National Standard Terrestrial Digital Television Coverage Network Planning Methods and Application Post-Print

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Abstract

With the application of digital terrestrial television transmission in China, DTMB has become the fourth international standard for digital terrestrial television, which will undoubtedly exert a tremendous and far-reaching influence on the development of China's digital television industry and its international advancement. During the construction of wireless transmitting stations, network planning constitutes a crucial task. This paper provides a concise overview of the fundamental knowledge pertaining to digital terrestrial television coverage network planning, with emphasis on several operating modes recommended by the national standard and commonly used formulas for coverage network planning calculations. Combined with a single-frequency network project, it discusses the calculation process and result visualization of the ICS Telecom NG coverage planning analysis software from the French company ATDI, thereby verifying the feasibility of employing simulation software for network planning, and proposes recommendations for network optimization tailored to this project.

Full Text

Planning Methodology and Application for National Standard Terrestrial Digital Television Coverage Networks

Abstract: With the terrestrial transmission application of digital television in China, DTMB has become the fourth international standard for terrestrial digital television, which will undoubtedly have a tremendous and far-reaching impact on the development of China's digital television industry and its international promotion. Network planning is a crucial task in the construction of wireless transmission stations. This paper provides a brief overview of the fundamental knowledge related to terrestrial digital television coverage network planning, with emphasis on several recommended operating modes of the national standard, commonly used formulas for coverage network planning calculations, and discusses the calculation process and result display of the ICS Telecom NG coverage planning analysis software from French company ATDI in the context of a single-frequency network project. The feasibility of using simulation software for network planning is verified, and suggestions for network optimization are proposed for this project.

Keywords: Terrestrial digital television; Wireless coverage planning; Simulation calculation
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1. Terrestrial Digital Television Coverage Network Planning

Terrestrial digital television network planning aims to achieve predetermined coverage objectives. Before constructing the coverage network, a systematic construction plan is developed in accordance with relevant industry standards, which includes configuring reasonable parameters such as the number of transmission stations, station locations, transmission power, antenna height, antenna type, and single-frequency network delay. This ensures that the network meets coverage requirements while minimizing construction costs and avoiding interference.

1.1 Terrestrial Digital Television Channel Characteristics

Terrestrial digital television transmission frequencies include meter waves (VHF) at 45-230 MHz and decimeter waves (UHF) at 470-800 MHz. Terrestrial digital television signals propagate freely in space and are significantly affected by external conditions, such as weather changes, reflections and scattering caused by terrain, buildings, and moving objects. In complex wireless channels, the presence of direct, reflected, and diffracted waves causes the received signal to be a composite of these waves, resulting in multipath effects. When multiple signals arrive at the receiver at different times, if the relative delay is much smaller than the symbol duration, the signals can be considered to arrive almost simultaneously, and multipath effects will not cause inter-symbol interference. However, if the delay exceeds the symbol duration, inter-symbol interference occurs, leading to signal fading.

1.3 Terrestrial Digital Television Transmission International Standards

The terrestrial digital television transmission standards currently adopted by the International Telecommunication Union include four standards: ATSC from the United States, DVB-T/T2 from Europe, ISDB-T from Japan, and DTMB from China. These four standards differ in channel coding and modulation schemes, each with its own technical advantages and disadvantages. In China, all urban terrestrial digital television systems adopt the national DTMB standard.

1.4 Operating Modes of the National Standard

In mainland China and Hong Kong, the terrestrial digital television standard primarily adopts the national standard. The seven operating modes recommended by the State Administration of Press, Publication, Radio, Film and Television are shown in Table 1 -1. Higher data rates enable higher-quality digital television services or more program channels within a single channel, but also result in higher reception thresholds. Based on laboratory testing and network deployment experience, Modes 1 and 2 are suitable for mobile reception; Mode 3 supports both fixed and mobile reception; Modes 4 and 5 are appropriate for high-bit-rate fixed reception in complex urban environments; and Modes 6 and 7 are suitable for very-high-bit-rate fixed reception in simple urban, suburban, and rural environments.

