Composition and Design Principles of Antenna Tuning Networks for Medium Wave Transmitters: Postprint

Authors: Xu Wenyu

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Abstract

The antenna feedline matching network of medium-wave transmitters plays a crucial role in the entire transmission system. Since modern transmission stations have widely adopted new digital modulation transmitters with relatively complete protection functions, the requirements for output matching networks are rather high. Problems with the antenna tuning network may, at best, affect the operational stability of the transmitter, and at worst, cause broadcast interruption accidents or even damage to the main components of the transmitter. On the other hand, due to the increasingly scarce land resources in recent years, most medium-wave transmission stations adopt dual-frequency or multi-frequency tower-sharing technology for matching network design, where mutual interference between frequencies presents significant difficulties in matching network design. This paper, based on the author's years of practical experience, discusses the composition, structure, and working principles of the antenna tuning network, and elaborates on the design principles of the matching network, hoping to provide a reference for peers in the field.

Full Text

Composition and Design Principles of Medium Wave Transmitter Antenna Tuning Networks

Abstract: The antenna feedline matching network plays a vital role in medium wave transmitter systems. Modern transmission stations have widely adopted digital modulation transmitters with comprehensive protection functions, imposing stringent requirements on output matching networks. Antenna tuning network issues can, at minimum, compromise transmitter stability, and at worst, cause broadcast interruptions or damage to major transmitter components. Furthermore, due to increasingly scarce land resources, most medium wave stations now employ dual-frequency or multi-frequency co-tower technology for their matching networks, creating mutual interference between frequencies and presenting significant design challenges. Drawing on years of practical experience, this paper discusses the composition, structure, and operating principles of antenna tuning networks, and elaborates on design principles for matching networks to provide a reference for industry peers.

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Author: Xu Wenyu

1.1 Pre-tuning Network

We recognize that for any medium wave transmitting antenna, input impedance varies across different operating frequencies. When impedance differences at antenna feed points are too large, co-tower network design becomes problematic. Therefore, balancing networks—pre-tuning networks—must be installed at the feed points of two or more co-tower frequencies. Pre-tuning networks not only balance impedance for each frequency at the feed point but also provide lightning protection and reduce power loss, thereby decreasing network design complexity. Figure 1 [Figure 1: see original paper] shows L0 and C0 as two pre-tuning network components.

1.2 Matching Network

Setting aside dual-frequency or multi-frequency co-tower scenarios and other interference factors, only a basic impedance matching network is needed between transmitter feedline and antenna. This fundamental network is the matching network, which primarily achieves impedance matching between feedline characteristic impedance Z and antenna input impedance R+jX while also reducing reflections and minimizing standing waves. Matching networks should exhibit good passband characteristics. Medium wave transmitter matching networks consist of inductors and capacitors (vacuum capacitors), with common configurations including T-type, π-type, Γ-type, and inverted Γ-type topologies. Figure 1 illustrates several matching network schematic diagrams.

1.3 Blocking Network

The matching network described above operates under interference-free conditions, representing an ideal scenario. However, due to land resource constraints and other factors, transmission stations often broadcast multiple frequencies simultaneously, resulting in dual-frequency or multi-frequency co-tower configurations where frequencies interfere with each other. To eliminate mutual influence between co-tower frequencies, one or more suppression networks—blocking networks—must be added. Blocking networks primarily suppress mutual interference between co-tower frequencies, maximizing rejection of co-tower frequencies from affecting the primary frequency. Figure 2 [Figure 2: see original paper] shows schematic diagrams of three common blocking network configurations.

1.4 Absorption Network

While blocking networks prevent interference from co-tower frequencies, how should interference from other frequencies at the same station be handled? Adding more blocking networks would make the entire network bulky and increase design complexity. Since interference from other station antennas is much smaller than co-tower frequency interference, passive absorption networks (also called notch filters) can be employed for elimination, with different absorption methods used based on interference intensity. Figure 3 [Figure 3: see original paper] illustrates schematic diagrams of four different absorption network configurations. The design principle for absorption networks is: when the interference frequency is lower than the primary frequency, use parallel resonance followed by series capacitance; when the interference frequency is higher, use parallel resonance followed by series inductance. This creates high impedance for the primary frequency while presenting low impedance or a direct path for interference frequencies, ensuring the primary frequency passes through while diverting interference frequencies to ground.

