FM Coverage Characteristics and Post-Parallel-Transmitter Test Records

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Abstract

This paper provides an in-depth investigation into the characteristics of FM coverage and presents parallel operation experiments utilizing two 10kW FM transmitters. It addresses the technical challenges that must be resolved for FM transmitter parallel operation, achieves transmission power enhancement, attains the desired listening quality, and provides cost-saving benefits. The analysis and conclusions are based on line-of-sight transmission, coverage field strength calculations, and FM broadcast parallel transmission.

Full Text

Abstract

This paper provides an in-depth exploration of FM coverage characteristics and presents a parallel operation experiment using two 10KW FM transmitters. It introduces the technical issues that must be resolved for parallel FM transmitter operation, achieving increased transmission power and improved listening effects while reducing costs. The analysis and summary are based on line-of-sight transmission, coverage field strength calculation, and FM broadcast parallel transmission.

Keywords: FM transmission; line-of-sight propagation; field strength normalization calculation; parallel operation experiment; field strength measurement; subjective evaluation

1. Relationship Between Wireless FM Coverage Effects and Transmitter Station Height and Power

FM broadcasting primarily transmits via line-of-sight propagation, with coverage generally limited to the line-of-sight distance D of the transmitting antenna. Line-of-sight transmission can be simply described by a formula (where H and T correspond to the effective height of the transmitting antenna and the effective height of the receiving antenna, respectively, in meters). This indicates that FM broadcast effective coverage has a positive correlation with antenna height and receiving antenna height—the higher the FM antenna, the broader the coverage range for the same transmission power. Consequently, FM transmitter stations are typically located at relatively high positions such as mountain tops, enabling longer transmission coverage with the same power.

For example, a station with a relative height of 1132m, antenna height of 30m, and receiving height of 10m, calculated according to the line-of-sight propagation distance formula:

As expressed in ITU-R P.1546-4 recommendation, the field strength coverage for different transmitting antenna heights is shown in Figure 1 [Figure 1: see original paper]. According to ITU-R 370-5 recommendation standards, field strength varies logarithmically and linearly with effective antenna height:

Where E1 and E2 represent the field strength values corresponding to heights h1 and h2, respectively, obtained from the FM coverage characteristic chart in Figure 1. And h1 $\leq$ h $<$ h2.

Appropriate transmission power allows positional advantages to be fully realized. The effective radiated power of a transmitter is calculated by the formula, where P is the transmitter's nominal output power, L is the feeder loss (typical value 1dB), and G is the transmitting antenna gain (typical value 10.3dB for a six-layer four-sided antenna). For a 10KW transmission system, the effective radiated power is:

Coverage service field strength calculation: Where is the effective radiated power (dB), is the normalized service field strength, obtained through table lookup or from Figure 1. A is the terrain ruggedness attenuation correction coefficient, as shown in Figure 2 [Figure 2: see original paper].

For example, in a relatively flat area 50 kilometers from this 10KW FM transmitter, the typical coverage situation is:

With the implementation of China's urbanization development strategy, city frameworks continue to expand, high-rise buildings proliferate, and various radio infrastructure and applications are widely used, leading to increasingly deteriorating electromagnetic environments in urban areas. The coverage effects of originally powered transmitters in urban areas have gradually worsened. Recently, our station conducted a parallel broadcasting experiment using a backup transmitter with the main transmitter, hoping to achieve coverage effects reaching or approaching a single 20KW unit. According to simple field strength formula calculations, theoretically, the power doubled after parallel operation, and the field strength in the coverage area should increase by 3 dB compared to before, significantly improving urban coverage listening effects.

2. Technical Experiment

The experiment was conducted on two identical HARRIS 10KW transmitters of the same brand and model, which were originally used as main and backup units. For FM transmitter parallel operation, especially high-power transmitters, the first requirement is ensuring synchronized broadcasting from both units. According to the GY/T154-2000 "Technical Specifications for FM Synchronized Broadcasting Systems" standard, the issues of same frequency, same phase, and same modulation for both transmitters must be resolved. These are also necessary conditions to ensure synchronized broadcasting and normal operation of both transmitters. In practice, the first problem to solve is the phase-synchronized synthesis of transmitter output power, followed by synchronized excitation to ensure both transmitters operate at the same frequency, with the same modulation and consistent phase shift, thereby achieving the goal of improved coverage area listening effects through parallel operation.