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2. Calculation Methods

2.1 Traditional Manual Calculation

Terrestrial digital television network planning is based on transmission models, whose accuracy directly affects the reliability of planning results. Transmission models can be broadly categorized into theoretical and empirical models. Due to the wide coverage area and complex transmission conditions of terrestrial digital television, theoretical models are not suitable; empirical models are generally adopted. According to testing and recommendations from broadcasting authorities, the primary transmission models applicable to digital television include the Okumura-Hata model, ITU-R370 model, ITU-R1546 model, and ITU-R526 model.

2.1.1 Maximum Line-of-Sight Coverage Distance Digital television signals are transmitted via line-of-sight. With known transmitter and receiver antenna heights, the transmission distance can be roughly estimated using the following formula:

$$D = 4.12(\sqrt{h_T} + \sqrt{h_R})$$

where D is the line-of-sight distance (km), h_T is the transmitter antenna height (m), and h_R is the receiver antenna height (m).

2.1.2 Free-Space Transmission Loss As the propagation distance of radio waves increases, the spherical surface area of space expands, causing the energy per unit area at the receiving point to gradually weaken. This energy loss is called free-space propagation loss. The free-space propagation loss calculation formula can be used for unobstructed link propagation calculations, such as microwave link loss calculations and indoor coverage calculations.

The free-space field strength E_0 at distance d from the transmitter is expressed as: [FORMULA]

The received field strength on flat ground is expressed as: [FORMULA] (dB V/m)

Assuming the field distribution on the receiving antenna surface has equal phase and amplitude, the effective area of the receiving antenna is: [FORMULA]

where G_r is the receiving antenna gain and λ is the wavelength at the center frequency.

The received power on the receiving antenna can be expressed as: [FORMULA]

In engineering practice, calculations are typically performed in dB. From the above equations, the free-space propagation loss L_s can be derived as: [FORMULA]

2.1.3 Non-Free-Space Transmission Loss The actual transmission environment for radio waves is typically non-free space. The Okumura-Hata model is commonly used for estimation in digital television engineering. The transmission loss P_L in the Okumura-Hata model is expressed as:

$$P_L = 69.55 + 26.16 \log f - 13.82 \log h_T - a(h_R) + (44.9 - 6.55 \log h_T) \log d$$

where P_L is the urban transmission loss (dB), f is the operating frequency (MHz), h_T and h_R are the effective heights of the transmitting and receiving antennas (m) respectively, $a(h_R)$ is the receiving antenna height correction factor, and d is the communication distance (km).

The receiving antenna height correction factor $a(h_R)$ is calculated as follows:

For small and medium cities: [FORMULA]

For large cities: [FORMULA]

Other commonly used correction factor calculation methods are as follows:

Suburban correction factor: [FORMULA]

Rural correction factor: [FORMULA]

Open area correction factor: [FORMULA]

2.1.4 Field Strength Calculation The received power level P_r expressed in decibels is: [FORMULA]

2.2 Simulation Software Calculation

Traditional manual calculation processes are complex, labor-intensive, and time-consuming. Nowadays, software tools can be used to complete coverage calculations, offering not only faster computation speed and higher efficiency, saving significant labor, but also improving the accuracy of results. This paper uses the ICS Telecom coverage planning analysis software from French company ATDI as an example to illustrate how to perform coverage calculations through simulation software. Network planning simulation calculations are mainly divided into three steps.

2.2.1 Basic Data Configuration **(1) Map Information** A key reason why simulation software produces more accurate results than manual calculations is its close integration with geographic information of the coverage area. Before calculation, appropriately detailed maps must be obtained from the software vendor. The ICS software includes seven layers, among which the .GEO digital terrain layer, .IMG+.PAL image layer, and .SOL clutter layer are essential for terrestrial digital television coverage calculations.

(2) Station Information Basic parameters to be configured for new stations include: station coordinates, transmission power, transmission antenna parameters, receiving antenna parameters, losses, operating mode, modulation type, etc.

Station site selection should prioritize existing stations and towers whenever possible. For new stations, factors such as power supply, program transmission, and construction conditions must be considered. Designers need to conduct on-site surveys and finalize locations based on simulation software coverage prediction results.

Transmission Power: During preliminary planning, transmission power is generally set based on the coverage area required by the user and previous engineering experience, then adjusted according to simulation results. Lower power should be used while ensuring adequate coverage.

Transmission Antenna Parameters: These include antenna gain, antenna height, antenna pattern, etc. Selection of transmission antennas must consider frequency range, maximum power, installation conditions, shape of the coverage area, installation dimensions, weight, and other factors.

Receiving Antenna Parameters: These include antenna gain, antenna height, etc. Selection must also consider the reception type: fixed or mobile reception, directional or omnidirectional reception, indoor or outdoor reception.

Losses: These include feeder loss and insertion loss. Feeder loss depends on the feeder type and must be selected appropriately based on transmission power. Larger feeder dimensions can handle higher power with lower loss but at higher cost.

Transmission Frequency: Generally requires analysis of the radio spectrum around the transmission station to select channels with relatively light usage and clean electromagnetic environments. In areas with scarce frequency resources, channels allocated to analog planning stations that have not yet been activated may be considered for digital television use.

Operating Mode and Modulation Type: These should be determined based on the number and quality of programs the client needs to transmit.

2.2.3 Coverage Result Display Calculation parameters mainly include receiving antenna height, coverage distance, coverage threshold, calculation model, etc. The coverage distance should generally be set slightly larger than the radius of the expected coverage area. If set too small, complete coverage cannot be obtained; if set too large, computation time becomes excessively long. The ICS software automatically generates a default typical threshold value based on the configured parameters, but custom thresholds can also be set according to the actual sensitivity of the receiver, and different colors can be assigned to display different field strength ranges.

In addition to coverage calculation for individual stations, the simulation software can also perform co-channel interference analysis. In this project, because the distance between the Hongshan and Shuixigou transmission stations (28 km) exceeds the PN sequence length requirement (16.7 km), co-channel interference occurs in the area near Hongshan between the two stations.

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3. Results Analysis

Taking the Urumqi single-frequency network and gap-filler coverage project in Xinjiang as an example, the simulation results are analyzed and compared with actual measurement results.

3.2 Point Measurement Data

The measured data basically aligns with the results obtained from the simulation software.

3.3 Results Comparison

Through comparative analysis, the measured data basically aligns with the results obtained from the simulation software, with over 75% of the area achieving good reception.

3.4 Network Optimization

In the co-channel interference analysis for this single-frequency network synchronous coverage, based on theoretical calculations with a reception threshold of 55 dB V/m:

(1) Because the distance between the two transmission stations (28 km) exceeds the PN sequence length requirement (16.7 km), co-channel interference exists in the single-frequency network formed by the two stations. However, for outdoor fixed reception, the actual reception performance in the co-channel interference area is better than theoretically predicted by simulation.

(2) Various optimization solutions are available to address this co-channel interference phenomenon, such as adjusting single-frequency network delay, adjusting transmission power, adjusting antenna patterns, and other methods, which can be used in combination.

(3) Due to the complex terrain and numerous mountains in Xinjiang, to ensure coverage rate, it is recommended to establish gap-filler relay stations in batches, first ensuring coverage of densely populated areas, then supplementing with stations in remote and sparsely populated areas based on available funding.

4. Conclusion

Through comparison between the coverage simulation prediction results of the single-frequency network and gap-filler coverage project and the actual measurement results after network construction, it can be verified that the simulation software predictions basically align with actual results. Coverage planning analysis software can serve as an auxiliary tool for engineering design of terrestrial digital television coverage network planning. By using simulation software for coverage network planning, the predicted post-construction network effects can be displayed intuitively, allowing users and design personnel to clearly understand the coverage effects after network completion. If predictions deviate from expected targets, relevant engineering parameters such as station location, antenna height, antenna pattern, antenna gain, and transmission power can be conveniently and quickly adjusted through iterative simulation calculations and modifications to achieve satisfactory coverage effects and obtain optimal design solutions.

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