1.5 Lightning Protection System

Transmission antennas typically exceed 60 meters in height, making them the tallest structures in their vicinity and excellent lightning conductors. Consequently, they face high lightning strike probability, particularly in lightning-prone regions where incidents of lightning damage to matching networks and transmitter components are common. Therefore, lightning protection devices must be incorporated into antenna feedline matching networks to ensure transmission system safety. Figure 4 [Figure 4: see original paper] shows schematic diagrams of three lightning protection network topologies.

2.1 Design of Matching, Blocking, and Absorption Networks

Before designing matching networks, planning must account for frequency spacing and power levels. The frequency ratio between co-tower frequencies should theoretically be no less than 1.1, though in practice it is best not to fall below 1.5, otherwise achieving an ideal matching network becomes difficult. An optimal antenna tuning network should demonstrate stability and reliability, with good matching characteristics, a voltage standing wave ratio (VSWR) below 1.1, and sufficient bandwidth. The configuration and quantity of blocking networks should be determined based on specific circumstances. Selection of inductors and capacitors in blocking networks depends on the blocked frequency magnitude and frequency spacing; smaller spacing results in greater power loss and higher voltage and power requirements for inductors and capacitors. Common blocking networks include series-then-parallel networks and parallel resonant circuits in series configuration, with the final resonant point matching the frequency to be blocked.

2.2 Design of Lightning Protection Networks

Lightning protection in antenna feedline matching networks can be implemented in several ways. The first method involves adding microhenry-level inductors and DC-blocking capacitors. Inductors pass low frequencies while blocking high frequencies, directly shunting some low-frequency lightning energy, whereas capacitors pass high frequencies while blocking low frequencies, isolating some low-frequency lightning energy to protect the transmitter from lightning strikes. The second method installs graphite discharge devices with spark gaps set to 1mm per 1kV standard. The third method designs lightning protection networks as shown in Figure 5 [Figure 5: see original paper], integrating blocking networks, matching networks, and antenna impedance conversion networks into a unified design to simplify the overall network system.

3. Matching Network Design and Installation Considerations

3.1 Component Selection Antenna feedline matching networks operate in harsh environments with large seasonal temperature variations, high temperatures, high voltages, and high power levels, making them susceptible to lightning strikes. Therefore, components with excellent electrical characteristics and high voltage tolerance should be used, with adequate design margins. At nodes with high voltage, multiple capacitors should be combined in series and parallel configurations. If space permits, larger diameter inductors are preferable, as this ensures overall network stability.

3.2 Installation Considerations Due to variations in component manufacturers and production batches, quality can be inconsistent. To prevent component issues from affecting the entire network, components—especially capacitors—should undergo voltage withstand testing before installation and only be used if they meet requirements. Insulating components in matching networks must be securely installed to avoid arcing or discharge from poor contact, and inductors should be placed perpendicular to each other to prevent magnetic coupling effects.

3.3 Ventilation and Heat Dissipation Antenna feedline matching networks generate substantial heat during operation. In summer, poor heat dissipation in the tuning room can cause temperatures to exceed 60°C, leading to network impedance variations, increased transmitter standing waves, and unstable operation. Therefore, ventilation and cooling measures must be implemented to ensure network stability. Tuning room cooling methods include natural ventilation, fan cooling, and underground negative pressure exhaust systems.

A well-performing transmitter is fundamental to safe broadcasting, but we cannot focus solely on transmitter maintenance while neglecting antenna feedline matching networks. A properly designed antenna feedline matching network is equally important as the transmitter itself. We must maintain antenna tuning networks as diligently as we maintain transmitters to improve transmission quality and ensure trouble-free safe broadcasting.

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(Author Affiliation: Huangchuan Medium Wave Relay Station, Henan Province)

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