2.1 Experiment Conducted According to the Predetermined Technical Renovation Plan

A passive 3dB signal distribution board was installed at the output of the original main transmitter's exciter. Using distribution cables of the same material and length, the exciter output signal was fed to the excitation signal distribution boards of both transmitters. Both transmitters were driven by the same exciter to ensure the requirements of same frequency, same phase, and same modulation for parallel operation. Figure 3 [Figure 3: see original paper] illustrates the exciter signal distribution. Using cables of the same material and length ensures consistency in line loss and phase shift fed to both transmitters, which is also critical for successful parallel operation.

At the output synthesis end of the two transmitters, a set of transmitter 3dB power combiners was installed to achieve parallel output synthesis. The spacing between the two transmitters was adjusted so that the two input ends of the output combiner corresponded exactly to the RF output ports of the transmitters. The combiner was supported on top of the transmitters to ensure minimal connecting devices at the combiner front end, reducing power loss and phase deviation. The output end of the 3dB combiner was connected to the transmitter system's multiplexer via rigid feeder. A 5KW absorption load was installed at the absorption end of the 3dB combiner to absorb residual power generated when the two transmitters have inconsistent phase shifts. After connecting all cables and rigid feeders according to the design plan, a test power meter was installed before the absorption load to monitor phase imbalance between the two transmitters, providing a reference for subsequent phase adjustment.

Both transmitter power supplies were turned on, and the output power of both transmitters was simultaneously increased to 5KW each. The power meter reading connected in series before the absorption load was observed to check phase consistency between the two transmitters. From the actual power meter readings, after parallel operation, the two transmitters achieved phase consistency, with power meter readings before the absorption load being relatively small.

The exciter power output was increased from 28W to 49.7W to achieve full-power, full-modulation operation of two 10KW units. The dummy load absorption power was tested. Tests were conducted on switching on/off, power ramping up/down, and power imbalance conditions: whether maintaining consistent power between the two transmitters or artificially creating power imbalance (adjusting the output power difference between the two transmitters to about 1KW), the power meter readings at the absorption load front end fluctuated within allowable ranges (averaging between 3-40 watts). It was confirmed that after normal operation of both transmitters, the residual power measured at the absorption load after parallel operation was within normal ranges. The absorption load used was an imported BIRD dummy load with a rated average power of 5KW and short-term capacity of 10KW, capable of handling any special power levels, power variations, or fault shutdown conditions. Power imbalance testing: adjusting the power of both transmitters to maintain an output power difference within 1KW, the measured absorption power data is omitted. When two 10KW transmitters maintained different transmission powers, the average value measured at the absorption load was within 40W, confirming that both transmitters could maintain phase-consistent operation.

After completing the experiment, both transmitters were maintained at full-power, full-modulation parallel operation for trial operation, i.e., both transmitters operated at full power 10KW, with 20KW full-modulation operation after parallel operation. The transmitters operated stably with normal technical indicators.

3. Field Strength Measurements Before and After Parallel Transmitter Experiment

Before and after the parallel operation experiment of two 10KW FM transmitters, based on GB/T 14109-1993 "Methods for Measurement of TV and FM Broadcasting Field Strength" and GB/T 16463-1996 "Methods and Technical Requirements for Subjective Assessment of Broadcast Program Sound Quality", a combination of vehicle mobile testing and fixed-point measurement was used to conduct field strength measurements at representative test points within the urban area and suburbs before and after the project renovation. Through statistical analysis of a large volume of road test data, the field strength values measured in the second test were overall 2.8 dB higher than those in the first test, with noticeable improvement in urban listening effects, especially at locations with complex electromagnetic environments in the original urban area where listening effects were substantially improved.

4. Effects of Parallel Transmitter Experiment

After parallel operation, both transmitters achieved full-power 10KW operation (20KW after parallel operation) with full modulation and continuous operation. The transmitters operated stably with normal technical indicators. On-site reception measurements and subjective evaluations were conducted in the urban area. The measured field strength values after renovation were overall 2.8 dB higher than before implementation, with measured data basically equivalent to theoretical calculated improvement values. Listening quality and effects in the urban area were significantly improved. The success of this parallel operation experiment inaugurated the prelude to high-power FM parallel operation experiments in our province, providing theoretical and practical experience, offering a feasible basis for strengthening broadcast transmission and coverage, with strong operability and practical significance.

References

[1] Technical Regulations for FM Broadcasting Coverage Networks GY/T196-2003
[2] ITU-R P.1546-4 Recommendation: Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3 000 MHz.
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Note: Figure translations are in progress. See original paper for figures.