Software-Defined Radio Technology in Digital Broadcasting and Television Systems: Postprint

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Abstract

With the continuous development of the era, radio technology has been applied in increasingly extensive domains, spanning from urban centers to remote rural villages, where digital radio and television broadcasting has become accessible to every household. This paper primarily investigates the practical implementation of software-defined radio technology and wireless digital coverage projects for radio and television programs.

Full Text

Abstract

As society continues to evolve, radio technology has permeated increasingly broad domains, extending from urban centers to remote rural villages where digital radio and television services based on radio technology have become ubiquitous in households. This paper investigates software-defined radio technology and its practical implementation in the wireless digital coverage project for radio and television programs.

Keywords: digital broadcasting television system; software-defined radio technology; television coverage rate

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1. Software-Defined Radio Technology Research

Radio refers to electromagnetic waves propagating through free space (including air and vacuum) within specific frequency bands. While the upper limit is consistently defined as 300 GHz, the lower limit varies across different radio frequency specifications—commonly 3 kHz to 300 GHz, though alternatives such as 9 kHz–300 GHz and 10 kHz–300 GHz are also encountered.

The principle of software-defined radio technology relies on current intensity variations within conductors. Radio waves are generated by exploiting this phenomenon, with information continuously loaded onto the waves through precise modulation. At the receiving end, signals are captured via spatial propagation characteristics, which induce current in conductors and trigger magnetic field transformations. Information is then extracted by demodulating these current changes, thereby achieving the ultimate goal of information transmission.

The software platform for radio technology adopts a layered architecture based on the OSI (Open Systems Interconnection) reference model, comprising function libraries, modulation algorithm libraries, image coding schemes (JPEG, MPEG, etc.), and signal streaming libraries. The hardware platform exhibits high expandability, strong openness, and broad applicability, primarily consisting of broadband digital-to-analog converters, high-speed digital signal processors, and analog front-ends. With diverse data sources—including audio, text, and images—different modulation schemes such as KPSK and DQPSK are employed across various standard systems.

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2. Significance of the Central Radio and Television Program Wireless Digital Coverage Project

2.1 Reducing Costs for Rural Audiences

China has established autonomous standards for the Central Radio and Television Program Wireless Digital Coverage Project. The proprietary AVS+ standard and independent intellectual property rights-based approaches fundamentally reduce China's technological dependence on foreign patents. Through this digital television network infrastructure, rural populations can access Central Radio and Television programs without requiring set-top box manufacturers to pay substantial patent licensing fees to foreign entities, thereby significantly reducing equipment costs.

2.2 Expanding Propagation Channels and Enhancing Influence

The Central Radio and Television Program Wireless Digital Coverage Project substantially improves television channel utilization, enabling multiple television programs to be transmitted through a single channel. This approach delivers clear image quality free from ghosting and with minimal external interference. Moreover, under mobile conditions and unconstrained by time or geographical limitations, portable handheld and vehicular televisions can receive high-quality programming anywhere. In an era of rapid multimedia development, the widespread application of software-defined radio technology has greatly extended channels for ideological, cultural, and value-based discourse. The establishment of this coverage project has strengthened the public service mechanism for radio and television, enabling mainstream media to disseminate positive, constructive, and advanced ideological culture throughout society and guiding citizens to establish correct worldviews, values, and outlooks on life.

2.3 Improving Rural Radio and Television Coverage

Low coverage rates in rural areas have long been a critical research topic in China. The Central Radio and Television Program Wireless Digital Coverage Project holds significant importance in fundamentally addressing this issue and achieving comprehensive rural coverage. First, terrestrial digital television transmitter stations have been established nationwide to receive television programs via satellite. Second, after television programs are converted into digital streams, modulation and amplification strictly follow national terrestrial digital transmission standards before broadcast transmission through antenna systems. This ensures comprehensive radio wave coverage across rural and remote regions. Third, to improve rural coverage, CCTV program digital signals are transmitted to geostationary satellites via a digital television headend and satellite earth station.

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3. Practical Implementation of the Wireless Digital Coverage Project

3.1 Terrestrial Digital Television Architecture

Traditional frequency resource allocation across regions suffered from imbalance. Although channels were assigned with spacing, co-channel interference remained unavoidable. With the maturation of GPS and Beidou satellite systems, China has pioneered the use of terrestrial digital television single-frequency networks (SFN) based on satellite transmission links. SFN features three synchronization characteristics: transmitter frequency synchronization, modulation bit synchronization, and modulation time synchronization. Since GPS and Beidou provide a frequency reference of 1PPS and a time standard of 10 MHz, they offer unified benchmarks for signal transmission from transmitters nationwide (frequency synchronization, bit synchronization, and time synchronization), creating favorable conditions for SFN establishment.

Research indicates that under equivalent transmission power and co-channel interference conditions, the coverage area of a single transmitter would decrease to less than 50%, creating a severe vicious cycle where transmitters compete by increasing power to expand coverage at the expense of others. SFN's three synchronization features enable significant diversity effects, allowing overlapping coverage from multiple transmitters. This improves the cliff effect at coverage edges, reduces total power consumption, enhances spectral efficiency, and increases coverage area for regional transmitters. However, implementing a national satellite-based SFN presents greater technical complexity compared to regional terrestrial SFN.

Two key technical challenges have been addressed: First, satellite link transmission delay is approximately 0.25 seconds, which satisfies the SFN requirement of less than 1-second maximum delay. Second, SFN requires modulation synchronization, mandating that TS streams be padded with null packets when received by SFN adapters and processed through QPSK modulators. By upgrading firmware code while maintaining existing hardware platforms and disabling PCR modification functions, current terrestrial digital television and SFN adapter manufacturers have added specific null packet insertion and recovery capabilities, ultimately achieving the desired terrestrial digital television SFN coverage.

3.2 Terrestrial Digital Broadcasting Architecture

The digital audio broadcasting transmission system utilizes multiplexing and encoding of three central radio programs (Channel 1, Channel 12, and Channel 16) at the headend to generate a single effective transport stream. Audio coding and channel coding/modulation follow the CDR standard and DRA+ specification, with the CDR standard also applicable to channel architecture. The program stream is received by the central satellite 100-channel broadcast encoding and multiplexing platform and transmitted via satellite link to the earth station, with reception via the Zhongxing-6B satellite (and also the Asia-Pacific satellite). Regional terrestrial transmitters nationwide continuously receive signals via satellite.

A professional digital audio broadcasting satellite integrated receiver decodes the signals, which are then received by a CDR model FM transmitter after complete decoding. Additionally, existing Channel 1 analog radio program broadcast frequencies may be incorporated into the transmitter planning scheme. The newly added CDR transmitter employs analog-digital simulcasting, broadcasting both Channel 1 analog FM programs and Channel 3 analog FM programs simultaneously. The analog FM broadcast transmitter power must match the original Channel 1 analog broadcast power according to software-defined radio technology requirements, with the simulcast analog power exceeding the digital signal power. A coaxial switching method enables flexible transmission switching between the original Channel 1 analog FM transmitter and the newly added CDR transmitter, while sharing the antenna system, existing multiplexer, feedline, and antenna with the original FM transmission system. Plans for adding CDR transmitters and renovation schemes should be scientifically formulated based on actual conditions. When receiving digital audio, professional audio receivers should be utilized (such as digital FM or CDR/FM-compatible radios).

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