmission remains primary, requiring consideration of frame structure differences corresponding to coverage ranges of 16 km, 23 km, and 36 km, thereby ensuring construction quality and optimizing the SFN network.

3.3 Adherence to SFN Optimization Principles

Currently, China' s terrestrial digital television broadcasting SFN optimization and construction are progressing steadily, driving societal development and enabling people to better enjoy direct conveniences brought by technology. Through long-term construction experience and systematic research, it has been established that SFN performance adjustment and optimization must prioritize reducing multipath interference formed by various transmission points in coverage overlap areas as the fundamental principle—an essential requirement for current SFN optimization. Based on this principle, SFN transmission point locations, antenna heights, transmission power, signal overlap areas, and tilt angles must all be scientifically designed and adjusted to better adapt to current societal development contexts and technological backgrounds, thereby improving overall network performance. Meanwhile, multipath signal relative delay has emerged as an important optimization method for network performance adjustment, requiring scientific understanding. Throughout the SFN construction process, engineering technicians must also comprehensively consider various factors and practical elements, as SFN construction is inherently susceptible to objective influences. Without practical and comprehensive consideration, final construction outcomes may be compromised. To further enhance optimization effectiveness, network conditions must be evaluated through continuous performance testing, repeated adjustment and optimization using multiple methods to determine final construction schemes, thereby comprehensively improving overall SFN performance.

In summary, against the backdrop of the technological era, people' s living environments and social production methods have undergone significant changes. Traditional terrestrial analog television broadcasting, as an important household appliance, has gradually exposed its application limitations and struggles to meet diverse user needs, leading to its gradual phase-out. The emergence of terrestrial digital television broadcasting, particularly the application of SFN technology, has transformed previous signal propagation methods and improved overall efficiency. However, due to rapid technological iteration, further optimization and adjustment are required through scientific system selection, emphasis on signal coverage overlap area configuration, and adherence to SFN optimization principles to ensure SFN networking better serves the public, holding important practical significance.

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