Medium-Wave Transmitting Antenna and Ground Screen (Postprint)

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Abstract

Medium wave broadcasting, as a traditional signal transmission method, has remained in continuous application and constitutes an indispensable channel for disseminating the voice of the Party and the state. However, medium wave transmission stations are gradually being encroached upon in the process of urbanization, with the surrounding environment and ground network of medium wave transmission antennas being directly impacted. This paper elaborates on several issues concerning the construction and maintenance of medium wave transmission antennas and ground networks.

Full Text

Preamble

Abstract: Medium-wave broadcasting, as a traditional signal transmission method, has been continuously utilized and represents an indispensable pathway for disseminating the voice of the Party and the state. However, in the process of urbanization, medium-wave transmission stations have gradually become engulfed, with the immediate victims being the surrounding environment of medium-wave transmitting antennas and their ground networks. This paper elaborates on several matters concerning the construction and maintenance of medium-wave transmitting antennas and ground networks.

Keywords: Medium-wave antenna; parameters; height; ground network

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In recent years, with the accelerated pace of urbanization construction, land originally located in suburban areas has been progressively urbanized, and the surrounding environment of medium-wave transmission stations has become surrounded by high-rise buildings. In some areas, these buildings even severely cover the antenna' s ground network, seriously affecting medium-wave broadcast transmission. Consequently, many medium-wave broadcast transmission stations are forced to face the situation of intensified maintenance or relocation. The construction and maintenance of medium-wave transmitting antennas and ground networks have become increasingly prominent in today' s broadcast technology applications. Based on the theory of medium-wave propagation, this article discusses relevant technical matters concerning the construction and maintenance of medium-wave transmitting antennas and ground networks.

1.1.1 Polarization

According to the propagation characteristics of radio waves, medium-wave broadcasting primarily relies on ground wave propagation during the day, and on both ground wave and sky wave propagation at night. The medium-wave band has relatively long wavelengths, and electromagnetic waves in this band experience relatively low loss when propagating along the ground, with relatively long propagation distances; therefore, ground wave propagation is predominantly used. During ground propagation, the loss of vertically polarized waves is lower than that of horizontally polarized waves, which is why medium-wave transmitting antennas predominantly employ vertically grounded antennas.

1.1.2 Radiation Pattern

The antenna' s radiation pattern is a circle in the horizontal plane, which suits broadcast requirements. Its terminal is open-circuited, making it a standing-wave antenna. As antenna height gradually increases, radiated energy progressively concentrates toward the ground plane direction. When antenna height exceeds one-half wavelength, sidelobes begin to appear. To expand service coverage, we desire maximum field strength in the ground plane. Therefore, we should maximize radiated field strength while avoiding sidelobes caused by high elevation angles.

1.1.3 Input Impedance

The antenna's input impedance can be obtained from antenna manuals. Numerical values are acquired from the curve of antenna height versus input impedance. Figure 1 [Figure 1: see original paper] shows the input impedance curve for guyed tower antennas (where H represents antenna height and λ represents wavelength). The voltage withstand capacity of impedance components in the antenna input matching network must have sufficient safety margins.

1.1.4 Radiation Efficiency

One of the primary technical indicators of medium-wave antennas is antenna radiation efficiency, denoted by A. The calculation formula for antenna efficiency is as follows:

 A = RA/(RA+RI)

where RI = Rg + Rc + Ri + Rw

RA: Antenna radiation resistance
Rg: Equivalent resistance of ground loss
Rc: Equivalent loss resistance of tuning coils series-connected in the antenna circuit
Ri: Equivalent resistance of insulation loss
Rw: Equivalent resistance of conductor loss

These resistances are all referenced to the antenna base current.

From the above formula, besides reducing losses in the antenna and its matching network, the method to improve antenna efficiency is to increase radiation resistance. Vertically grounded antennas often employ a height of one-half wavelength, where radiation resistance is approximately 100 ohms. Antenna radiation efficiency is generally 70%~80%.

1.2 Losses in Medium-Wave Transmitting Antennas

From the antenna efficiency formula in Section 1.1.4, losses in medium-wave transmitting antennas can generally be categorized into conductor loss, dielectric loss of insulators, and loss of vertically grounded antennas, among others.

Although medium-wave antennas often use steel towers as radiating elements, their losses are negligible. Regarding dielectric loss of insulators, since high-frequency ceramics are used in antenna equipment, this type of loss is also very small. However, it must be noted that if ordinary ceramic insulators are used, especially in areas contacting high-frequency conductors, these insulators will heat up due to high losses. Since insulators are poor thermal conductors, heat accumulation can cause insulators to crack. Even when high-frequency ceramic insulators are used, heat accumulation and cracking can occur if impurities are mixed inside the insulator body. The loss of medium-wave antennas is primarily determined by ground wire loss. The earth constitutes part of the grounded antenna’ s return circuit, and when current passes through the earth back to the antenna base, losses occur. The energy loss is much greater than the previous two types. Therefore, for medium-wave transmitting antennas, whether in construction design or daily maintenance, it is of significant importance to devise methods to reduce ground losses.

1.3 Antenna Height

In terms of form, there are many types of medium-wave transmitting antennas. The most widely used today are mast-type single-tower (guyed tower) antennas and self-supporting tower antennas.

The height of vertical antennas is typically selected appropriately based on service coverage, investment scale, and site size. The preferred height is approximately one-half of the operating wavelength. Practical experience has proven that 0.53 times the operating wavelength is optimal. Due to erection difficulties, it cannot be made extremely high. The height can also be selected between one-third to one-half of the operating wavelength. If the height is lower, the resistive component in the antenna' s input impedance becomes relatively low, resulting in higher losses and very low antenna efficiency.

Certainly, from a technical specification perspective, the heights of medium-wave antennas are standardized, such as a height of 76m. At lower frequencies, the standardized tower height appears insufficient. In such cases, besides meeting requirements through reasonable adjustment of operating frequency, forms such as inverted-L antennas and T-shaped antennas can be adopted. That is, by adding appropriate reactive loads to the top of the vertical antenna, the current distribution in the antenna can be transformed, moving the current antinode upward. The antenna' s effective height approaches its geometric height, improving radiation effectiveness. Simultaneously, this places the bottom of the antenna' s vertical section near the current standing wave node, increasing the antenna' s input impedance and relatively weakening ground loss. Additionally, there is another form: slanted top loading. When antenna height is less than 0.25 wavelength, making the sum of tower height and slanted line equivalent height approach its geometric height can expand the antenna' s radiation range, but this antenna form is not recommended. The top of this antenna consists of slanted lines drawn from the antenna top, and the downward slant generates vertically polarized field strength, which weakens the radiation from the vertical section.

Furthermore, antenna height selection should generally avoid the impedance resonance region at 0.4 times the wavelength. Within the resonance region, the antenna' s input impedance varies significantly, resulting in excessively high Q-factor, narrow antenna bandwidth, and extreme impedance instability, which is greatly affected by environmental conditions and prone to generate sideband standing wave ratio.

1.4 Antenna Voltage

The voltage issue of medium-wave transmitting antennas requires attention. With increasing transmitter power and modulation changes, excessively high antenna input voltage or top voltage can cause insulation breakdown or spatial discharge phenomena.

When power is constant, the magnitude of input voltage is determined by the antenna’ s input impedance. When antenna height is one-half wavelength, its terminal voltage is comparable to input voltage; when antenna height is one-quarter wavelength, its terminal voltage is relatively large.

1.5 Antenna Feeding

Steel tower antennas have two feeding methods: series feeding and parallel feeding. If the steel tower is insulated from ground, series feeding is employed; if the steel tower base is directly grounded, parallel feeding is used. Traditional medium-wave antennas adopt series feeding. The advantage of parallel feeding is that the antenna can be directly grounded, i.e., DC grounded, making the discharge of the transmission system faster and more effective. The input impedance at the antenna feed point is similar to the characteristic impedance of the feedline, facilitating matching. The disadvantage is that current distribution on the antenna increases at the bottom, affecting directivity, and the series capacitor used to neutralize antenna reactance has high voltage across it. Parallel-fed self-supporting medium-wave antennas have been widely applied abroad with mature technology, and are gradually being recognized and adopted by various radio stations domestically.

2. Ground Network

Theoretical research has proven that antenna loss power decreases with increasing distance from the antenna base, with ground loss concentrated primarily near the antenna base. Therefore, a uniformly distributed radial ground network is laid near the ground surface with the antenna base as the center, typically with one wire every 3 degrees, totaling 120 wires. The more wires in the ground network, the smaller the ground loss resistance, and the higher the antenna efficiency. Wire length is 0.5 wavelength but must extend beyond the projection range of the antenna top on the ground. Although ground current has significant values in ranges beyond half a wavelength, this belongs to the radio wave propagation loss range rather than the induction field range, and is unrelated to antenna efficiency. To provide a good return path for the antenna’ s ground current, ground networks should be radial rather than criss-crossed mesh patterns, because ground current has no direct return path in mesh loops.

The electromagnetic field near the antenna is relatively strong. To reduce losses, ground network wires should be laid as close to the ground surface as possible, especially near the antenna. Considering the large antenna field area, laying the entire ground network on the ground surface wastes land resources; its burial depth is generally 30-50 centimeters, based on the principle of not being subject to damage. Ground network wires typically select copper wires with a diameter of 3 millimeters. In severe cold regions, especially when the ground freezes, wires can be pulled apart. During wire laying, slight slack should be allowed. A copper busbar is connected to the shielding copper sheet at the base of the antenna base insulator, and the starting ends of ground network wires should be uniformly distributed and welded to this busbar. The ground resistance value should be less than 2 ohms.

3. Maintenance

Maintenance of antenna systems, especially for steel towers and their ground networks, must receive sufficient attention. Compared to other broadcast equipment, they are exposed to outdoor operation and suffer erosion from wind, sun, rain, lightning, and freezing conditions.

Regarding inspection and maintenance of medium-wave transmitting antennas and ground networks, operations must strictly follow the "Medium and Short Wave Antenna Feeder Operation and Maintenance Regulations." Daily patrols and inspections are important guarantees for ensuring normal operation of medium-wave broadcast transmitting antennas. During routine maintenance, ground anchor rods, turnbuckles, etc., should be inspected and maintained, with rust prevention treatment applied. Tower base insulators should be cleaned. Lightning protection systems should be inspected before and after the rainy season. Problems such as arcing, insulator damage, and abnormal tower verticality of guy wires should be promptly addressed. Patrols should be intensified when seasons and climate change. Additionally, tower structures should be regularly inspected. If weld cracking or incomplete welding is discovered, timely rewelding should be performed. Loose bolts should be tightened. Severely corroded screws should be replaced immediately. If water accumulates inside seamless steel tube tower columns, holes can be drilled at the bottom to drain water. The drainage hole diameter should not affect tower structural strength, and the cause of water accumulation should be identified and eliminated. Local anti-corrosion treatment should be applied after rewelding or drilling.

According to local climate conditions, tower structures, mast guy wires, insulator frames, etc., of antenna systems should be regularly inspected to ensure tower structural safety. The major overhaul cycle for medium-wave antennas generally varies according to regional climate conditions: every 8 years in dry, non-corrosive regions; every 5 years in ordinary regions; and every 3 years in coastal and severely corrosive regions. Cases of tower collapse due to neglected major overhauls have occurred and should serve as warnings.

Furthermore, the ground network is a concealed underground project, and its maintenance should not be neglected. The resistance of the high-frequency ground network should be tested regularly. A good ground network typically has ground resistance of 0.4 ohms. When planting crops in the antenna field area, avoid breaking ground network wires during plowing. If a ground network wire breaks, it should be repaired promptly. Do not parallel connect it to a nearby wire, as eddy currents will increase losses. The best solution is to resolder the broken wire with tin. The secondary solution is to drive a grounding rod at the terminal of that ground network wire.

Medium-wave broadcasting is an indispensable effective signal transmission pathway, playing an irreplaceable role during critical periods such as emergencies and natural disasters. As outdoor broadcast transmission equipment, medium-wave antennas and ground networks constitute an indispensable and important component of medium-wave transmission stations. Whether during construction or maintenance, they still require sufficient attention, as they are extremely important for improving medium-wave broadcast quality.

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