On-site Environmental EMI Evaluation of the NSRT Servo Control System[*]

Li Xiaofeng³ Ma Ling² BAAN Willem A²

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Abstract

The servo control system is an important component of a radio telescope and is electronic equipment with a high radiation level. For existing radio telescopes, different sub-devices in the system are distributed at different locations of the telescope, making it difficult to conduct electromagnetic interference measurements in a laboratory environment. To address this problem, based on the servo control system of the Nanshan 26 m Radio Telescope (Nanshan Radio telescope, NSRT), an electromagnetic interference assessment of the servo control system in an on-site environment was carried out, providing technical support for further electromagnetic protection. First, the electromagnetic interference mechanism of the servo control system was briefly analyzed. Through on-site environmental electromagnetic interference measurements, data calibration, and removal of environmental noise, the radiated emission spectra of different devices were obtained. In addition, according to the radiation threshold of the telescope, the Entropy Weight Method (Entropy Weight Method, EWM) model was used to evaluate the electromagnetic interference of different devices in the system, and the radiation levels and shielding protection requirements of different devices were given. On this basis, the electromagnetic protection scheme of the system and related considerations were discussed.

Full Text

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On-site Environmental EMI Evaluation of the NSRT Servo Control System*

Fan Yuming1 Xiang Binbin1† Liu Qi2‡ Cai Minghui2 Wang Na2 Zhang Chao2 Zheng Xianze2
Li Xiaofeng3 Ma Ling2 BAAN Willem A2

(1 College of Mechanical Engineering, Xinjiang University, Urumqi 830017)
(2 Xinjiang Astronomical Observatory, Chinese Academy of Sciences, Urumqi 830011)
(3 The 33rd Research Institute of China Electronics Technology Group Corporation, Taiyuan 030006)

Abstract The servo control system is an important component of a radio telescope and is electronic equipment with a high radiation level. For completed radio telescopes, different subsystems are distributed at different positions on the telescope, making it difficult to carry out electromagnetic-interference measurements in a laboratory environment. In response to these issues, this study takes the servo control system of the Nanshan 26 m Radio Telescope (Nanshan Radio Telescope, NSRT) as the basis and conducts an electromagnetic-interference evaluation of the servo control system under on-site environmental conditions, providing technical support for further electromagnetic protection. First, the electromagnetic-interference mechanism of the servo control system is briefly analyzed. Through on-site environmental electromagnetic-interference measurements, data calibration, and removal of environmental noise, the radiated-emission spectra of different devices are obtained. In addition, according to the telescope radiation threshold, the Entropy Weight Method (EWM) model is used to evaluate the electromagnetic interference of different devices in the system, and the radiation levels and shielding-protection requirements of different devices are given. On this basis, electromagnetic-protection schemes for the system and related considerations are discussed.

Keywords Telescopes: radio telescopes, instrumentation: servo control system, methods: interference evaluation, techniques: electromagnetic compatibility

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1 Introduction

Radio astronomy detects and analyzes the radio-frequency bands in the electromagnetic-wave spectra radiated by celestial bodies, thereby revealing the physical properties, chemical composition, and evolutionary laws of cosmic objects[1]. As radio telescopes are upgraded toward higher sensitivity, wider frequency coverage, and larger bandwidth[2], system-level electromagnetic compatibility has become a focus of interdisciplinary research and is directly related to the reliability of observational data and the credibility of scientific discoveries[3].

Studies have shown that the intensity of radio-frequency interference generated by artificial radiation sources, such as communication base stations and industrial equipment, usually far exceeds that of natural interference[4], and is particularly prominent in low-frequency observing bands such as L, S, and C[5]. Because radio telescopes have extremely high sensitivity, their electromagnetic-compatibility thresholds must far exceed national military standards, such as the GJB 151B limit of 80 dB[6], and local shielding specifications may even reach 140 dB[7]. In addition, differences in operating levels among spatially distributed devices can readily cause mutual interference, and radiation from the telescope' s own subsystems as well as environmental noise may both mask weak celestial signals[8].

As the core actuator that enables arcsecond-level pointing accuracy, as in the U.S. 100 m Green Bank Telescope, and stable tracking functions in a radio telescope, the servo control system has attracted considerable attention with regard to the electromagnetic compatibility of its sub-devices, such as servo drives and motors. The high-power components integrated in this system, such as servo drives, permanent-magnet motors, and high-precision shaft-angle encoders, generate significant electromagnetic interference (Electro-magnetic Interference, EMI) during operation, which has drawn sustained attention from relevant research teams. For example, the 500 m aperture spherical radio telescope

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† xiangbinbin031@163.com
‡ liuqi@xao.ac.cn

(Five-hundred-meter Aperture Spherical radio Telescope, FAST) project team constructed an anechoic-chamber test platform, systematically analyzed the interference characteristic spectrum of motor power components, and designed an electromagnetic shielding scheme to suppress interference[9−11]. The Qitai Radio Telescope (QTT) project team adopted a multi-scale evaluation method and established an RF-chip EMI traceability model from the component level to the board level, revealing the quantitative mapping relationship between radiation intensity and protection level[12]. However, servo-system high-power equipment generally has such characteristics as large volume and complex spatial layout, and traditional anechoic-chamber testing methods face inherent limitations of insufficient spatial adaptability. In addition, as the electromagnetic environment continues to deteriorate, the utilization rate of frequency bands becomes increasingly high, and various wireless services coexist[13], there is a certain degree of difficulty in measuring equipment radiation emissions in field environments. For example, existing signal–noise separation algorithms find it difficult to effectively handle frequency-domain coupling effects; there are deficiencies in decoupling the equipment intrinsic radiation from environmental scattered signals[14−16]; and system-level evaluation algorithms are limited by preset system topologies. Methods such as the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) and the Analytic Network Process (ANP) are difficult to adapt to the topological dynamic changes of complex electromagnetically coupled systems[17].

In summary, the servo control system of a radio telescope has relatively strong EMI, and it is difficult to conduct measurements in an anechoic-chamber environment. In response to this problem, this paper, relying on the NSRT servo control system, carries out EMI measurement and comprehensive evaluation of different devices in the system under field-environment conditions, providing important technical support for the further design of a system electromagnetic-protection scheme.

2 Analysis of the Interference Mechanism of the Servo Control System

The NSRT site is located on the northern slope of the central Tianshan Mountains in Eurasia, at an altitude of 2080 m and about 70 km from Urumqi. NSRT is equipped with four cryogenic receivers, operating in the L, S/X, C, and K bands, respectively[18]. In recent years, in order to mitigate the influence of electromagnetic interference from NSRT' s own electronic equipment and from within the observatory site on astronomical observations, we have adopted comprehensive electromagnetic-protection measures. Specifically: (1) the servo drives are installed below the antenna foundation, and the influence of the drives' strong electromagnetic radiation on astronomical observations is mitigated by the concrete wall; (2) a shielded room is built below the telescope foundation, and strong electromagnetic-interference sources in the observation room, such as digital terminals, the time–frequency system, and computer-network equipment, are moved into the shielded room for centralized protective treatment; (3) the windows of the observation room are protected to suppress electromagnetic interference from electronic equipment such as displays inside the observation room; and (4) centralized rooms for observatory building equipment are given overall shielding treatment, thereby mitigating the influence of electromagnetic interference from optical-telescope equipment on astronomical observations.

However, no specific protective measures have been implemented for components such as the azimuth and elevation motors and shaft-angle encoders in the servo control system. It is therefore necessary to carry out systematic electromagnetic-interference measurement and evaluation for the servo control system, so as to provide technical support for further electromagnetic protection. This section starts from the mechanism of electromagnetic radiation and briefly analyzes the influence of the servo control system on astronomical observations.

2.1 System Structure and Working Principle

The Xinjiang Astronomical Observatory NSRT servo control system adopts a layered layout architecture, including a coordinated control system consisting of the underground control layer, the ground azimuth-track layer, and the elevation-platform layer. Its spatial distribution is shown in Figure 1. The system uses three closed-loop control cores. In the underground control layer, a servo-drive cluster supplies power output through high-power cables to the drive units in the ground azimuth-track layer and the elevation-platform layer, forming the main speed-loop-based control channel. Each drive unit adopts an integrated motor–power-amplifier design to form a current loop, and realizes motion control of the azimuth axis ($-270^{\circ} \sim 270^{\circ}$) and elevation axis ($5^{\circ} \sim 88^{\circ}$) through a dual-motor dynamic-torque balanced-distribution algorithm. Combined with shaft-angle encoders, arcsecond-level real-time position feedback is achieved, forming a full-chain closed-loop control system. This control scheme satisfies the requirements of different scientific observations with the 26 m radio telescope by optimizing power-transmission efficiency and motion-control precision.

2.2 Analysis of the Interference Mechanism

The working principle of the servo control system is shown in Figure 2. When the stator winding of the drive motor adopts a Y-type connection, because the three-phase voltages are not completely symmetrical, a common-mode (conducted) voltage will appear between the neutral point of the stator winding and ground[19]. Here, point o denotes the midpoint of the DC bus, point n denotes the neutral point of the motor stator winding, and point g denotes the motor reference ground. Q_i $(i = 1, 2, \cdots, 6)$ denotes the switching state of the IGBT drive signal (on is 1, off is 0).

During steady-state operation of the motor, the mathematical description of the common-mode voltage V_{cm} can be defined as the potential difference between n and g[20]:

$$V_{\mathrm{cm}} = V_{\mathrm{no}} + V_{\mathrm{og}}, \tag{1}$$

where V_{no} denotes the potential difference of n relative to o, and V_{og} is the potential difference between g and o. Since the amplitude of V_{og} is significantly lower than that of V_{no} and its dynamic response is slow, under the condition of symmetrical three-phase windings, the motor-terminal common-mode voltage can be simplified as:

$$V_{\mathrm{cm}} \approx V_{\mathrm{no}} = \frac{1}{3}\left(V_{\mathrm{AO}} + V_{\mathrm{BO}} + V_{\mathrm{CO}}\right), \tag{2}$$

where V_{AO}, V_{BO}, and V_{CO} denote, respectively, the voltages of the inverter three-phase output terminals relative to the midpoint o of the DC bus. Their expressions are:

$$\begin{cases} V_{\mathrm{AO}} = \dfrac{(Q_1 - Q_4)}{2} V_{\mathrm{dc}}, \\ V_{\mathrm{BO}} = \dfrac{(Q_2 - Q_5)}{2} V_{\mathrm{dc}}, \\ V_{\mathrm{CO}} = \dfrac{(Q_3 - Q_6)}{2} V_{\mathrm{dc}}. \end{cases} \tag{3}$$

For the two-phase differential-mode voltages output by the inverter, their mathematical characterization can be decomposed into the following three groups of line voltages:

$$\begin{cases} V_{\mathrm{AB}} = V_{\mathrm{AO}} - V_{\mathrm{BO}} = (Q_a - Q_b)V_{\mathrm{dc}}, \\ V_{\mathrm{BC}} = V_{\mathrm{BO}} - V_{\mathrm{CO}} = (Q_b - Q_c)V_{\mathrm{dc}}, \\ V_{\mathrm{AC}} = V_{\mathrm{AO}} - V_{\mathrm{CO}} = (Q_a - Q_c)V_{\mathrm{dc}}. \end{cases} \tag{4}$$

where Q_a, Q_b, and Q_c are the switching logic variables of the upper-bridge-arm IGBTs.

Visible labels in Fig. 1: Sub-reflector support frame; Main surface load-bearing structure; Elevation structure; Elevation shaft angle encoder; S-pole rotor; N-pole rotor; Stator; Sub-reflector; Main reflector; Feed cabin; Deceleration structure; Elevation motor assembly; Structural type; Upper-level PC terminal; Cable; Other equipment compartments; Servo drive; Ground; Azimuth drive wheel; Cable; Azimuth structure; Azimuth motor assembly; Azimuth shaft angle encoder.

Figure 1 Spatial distribution of the overall structure of the servo control system

Fig. 1 Spatial distribution of the overall structure of the servo control system

Visible labels in Fig. 2: Input cable; Drive circuit; Control circuit; Shaft angle encoder; Speed reducer; Motor; Radio telescope; Ground; Inverter circuit; $V_{\mathrm{dc}}/2$; $V_{\mathrm{dc}}/2$; Q_1; Q_2; Q_3; Q_4; Q_5; Q_6; $(Q_a)a$; $(Q_b)b$; $(Q_c)c$; i_a; i_b; i_c; A; B; C; n; L; C_p; g.

Figure 2 Working principle diagram of the servo control system

Fig. 2 Servo control system working principle diagram

The pulse-width modulation (Pulse-Width Modulation, PWM) drive signal output by the servo driver is ideally a rectangular pulse wave. However, under the influence of the non-ideal switching characteristics of practical circuits, its voltage waveform exhibits a quasi-trapezoidal feature, as shown in Fig. 3. Here, the amplitude voltage of the trapezoidal wave is V_{dc}, the period is T, the rise time t_r is equal to the fall time t_f, and the time interval between the points at which the rising and falling edges reach 50% of the amplitude is denoted as t_{on}. When power devices switch on and off at high speed, large voltage slew rates $\mathrm{d}V/\mathrm{d}t$ and current slew rates $\mathrm{d}i/\mathrm{d}t$ are generated. As a result, in addition to the fundamental component, the PWM signal also carries a large number of higher-order harmonics [21]. Specifically, $\mathrm{d}V/\mathrm{d}t$ excites displacement currents through capacitive coupling channels, while $\mathrm{d}i/\mathrm{d}t$ produces induced voltages along inductive coupling paths; together, these constitute the principal factors responsible for high-frequency conducted interference in the drive system.

Figure 3. Schematic diagram of an ideal trapezoidal pulse signal

Fig. 3 Ideal trapezoidal pulse signal schematic

The time-domain expression of the ideal trapezoidal wave is:

$$V(t)=\begin{cases}\dfrac{V_{\mathrm{dc}}}{t_r}t, & (t_0,t_0+t_r),\\ V_{\mathrm{dc}}, & (t_0+t_r,t_0+t_{\mathrm{on}}),\\ \dfrac{t_{\mathrm{on}}+t_f-t}{t_f}V_{\mathrm{dc}}, & (t_0+t_{\mathrm{on}},t_0+t_{\mathrm{on}}+t_f).\end{cases} \tag{5}$$

In the formula, the initial time of the voltage pulse signal is set as $t_0 = 0$.

Applying the Fourier transform to $V(t)$, the amplitude-frequency characteristic of the voltage trapezoidal pulse wave is obtained as [22]:

$$V = 2dV_{\mathrm{dc}}\left|\frac{\sin(n\pi d)}{n\pi d}\right|\left|\frac{\sin\left(n\pi\dfrac{t_r}{T}\right)}{n\pi\dfrac{t_r}{T}}\right|. \tag{6}$$

In the formula, n is the harmonic order, usually taken as the sequence of natural numbers, and d is the duty ratio of the trapezoidal wave, $d = t_{\mathrm{on}}/T$.

Given $d = 0.025$ and the operating frequency $f = 10$ kHz, when the rise time t_r varies from 1 μs to 0.1 μs, and the voltage varies from 220 V to 440 V, the variation curves of the bus voltage over the frequency band from 10 kHz to 100 MHz are obtained respectively. The variation trend conforms to the spectral envelope after Fourier decomposition, and the results are shown in Fig. 4. In the figure, the unit dB/dec means that for every tenfold increase in frequency, the gain decreases by 20 dB.

It can be seen from the data in Fig. 4(a) that, when the switching time t_r and frequency f are fixed, an increase in the system bus voltage V_{dc} enhances the amplitude of the high-frequency harmonic components in the output waveform. This phenomenon indicates that an increase in power level—usually accompanied by an increase in bus voltage—causes the EMI intensity of high-power devices to grow nonlinearly. In the experimental data of Fig. 4(b), when V_{dc} and f remain constant, shortening the rise time t_r of the trapezoidal pulse produces a dual coupling effect: on the one hand, the increase in the switching speed of the power device leads to a sharp increase in $\mathrm{d}V/\mathrm{d}t$; on the other hand, the proportion of high-frequency components in the signal spectrum and their distribution bandwidth exhibit synchronous expansion. Therefore, with the trend toward high-power-density design in modern power-electronic systems, such coupling effects will be further amplified.

In summary, in addition to the fundamental component, the PWM signal output by the servo driver carries a large number of higher-order harmonics and is the main radiation source in the system. Its characteristic high-frequency switching behavior interacts with parasitic parameters, emitting electromagnetic energy outward through two paths—spatial radiation and cable conduction—and thereby causing interference to astronomical observations.

2.3 Coupling Path Analysis

The analysis in Section 2.2 shows that the servo driver is the main interference source in the system, and its coupling paths can be divided into conducted emission and radiated emission. The common-mode (Common Mode, CM) interference coupling paths are shown in Fig. 5. One is the power-device coupling path, the inverse-

The high-frequency switching of the converter switching devices generates pulse voltages, which excite the capacitive coupling current I_{cm} through the heat-sink–housing parasitic capacitance and form a low-impedance loop through the grounding impedance at the power-supply terminal. The second is the motor-side coupling path, in which the interference signal is transmitted through the three-phase cable to the motor windings and forms a closed loop via the distributed capacitance between the stator windings and the motor housing, thereby producing the ground common-mode current I_{cm}.

(a) Spectrum of trapezoidal pulses with different voltages from 0.01 to 100 MHz

(b) Spectrum of trapezoidal pulses with different frequencies from 0.01 to 100 MHz

Fig. 4 Amplitude-frequency characteristics of trapezoidal waves with different parameter variations

Fig. 5 Conducted interference coupling paths in the system

$$I_{\mathrm{cm}} = C\frac{\mathrm{d}V}{\mathrm{d}t} \approx \frac{CU}{t_r + t_f}. \tag{7}$$

In the formula, I_{cm} denotes the common-mode EMI current, C is the parasitic capacitance parameter between the power switching device and the heat sink, and U denotes the DC bus voltage on the rectifier-bridge side.

In path 2, the three-phase cable forms an equivalent antenna structure due to high-frequency current variations and radiates high-frequency electromagnetic waves into space. The motor, acting as an inductive load, generates an alternating magnetic field in its windings under high-frequency harmonic excitation, and interference energy leaks outward through the distributed capacitance of the windings, apertures in the motor housing, and gaps at cable connections [23]. When the common-mode interference frequency exceeds the 30 MHz threshold, the impedance of the conducted path increases, and electromagnetic energy is more likely to affect nearby equipment through spatial radiation. At this point, radiated interference becomes the dominant interference mode [24], and the radiated-emission coupling path is shown in Fig. 6.

From the above analysis, it can be seen that the servo drive is the main interference source, and its coupling paths are mainly conducted emission and radiated emission, namely high-frequency

Electromagnetic waves can be emitted conductively through the cable between the driver and the motor; at the same time, high-frequency electromagnetic waves radiate outward through space, thereby affecting astronomical observations.

Fig. 6 Radiated interference coupling paths in the system

3 On-Site Environmental EMI Assessment

It can be seen from Section 2.1 that the servo control system is composed of multiple high-power motors, servo controllers, shaft-angle encoders, and other components. Considering that the system power is very high and the interconnections are complex, it is difficult to carry out EMI measurements in a laboratory environment; therefore, EMI measurements must be performed in the on-site environment. However, on-site environmental measurements are affected by the external electromagnetic environment, so the measurement data must be rigorously calibrated; that is, electromagnetic interference in the environment must be removed to obtain an accurate radiated-emission spectrum of the equipment.

In addition, since devices such as motors, servo drives, and shaft-angle encoders in the system are distributed at different positions on the telescope, and the EMI control requirements for equipment at different positions differ, in order to conduct further EMI assessment, on-site EMI measurements are planned for different devices separately. Furthermore, to more intuitively evaluate the radiation levels of different devices in the system and the electromagnetic compatibility design requirements, an evaluation model based on the entropy weight method (Entropy Weight Method, EWM) is considered. By quantifying the difference between the radiated-emission level of each device and its interference-control requirement—the radiated exceedance—the EMI control levels of different devices and different frequency bands can be evaluated intuitively, and specific electromagnetic protection design requirements can be given, providing a basis for further electromagnetic protection design.

3.1 EMI Measurement and Data Calibration

According to the above analysis, the RE102 measurement item of the national military standard GJB 151B is adopted to carry out radiated-emission tests on each device in the servo control system. Considering that the EMI frequency bands of the equipment are mainly concentrated below 6 GHz, and in combination with the low-frequency observation requirements of radio astronomy, the measurement frequency band is set to 150–6000 MHz. In addition, considering the later problem of environmental interference removal, EMI measurements are carried out separately under the equipment power-off state and the normal operating state, including both horizontal-polarization and vertical-polarization states. Fig. 7 shows the test system and link schematic. The system consists of a measurement antenna, a low-noise amplifier (Low Noise Amplifier, LNA), a signal analyzer, a measurement computer, and other components. The distance between the horizontal center axes of the device under test and the measurement antenna is maintained at 1 m, and the height of the antenna center axis above the ground plane is 1.2 m. Considering that equipment radiation contains transient interference, a peak detector and a max-hold measurement mode are used to ensure the completeness of the measurement data.

Fig. 7 Test system and link

After measurement, the data are calibrated according to Eq. (8), yielding the power P_s at the antenna aperture:

$$P_s = P - G_A - G_{\text{sys}}, \tag{8}$$

where P is the signal power recorded by the signal analyzer, in dBm; G_A is the antenna gain; and G_{sys} is the test-system gain. G_{sys} can be obtained by the system-gain calibration method in Ref. [25].

According to Eq. (9), the antenna-aperture power P_s is normalized to field strength:

$$E(\text{dB}\mu\text{V/m}) = P_s(\text{dBm}) + AF(\text{dB}) + 107, \tag{9}$$

where E is the field strength at the antenna aperture; 107 is the standard conversion coefficient between the power unit dBm and the voltage unit dBμV in a 50 Ω impedance system; and AF is the antenna factor.

3.2 Background-Noise Elimination

Through the EMI measurement and data calibration in Section 3.1, the radiated-emission spectrum of the equipment is obtained. The environmental interference in the spectrum, such as radio-service signals (communication signals and digital television signals) and signals radiated by other unrelated equipment, is shown in Fig. 8. This paper adopts an existing signal–noise separation algorithm. Through statistical analysis of the equipment shutdown state and normal operating

the correlations among the radiation-emission spectra under operating states, and eliminate environmental electromagnetic interference.

[Visible labels in Fig. 8: field strength (dBμV $\cdot$ m^{-1}); frequency/MHz; background noise; other noise signals; digital television signals; radio operations signals.]

Fig. 8 150–1000 MHz elevation-motor ambient noise in the field environment

Fig. 8 150–1000 MHz elevation motor ambient noise in field environment

For environmental EMI removal, the noise and signal in the spectrum must first be separated. The signal-separation method is intended to adopt the 20% threshold algorithm proposed in ITU-R Recommendation SM.1753-2 of the International Telecommunication Union[26]; its algorithmic procedure is shown in Fig. 9. With this algorithm, the threshold dataset $R_{(t,s)}$ for each interval can be obtained, where t is the frequency point and s is the field strength corresponding to that frequency point. This algorithm is based on the optimal-selection criterion for noise samples: the 20% of data with the lowest amplitudes in the spectral samples are selected as the interval characterizing the noise features. First, the amplitude data over the full frequency band are sorted in ascending order, the lowest 20% of low-amplitude samples are extracted, and their arithmetic mean is calculated to obtain the noise-baseline estimate (NBE). Then, a dynamic threshold interval is set based on the NBE, i.e., a 3–5 dB margin is superimposed on the NBE to separate the radiated signal from the noise. Since the background noise must be compared with the true signal in the same frequency band, for ease of subsequent data processing the threshold dataset is rewritten as $R[n]$, where n denotes the sequence number of the acquired data point, and $R[n]$ corresponds to the field-strength value of each acquisition point.

[Visible formulas and labels in Fig. 9:]

Correction factor for adjusting the separation threshold:

$$\alpha = 0.2$$

$$\mu V_s = \frac{1}{[\alpha n]} \sum_{k=1}^{[\alpha n]} S_s(k)$$

Base noise:

$$S_s = \alpha \times 100\%$$

$$P_s(F \cdot V)$$

Dynamic threshold:

$$R_{(t,s)} = \mu V_s + \omega$$

$$\omega = [3, 5]$$

Isobaric segmentation:

$$d > w_{\max}$$

$$F_i = F_0 + i \cdot d$$

$$c = \left\lfloor \frac{F_{\max} - F_0}{d} \right\rfloor + 1$$

$$w = k \times l$$

Magnitude value:

$$V_s[n] = \bigcup_{i=1}^{c} B_i$$

Isometric interval:

$$B_i = \{V[(i-1)l+1],\, V[(i-1)l+2],\, \dots,\, V[il]\}$$

Standard deviation:

$$\sigma V_s = \sqrt{\frac{1}{N_\alpha} \sum_{k=1}^{N_\alpha} \left(S_s(k) - \mu V_s\right)^2}$$

Dynamic threshold correction:

$$R_{(t,s)} = \mu V_s + \omega \cdot \sigma V_s$$

Fig. 9 20% threshold algorithm architecture[26]

Fig. 9 20% threshold algorithm architecture[26]

On the basis of the above method, we optimized the signal-noise separation method; that is, spectral segmentation is used, and the interval-division results are obtained. The dataset $B[n]$, composed of the field strength corresponding to each frequency sampling point in the interval-division results, and $R[n]$ are used for signal identification. When the field-strength value in the dataset $B[n]$ is greater than the field-strength value of the corresponding frequency point in $R[n]$, it is identified as an EMI signal, and its frequency-amplitude data $(F[n], V[n])$ are recorded. Here, $F[n]$ is the frequency dataset of the EMI signal, and $V[n]$ denotes the field-strength dataset at the corresponding frequencies.

Conversely, it is classified as environmental background noise, and the noise database $B[g]$ is established.

Based on the established noise database, frequency-point alignment processing is performed on the EMI signal and the environmental noise, and an accurate data-mapping relationship is established. A similarity algorithm is used to analyze the features of the frequency-point data and complete signal-feature discrimination; noise removal is performed on similar signals; and, through data reconstruction and integration, the inherent radiation characteristics of the equipment are obtained. The specific process is as follows:

(1) Frequency-point correspondence—To further analyze the signal characteristics, it is necessary to establish

the frequency-point mapping relationship between the polarized signals $(F_{\mathrm{H}}, F_{\mathrm{V}})$ and the environmental noise F_{B}. Here, F_{H} is the frequency dataset of the horizontally polarized signal, F_{V} is the frequency dataset of the vertically polarized signal, and F_{B} is the frequency dataset of the environmental-noise signal. For non-overlapping frequency bands, they can be directly incorporated into the EMI feature set M; for overlapping frequency bands $\mathrm{Fre}(i)$, the dataset (S, Y) is used for storage, reflecting the coupling characteristics between signal strength and background noise. Here, X_F denotes the dataset of overlapping frequency bands in the environmental-signal frequencies, and Y_F denotes the dataset of overlapping frequency bands in the polarized-signal frequencies,

$$\begin{cases} S = \{X_F \mid F \in \mathrm{Fre}(F_{\mathrm{B}})\}, \\ Y = \{Y_F \mid F \in \mathrm{Fre}(F_{\mathrm{H}}, F_{\mathrm{V}})\}. \end{cases} \tag{10}$$

(2) Similarity discrimination—introduce the Pearson correlation coefficient $\beta_{(x,y)}$ to evaluate the linear correlation between the polarized signal and the background noise. The Pearson correlation coefficient is normalized by the covariance $\mathrm{cov}(x, y)$ and the standard deviations σ_{xy}, which can effectively overcome the influence of dimensional differences on the evaluation result. According to references [27-29] and verification with measured samples, the similarity threshold is determined as $\tau = 0.4$. The calculation formula is as follows:

$$\beta_{(x,y)} = \frac{\mathrm{cov}(x, y)}{\sigma_x \sigma_y} = \begin{cases} \beta_{(x,y)} < \tau, \\ \beta_{(x,y)} \geq \tau. \end{cases} \tag{11}$$

(3) EMI removal—when the correlation is relatively strong, i.e., $|\beta| \geq 0.4$, perform the differencing operation $D_F = Y - S$, and update the processed data into the feature set M'; when the correlation is relatively weak, directly retain the original data in the set M', thereby avoiding the loss of effective signals.

(4) Spectral reconstruction—superimpose the difference D_F stored in M' with the background-noise data B_{noise} at the corresponding frequency in the floor noise $B[g]$, generating a new set M_{new}, i.e., it is calculated by the frequency-point calibration algorithm in formula (12), where F is the frequency set of the overlapping frequency bands of the equipment' s own EMI signal,

$$M_{\text{new}} = \{(F, D_F + B_{\text{noise}}) \mid (F, D_F) \in M'\}. \tag{12}$$

The amplitudes at each frequency point in M' are used to replace the corresponding components of $B[g]$, while the original noise characteristics of the non-signal frequency bands are retained. The data in the feature sets M and M_{new} are sorted and updated in ascending order of frequency, thereby reconstructing the polarized signals P_{H} and P_{V} after noise removal.

The results after noise removal for the servo control system, as shown in Figure 10, indicate that: below 1000 MHz, the servo driver is dominated by narrowband interference, with a maximum of 70 $\text{dB}\mu\text{V} \cdot \text{m}^{-1}$; in the 1000–3000 MHz band, broadband and narrowband interference coexist. Below 700 MHz, the azimuth motor is dominated by broadband interference, with a maximum of 35 $\text{dB}\mu\text{V} \cdot \text{m}^{-1}$; above 700 MHz, narrowband interference appears. Below 1000 MHz, the shaft-angle encoder mainly exhibits narrowband interference, while a small amount of narrowband interference remains in the high-frequency band. The interference characteristics of the elevation motor are similar to those of the azimuth motor, but below 600 MHz it exhibits the coexistence of narrowband and broadband interference. In summary, all sub-devices in the system have relatively strong interference, and the servo driver is the main interference source.

3.3 Interference Evaluation Based on EWM

Section 3.2 obtained the radiated-emission spectra of different devices in the servo control system. To intuitively evaluate the radiation levels of different devices in the system and the shielding-protection levels, this section intends to adopt the EWM evaluation method and, based on the radiation levels and interference thresholds of the devices, intuitively evaluate the EMI control levels of different devices and different frequency bands.

Reference [30] provides a calculation method for the interference electric-field limit at equipment installation positions. By comprehensively considering the installation positions of different devices in the servo control system, together with the interference electric-field threshold at the feed aperture of the 26 m radio telescope and the antenna sidelobe gain, the interference-level thresholds, i.e., radiation thresholds, of the servo driver, elevation motor, azimuth motor, and shaft-angle encoders are quantified. The results are shown in Figure 11. It can be seen from Figure 11 that, within the 150–6000 MHz band, the interference-level thresholds of the devices differ, and in descending order they are the servo driver, azimuth motor, elevation motor, azimuth shaft-angle encoder, and elevation shaft-angle encoder. Among them, the radiation thresholds of the servo driver and the azimuth motor differ by about 2 dB. The threshold of the elevation shaft-angle encoder installed on the support rotating shaft of the main reflector is about 15 dB lower than that of the servo driver; that is, the closer it is to the telescope focus, the lower the threshold, and the higher the electromagnetic-compatibility control requirement.

Based on the above radiation-threshold levels of the devices and the radiated data after removing environmental noise, the radiated exceedance can be calculated. The EWM algorithm is used to construct a weighting model, and objective weighting is realized by quantifying the dispersion degree of the indicator data. Compared with subjective weighting methods that rely on expert experience, such as the analytic hierarchy process, EWM is data-driven and has greater advantages in calculation accuracy, objectivity, and decision-making effectiveness; it is a better evaluation scheme. Its evaluation procedure is shown in Figure 12.

Based on the EWM algorithm procedure, and in combination with the radiated exceedance data, the interference evaluation of the NSRT servo control system is completed. The specific steps are as follows.

(a) 150–6000 MHz servo-drive electromagnetic radiation

(b) 150–6000 MHz azimuth-motor electromagnetic radiation

(c) 150–6000 MHz azimuth-encoder electromagnetic radiation

(d) 150–6000 MHz elevation-motor electromagnetic radiation

Fig. 10 Radiation characteristics of each device after noise elimination

Fig. 10 Radiation characteristics of equipment after noise elimination

(1) Normalization and decision matrix—Because the indicators differ in order of magnitude and numerical range, a range method is used to build a standardization framework, mapping the raw data into the interval $[0, 1]$. The specific formulas are as follows:

$$\begin{cases} Z_{ij}^{+} = \dfrac{X_{ij} - X_{\min}}{X_{\max} - X_{\min}}, \\ Z_{ij}^{-} = \dfrac{X_{\max} - X_{ij}}{X_{\max} - X_{\min}}. \end{cases} \tag{13}$$

Here, Z_{ij}^{+} is defined as a positive indicator, and Z_{ij}^{-} is defined as a negative indicator. i is the sample equipment number, and j is the indicator corresponding to each piece of equipment. $1 \le i \le m,\ 1 \le j \le n$. Through this processing, dimensional differences among indicators are eliminated, forming the normalized decision matrix $Z_{m\times n}$ (assuming m is a negative indicator):

$$Z_{m\times n} = \begin{bmatrix} \frac{X_{11}-\min(X_1)}{\Delta X_1} & \cdots & \frac{X_{1n}-\min(X_1)}{\Delta X_1} \\ \vdots & \ddots & \vdots \\ \frac{\max(X_m)-X_{m1}}{\Delta X_m} & \cdots & \frac{\max(X_m)-X_{mn}}{\Delta X_m} \end{bmatrix}. \tag{14}$$

Here, ΔX_m denotes the range of the indicators of the m-th piece of equipment, i.e., the difference between the maximum and minimum values of that indicator.

Fig. 11 Radiation thresholds of system sub-equipment

(2) Information entropy calculation—Information entropy is an important concept used to measure the degree of dispersion and information content of indicator data. The normalized values z_{ij} of $Z_{m\times n}$ are directly used as the standardized indicator values p_{ij}, and the entropy value is iteratively solved using the following formula:

$$H_j = -\delta \sum_{j=1}^{n} p_{ij} \ln(p_{ij}). \tag{15}$$

Here, the adjustment coefficient $\delta = 1/\ln n$, which ensures that the entropy value $H_j \in [0,1]$. If $p_{ij} = 0$, to avoid computational errors, this datum must be removed.

Fig. 12 EWM algorithm assessment process

(3) Difference coefficient—The difference coefficient K_j is the complementary measure of information entropy, and its value range is strictly limited to $[0,1]$:

$$K_j = 1 - H_j, \tag{16}$$

The larger the value of K_j, the higher the discrimination degree of this indicator and the lower the information redundancy.

(4) Indicator weight allocation—The weight matrix w composed of the weights ω_j of all indicators satisfies the normalization condition and can reflect the objective importance of the indicators. The specific calculation is as follows:

$$\begin{cases} \omega_j = \dfrac{K_j}{\sum\limits_{j=1}^{n} K_j}, \\ w = [w_1, \dots, w_{m-1}, w_m]^{\mathrm{T}}. \end{cases} \tag{17}$$

(5) Comprehensive score calculation—The comprehensive assessment score is calculated using the indicator weights and standardized values. The formula is:

$$S_i = \sum_{j=1}^{n} \omega_j \cdot z_{ij}. \tag{18}$$

The comprehensive estimated value $S_i \in [0, 1]$; the larger the value, the better the comprehensive performance of the scheme.

(6) Example—For the NSRT servo control system, in order to achieve

To simplify and visualize the assessment results, based on the distribution pattern of radiation thresholds, 11 key frequency points were selected in each of the 0.15–1 GHz and 1–6 GHz frequency bands as assessment nodes, in order to construct a comprehensive assessment indicator system for frequency-domain radiation exceedance. The radiation exceedance can be predicted from the radiation level and the radiation threshold, expressed as

$$\mathrm{SE}_m[n] = U_m[n] - U_\mathrm{p}[n]. \tag{19}$$

Here, $\mathrm{SE}_m[n]$ is the shielding effectiveness of the m-th device at the n-th point; $U_m[n]$ is the field-strength amplitude of the m-th device at the n-th frequency point; and $U_\mathrm{p}[n]$ is the radiation threshold corresponding to the m-th device at the n-th frequency point.

After normalization, the decision assessment matrices are obtained as follows:

$$\mathrm{SE}_\mathrm{low} = \begin{bmatrix} 1.00 & 1.00 & \cdots & 1.00 \\ \vdots & \vdots & \ddots & \vdots \\ 0.25 & 0.19 & \cdots & 0.35 \end{bmatrix}, \tag{20}$$

$$\mathrm{SE}_\mathrm{high} = \begin{bmatrix} 1.00 & 1.00 & \cdots & 0.00 \\ \vdots & \vdots & \ddots & \vdots \\ 0.52 & 0.65 & \cdots & 1.00 \end{bmatrix}. \tag{21}$$

Here, SE_low denotes the normalized radiation-exceedance values corresponding to the frequency band below 1 GHz, and $\mathrm{SE}_\mathrm{high}$ denotes the normalized radiation-exceedance values corresponding to the frequency band above 1 GHz.

Figure 13 shows the assessment results for different devices and different frequency bands. It can be seen that, in the frequency band below 1 GHz, the score of the servo drive is significantly higher than that of the other devices, indicating that its radiation exceedance far exceeds that of the other devices and that it makes the greatest contribution to electromagnetic interference; therefore, it has the highest electromagnetic-protection priority. The assessment scores of the azimuth shaft-angle encoder and the elevation shaft-angle encoder are close to each other and are both higher than those of the drive motors, indicating that their electromagnetic-interference contributions relative to the threshold are at a medium level; their electromagnetic-protection priority is lower than that of the servo drive but higher than those of the azimuth and elevation drive motors. The assessment scores of the azimuth motor and the elevation motor are close to each other. Compared with the servo drive and the shaft-angle encoders, their contributions to electromagnetic interference are relatively low, and their electromagnetic-protection priority is also lower than those of the servo drive and the shaft-angle encoders. In addition, for the frequency band above 1 GHz, the assessment value of the elevation shaft-angle encoder is much higher than those of the other devices, meaning that its electromagnetic-interference magnitude is relatively high with respect to the radiation threshold and that its electromagnetic-protection priority is the highest within this frequency range. The assessment scores of the servo drive, the azimuth shaft-angle encoder, and the elevation motor are close to each other and are all much higher than that of the azimuth motor, indicating that their contributions to electromagnetic interference are greater than that of the azimuth motor, and their electromagnetic-protection priorities are also higher than that of the azimuth motor.

Fig. 13 Comprehensive assessment scoring for equipment
Visible plot labels: "Assessment score" ; "Below 1 GHz" ; "Above 1 GHz" ; "Servo drive" ; "Azimuth motor" ; "Azimuth encoder" ; "Elevation motor" ; "Elevation encoder" .

3.4 System Shielding Requirement Analysis

The assessment results in Section 3.3 intuitively give the electromagnetic-interference contribution and electromagnetic-protection priority of each device in the system. This section, based on the radiation level $U_m[n]$ of different devices in the servo control system, and in combination with the radiation threshold $U_\mathrm{p}[n]$ corresponding to the installation position of each device, introduces the engineering safety margin φ on the basis of formula (19), and calculates the electromagnetic shielding requirement SE_{mn} of different devices by formula (22). In addition, considering practical influencing factors such as material aging effects, process discreteness, and equipment coupling leakage, $\varphi = 15$ dB is determined [10]:

$$\mathrm{SE}_{mn} = U_m[n] - U_\mathrm{p}[n] + \varphi. \tag{22}$$

According to the above calculation method, the shielding requirements of different devices are quantified. Figure 14 shows the quantified results of the shielding requirements. It can be seen that the electromagnetic-protection design requirements for the devices are highest in the low-frequency band, and as the frequency increases, the shielding requirements show a downward trend.

From the data comparison, the servo drive is the device with the highest shielding requirement in the system: its shielding requirement in the 150–1000 MHz frequency band is 72 dB, while in the 1–6 GHz frequency band its shielding requirement is significantly weakened. The shielding requirements of the azimuth shaft-angle encoder and the elevation shaft-angle encoder are 45 dB in the 150–1000 MHz frequency band, and must satisfy 25 dB in the 1–6 GHz frequency band. The shielding requirements of the azimuth motor and the elevation motor are 45 dB in the 150–1000 MHz frequency band; in the 1–6 GHz frequency band, the shielding requirements are greatly reduced.

4 Electromagnetic Protection Considerations

Based on the calculation results for the system shielding requirements in Section 3.4, the drives, motors, and shaft-angle encoders in the servo control system all exhibit evident [[text continues off page]]

significant electromagnetic interference, and the key protection frequency band is below 6 GHz. The overall electromagnetic protection considerations for the system are as follows:

Fig. 14 Electromagnetic shielding requirements for system equipment

(1) The servo drive is the interference source with the highest radiation level in the system. It should be installed beneath the telescope foundation to minimize the coupling between electromagnetic interference and the telescope receiving system. On this basis, shielding and filtering technologies should be combined to suppress both the radiated-emission interference and conducted-emission interference of the drive. First, the drive should be installed in a high-performance shielded room, and the shielding effectiveness of the shielded room in the 150 MHz–6 GHz band should be greater than 72 dB. In addition, considering that the motor is a high-power electronic device, the performance and reliability of the customized power filter must be considered. For other communication signals entering the shielded room and interconnecting with the controller, their operating frequencies should be measured, appropriate signal filters should be customized accordingly, and tests should be conducted to verify that the introduced filters have no effect on the communication signals, so as to ensure stable system operation.

(2) The drive motor also exhibits significant interference. Its main interference source is the motor resolver, and the interference signal is conducted through signal lines to the outside of the motor housing. Therefore, a shielding box should be used to provide overall shielding for the motor. The shielding effectiveness of this shielding box in the 150 MHz–6 GHz band should be greater than 45 dB, and filters should be used to suppress internal radiated signals from being conducted through cables to the outside of the shielding enclosure.

(3) The angular encoder is also an electromagnetic interference source that cannot be ignored. Its radiation source is likewise the resolver, and the interference signal is radiated through signal lines to the outside of the encoder housing. Its protection requirement is a shielding effectiveness greater than 45 dB in the 150 MHz–6 GHz band. The difficulty in protecting the angular encoder lies in the fact that it is installed on the elevation axis or azimuth axis and contains sliding parts, making high-performance electromagnetic shielding difficult. It is necessary to build an experimental platform according to the actual engineering scenario, and to improve the reliability of the shielding scheme through shielding-performance measurements and scheme optimization. In addition, considering the extremely high measurement-accuracy requirements of the angular encoder, the electrical signal can be converted into an optical signal and transmitted via optical fiber to the servo-drive control unit, thereby avoiding any influence of the introduced signal filter on measurement accuracy. Moreover, shielding of the optical fiber can be realized through a waveguide tube; the technology is mature and low in cost.

The above analysis shows that, in the servo control system, the equipment with the highest shielding requirement is the servo drive (72 dB). At present, the shielding effectiveness of the shielded room can reach 100 dB, which is sufficient to solve the electromagnetic interference problem of the servo drive. In addition, all other equipment in the system adopts a shielding scheme combining shielding and filtering. The technology has become mature and can meet the shielding-protection requirements, thereby solving the overall electromagnetic-protection problem of the system.

5 Conclusions

This paper focuses on the electromagnetic interference problem of the Nanshan NSRT servo control system and carries out EMI measurement and evaluation of equipment under on-site environmental conditions. First, the radiated-emission measurement method in GJB 151B was adopted to measure the radiated emissions of different equipment in the system, and environmental electromagnetic interference was eliminated through signal–noise separation and signal-correlation analysis. On this basis, the interference-level limits at the installation positions of different equipment were quantified, and an EWM evaluation model based on the amount of radiated exceedance was constructed to evaluate the electromagnetic-protection requirement levels of different equipment in the system. In addition, according to the shielding-design requirements of different equipment, the electromagnetic-protection approaches and key technical points for different equipment were discussed, providing important technical support for further electromagnetic-protection scheme design. In the future, we will use actual telescope observational data to further analyze the influence of electromagnetic interference from the servo control system on scientific observations.

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References

[1] Wang N, Xu Q, Ma J, et al. SSPMA, 2023, 66: 154

[2] Nan R, Li D, Jin C, et al. IJMPD, 2011, 20: 989

[3] GJB 72A-2002 *Terminology for Electromagnetic Interference and Electromagnetic Compatibility*. Beijing: Military Standard Publishing and Distribution Department of the General Armament Department, 2003

[4] Ekers R D, Bell J F. 2000, arXiv: astro-ph/0002515

[5] Zhang Haiyan, Wu Mingchang. *Science and Technology Overview*, 2018, 12: 54

[6] *GJB 151B-2013 Measurement of Electromagnetic Emission and Susceptibility of Military Equipment and Subsystems*. Beijing: Military Standards Publishing and Distribution Department of the General Armaments Department, 2013

[7] Tang Renkai, Li Rong, Liu Qi, et al. *Chinese Journal of Radio Science*, 2024, 39: 640

[8] Liu Ye, Liu Qi. *Scientia Sinica: Physica, Mechanica & Astronomica*, 2019, 49: 121

[9] Zhang H Y, Nan R D, Gan H Q, et al. URSI AP-RASC. IEEE, 2016: 1–3

[10] Zhang H Y, Wu M C, Yue Y L, et al. RAA, 2018, 18: 048

[11] Zhang H Y, Wu M C, Yue Y L, et al. RAA, 2020, 20: 075

[12] Wang Ziyue, Li Rong, Liu Qi, et al. *Acta Astronomica Sinica*, 2024, 65: 63

[13] Yuan Li, Liu Qi, Sun Zhengwen, et al. *Chinese Journal of Radio Science*, 2017, 32: 650

[14] Yan Tianfeng, Ma Rui. *Journal of Computer Applications*, 2011, 31: 2922

[15] Zhang Quntao, Liu Qi, Sun Zhengwen, et al. *Science Technology and Engineering*, 2016, 16: 191

[16] Liu Qi, Feng Dongdong. *Chinese Journal of Radio Science*, 2021, 36: 201

[17] Deng Quan. *Research on Electromagnetic Interference Suppression and Electromagnetic Compatibility Assessment Methods in EMC Measurements*. Mianyang: Southwest University of Science and Technology, 2024: 1–74

[18] Liu Qi, Liu Ye, Chen Maozheng, et al. *Acta Astronomica Sinica*, 2019, 60: 54

[19] Zhao Yuheng, Zhou Huawei, Chen Min, et al. *Micromotors*, 2023, 56: 53

[20] Zhong Zaimin, Wang Qinglong, Yin Xing. *Electric Machines & Control Application*, 2021, 48: 26

[21] Sun Li, Nie Jianhong. *Servo Control*, 2010, 6: 33

[22] Xiong Shibo, Huang Changyi. *Fundamentals of Measurement Technology in Mechanical Engineering*. Beijing: China Machine Press, 2006: 15–55

[23] Wei Siqi. *Research on Prediction Methods for Radiated Interference in PWM Motor Drive Systems*. