Design and Application of a Three-Frequency Shared-Tower Antenna Tuning Network for Zhoukou Medium-Wave Relay Station (Postprint)

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Abstract

Tri-frequency co-tower technology employs a single transmission antenna to simultaneously broadcast three radio programs at different frequencies. For transmission stations with numerous frequencies and insufficient land area for antenna installation, this technology not only resolves multi-frequency transmission challenges but also yields significant savings in capital and land area. The Zhoukou Medium Wave Station originally possessed a 120-meter guyed tower operating in a dual-frequency co-tower configuration at 1098 kHz (25 kW) and 900 kHz (10 kW). A new 603 kHz (25 kW) transmitter has been added. Calculations demonstrate that the ratios between all frequencies exceed 1.25, satisfying the prerequisites for co-tower operation. A tri-frequency split-feed co-tower system was implemented; through the addition and adjustment of blocking networks and trap networks, three single-channel networks were integrated into a unified tri-frequency co-tower antenna tuning network, achieving the anticipated outcomes.

Full Text

Preamble

Title: Design and Application of a Tri-Frequency Co-Tower Antenna Tuning Network at Zhoukou Medium Wave Relay Station

Abstract: Tri-frequency co-tower technology enables a single transmitting antenna to simultaneously broadcast three programs on different frequencies. For transmission stations with numerous frequencies and insufficient land area for installing multiple antennas, this technology not only solves the multi-frequency transmission problem but also saves substantial capital and land resources. The

Zhoukou medium wave station originally operated a 120-meter guyed tower with dual-frequency co-tower operation at 1098 kHz (25 kW) and 900 kHz (10 kW). A new 603 kHz (25 kW) transmitter has been added. Calculations show that the ratios between all frequency pairs exceed 1.25, meeting the requirements for co-tower operation. Through tri-frequency separate-feed co-tower implementation, and by adding and adjusting blocking networks and trap networks, three single-channel networks were merged into a complete tri-frequency co-tower antenna tuning network, achieving the desired results.

Keywords: Tri-frequency co-tower technology; Investment savings; Desired results

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1. Technical Conditions for Tri-Frequency Co-Tower Networks

As is well known, tri-frequency co-tower technology imposes specific requirements on total transmitter power, frequency spacing, antenna characteristic impedance, and other frequency considerations at the station. The Zhoukou medium wave relay station in Henan Province currently operates a 120-meter guyed mast antenna with a 1-meter face width. The antenna impedance values near the three frequencies are shown in Table 1 . All three transmitters are DAM solid-state digital modulation transmitters, with frequency interval ratios exceeding 1.25. The total transmission power is 60 kW, and the existing dual-frequency co-tower system has operated stably for many years. The original dual-frequency co-tower network is illustrated in Figure 1 [Figure 1: see original paper]. In summary, all conditions for implementing tri-frequency co-tower operation are fully satisfied.

Additionally, the design must address interference from the station's own or nearby medium wave frequencies to minimize external electromagnetic environmental impact on the three co-tower frequencies. Component values for each frequency branch are calculated based on the broadcast frequency, power, and antenna impedance at each frequency point. Simultaneously, component power margins, voltage withstand, and current carrying capacity must be considered. For capacitors, series-parallel or parallel-series configurations can enhance voltage and current withstand capability. For inductors, thicker coils improve power handling and heat dissipation.

2. Design Principles for Tri-Frequency Co-Tower Antenna Tuning Networks

The tri-frequency co-tower antenna tuning network requires that each frequency branch employ two blocking networks to reject the other two frequencies, preventing them from flowing back into the transmitter through the branch and causing interference. Additionally, two trap networks must be installed on each branch to maximally absorb residual components from the other frequencies. The design must also address interference from the station's own or nearby medium wave frequencies to minimize external electromagnetic environmental impact. Component values for each frequency branch are calculated based on broadcast frequency, power, and antenna impedance at each frequency point. Simultaneously, component power margins, voltage withstand, and current carrying capacity must be considered. For capacitors, series-parallel or parallel-series configurations can enhance voltage and current withstand capability. For inductors, thicker coils improve power handling and heat dissipation.

2.1 Blocking Network Design

The principle of blocking networks is based on the fact that when an L-C parallel circuit resonates at a particular frequency, its impedance tends toward infinity. Therefore, L-C parallel circuits are employed as blocking networks. Within the medium wave band of 500–1600 kHz, once the capacitor value C is determined, the inductor value L can be calculated using $\omega\mathrm{L} = 1/\omega\mathrm{C}$ (or $\mathrm{L} = 1/\omega^2\mathrm{C}$). In practical design, considering sideband frequency effects and market availability of components, it is preferable to first select the capacitor value and then choose an appropriate resonant coil. The capacitor and inductor values for each branch of the three-frequency blocking network are shown in Table 2 .

2.2 Trap (Absorption) Network Design

As previously analyzed, trap networks differ from blocking networks in that they must allow other frequencies to pass to ground. Therefore, trap networks employ L-C series resonance, which presents a direct short circuit at the resonant frequency. However, the station's own frequency must not be allowed to pass through the trap to ground, so a blocking network must be designed to reject the station's frequency and then be connected in series with the series resonant network. This achieves both prevention of the station's frequency from reaching ground and absorption of the other two frequencies. Since local frequencies of 567 kHz and 828 kHz exist, trap networks were added to the 603 kHz antenna tuning network (as shown in Figure 2 [Figure 2: see original paper]). Using the formula $\mathrm{f} = 1/(2\pi\sqrt{\mathrm{LC}})$, the trap network for 567 kHz uses a capacitor of 809 pF and inductor of 98 H, while the 828 kHz trap uses a capacitor of 1000 pF and inductor of 37 H. A parallel capacitor bank of 3800 pF then makes the network parallel-resonant at 603 kHz.

In a parallel resonant network, current flows through both the working frequency and the blocking frequency. According to the formula, where W represents the feedline characteristic impedance, Ra the real part of antenna impedance, and Xa the imaginary part, the tri-frequency co-tower pre-tuning network can be constructed based on these parameters.

The total currents in the inductor and capacitor, ILT and ICT, can be determined. Considering 100% modulation, components must withstand maximum currents of 1.3 times the total current. Taking the 603 kHz branch blocking 1098 kHz as an example, according to the formulas with f = 603x10, f_0 = 1098$×10^{3}$, we obtain t = 0.549 and $\alpha = 0.786$. The working current is calculated from P = 10$×10^{3}$, RA = 40, yielding I = 15.8 A.

The blocking voltage E_0 is determined by the formula. Substituting into the previous equations yields ILT = 33.29 A and ICT = 25.29 A. Therefore, at 100% modulation, the total current withstand for element L is 1.3ILT = 44 A, and for element C is 1.3ICT = 32 A.

The voltage withstand for L and C is calculated as VL = VC = 6820 V. Considering 100% modulation, the voltage withstand requirement becomes 3VL = 3VC = 20460 V. Similarly, other blocking network component voltage withstand values can be calculated, as shown in Table 3 .

Due to the canceling characteristics of capacitive and inductive reactance, appropriate selection of inductors and capacitors enables reactance cancellation on each frequency branch, maximally achieving the RA + j0 condition. Because the real parts of the antenna impedance at 900 kHz and 1098 kHz are both greater than the characteristic impedance of the feedline, a Γ-type matching network is used, while a T-type network is employed for 603 kHz. The L and C parameters are determined according to the matching network formulas.

3. Conclusion

Following design, installation, and commissioning, monitoring and testing of the transmission performance were conducted. All electroacoustic indicators of the three transmitters meet design requirements, and field strength measurements also satisfy specifications. The tri-frequency co-tower network has been successfully completed. Under current conditions of site and funding limitations, tri-frequency co-tower technology is increasingly important. The Zhoukou medium wave station has made a bold attempt in this regard, representing a new breakthrough in technical innovation for the station. However, several issues require further resolution, including transmitter stability, component durability, and heat dissipation.

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