Terrestrial Digital Television Single Frequency Network Research Postprint

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Abstract

The introduction of Single Frequency Networks (SFN) has effectively alleviated and improved the increasingly tense situation of broadcast television frequency resources. This paper, combined with a multi-site DTMB SFN networking instance, proposes three technical solutions—delay, power, and antenna downtilt angle—to optimize the network, achieving favorable coverage results.

Full Text

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Research on Terrestrial Digital Television Single-Frequency Networks

Abstract: The introduction of single-frequency networks effectively alleviates and improves the increasingly tense situation of radio and television frequencies. This paper proposes a three-pronged technical approach—delay, power, and antenna downtilt angle—to optimize the network, achieving favorable coverage results based on a DTMB single-frequency network multi-site deployment case study.

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1. Single-Frequency Network Architecture

A single-frequency network (SFN) refers to multiple transmitter stations broadcasting identical signals simultaneously on the same frequency to cover a specific area, thereby improving spectrum utilization and network coverage quality.

Establishing a secure and efficient SFN requires solving the "synchronization" problem, which is primarily addressed through GPS synchronous clock reference sources and SFN adapters.

1.1 Frequency Synchronization

To ensure stable decoding of signals transmitted throughout the system, all transmitters in an SFN must output signals at identical frequencies. This demands high frequency accuracy and stability from each transmitter.

1.2 Time Synchronization

For signals from other transmitters to fall within the delay range that receivers can tolerate, all transmitters in the system must be strictly time-synchronized. This means the same signal frame should be transmitted by each transmitter at precisely the same moment.

1.3 Bit Synchronization

When transmitters in an SFN send identical signal frames at the same time, all signal frames must undergo identical modulation. Signal frames transmitted by different transmitters at different moments should be completely consistent without any tolerance.

The maximum inter-station distance is a critical parameter for terrestrial digital television single-frequency networks, determining transmitter site selection, construction costs, and network complexity. This maximum distance primarily depends on the system's ability to resist echo interference—greater tolerable echo delay allows larger inter-station distances. The theoretical maximum distances under the three national standard frame header formats are: PN420 frame header, L=16.67 km; PN595 frame header, L=23.61 km; PN945 frame header, L=37.5 km.

In 2015, Hunan Broadcasting Mobile Television Co., Ltd. implemented a four-site SFN deployment in Changsha, Hunan. The station parameters were as follows: **Yuelu Mountain:** altitude 300 m, antenna height 20 m, average relative height to receivers 280 m, transmitter power 1 kW. **Damoling:** altitude 777 m, antenna height 30 m, average relative height to receivers 750 m, transmitter power 1 kW. **Tiaoma:** altitude 230 m, antenna height 20 m, average relative height to receivers 200 m, transmitter power 1 kW. **Nanyue:** altitude 70 m, antenna height 190 m, average relative height to receivers 210 m, transmitter power 0.5 kW. The spatial relationships among the four base stations are shown in Figure 1 [Figure 1: see original paper].

Based on these station distances and the national standard SFN frame header format theory, the distances between Damoling, Yuelu Mountain, Tiaoma, and Nanyue exceed the theoretical maximum for the PN945 frame header format. Each base station's coverage effectiveness varies according to altitude and tower height factors. The actual coverage performance of the four stations without any network optimization is shown in Figure 2 [Figure 2: see original paper].

3. Network Optimization

SFNs impose stringent synchronization requirements, particularly when transmitter spacing exceeds the distance corresponding to the guard interval, making network interference likely in overlapping coverage areas.

Three primary optimization methods exist for SFNs: adjusting transmitter power, adjusting transmitter delay, and adjusting antenna downtilt angle. In practical deployment environments—especially when the SFN contains transmitters far beyond the guard interval—delay adjustment alone can create new interference in previously well-covered areas when optimizing partial overlap zones. Additionally, reducing power at high-altitude stations to eliminate overlap interference simultaneously reduces effective coverage area.

After technical discussion and comprehensive evaluation, we implemented a solution combining antenna downtilt adjustment and transmitter delay to eliminate overlap interference, achieving network optimization and improved overall coverage. Based on station conditions and actual coverage performance, signal measurements in overlapping areas revealed that although field strength met reception standards, program stream decoding failed due to severe interference, with interference zones continuously shifting within overlap areas due to various natural factors.

Optimization Implementation

(1) Adjusting transmission distances: Damoling station's east-facing antenna half-power transmission distance was set to 18 km, and south-facing full-power transmission distance to 18 km. Yuelu Mountain station's four-sided antennas were all set to 25 km half-power transmission distance. Tiaoma station's south, west, and north-facing antennas were all set to 20 km half-power transmission distance. Nanyue station's north-facing antenna full-power transmission distance was set to 63 km. Xingsha station remained unadjusted due to its power class and geographic location.

(2) Adjusting antenna azimuth angles: Using Damoling station as an example, we calculated required angle adjustments based on desired coverage distance. Figure 3 [Figure 3: see original paper] shows Damoling station's vertical plane radiation pattern, indicating a half-power angle of 5.2° and full-power angle of 14°, with manufacturer-specified electrical tilt of 1.2°.

The antenna downtilt angle ( ) is calculated as: = (half-power or full-power angle)/2 + arctan(H/R) - electrical tilt

Where H is the average relative height to receivers, R is the desired coverage radius, α is the antenna's half-power angle in the vertical plane, and c is the electrical tilt.

The relationships between these parameters are shown in Figure 4 [Figure 4: see original paper].

Calculation results: - East-facing antenna downtilt: = 5.2/2 + arctan(750/18000) - 1.2 = 3.78° - South-facing antenna downtilt: = 7/2 + arctan(750/18000) - 1.2 = 8.18°

After adjusting antenna azimuth angles and transmitter delays, subsequent signal measurements in overlapping coverage areas demonstrated that the base stations achieved the desired effect. Overlap zones exhibited controlled signal overlap that satisfied reception conditions. For isolated small-area "shadow coverage" issues preventing normal reception, small frequency-shifting repeaters could provide supplementary coverage.

Overall, this optimization was successful, accumulating substantial experience for future DTMB single-frequency network deployments.

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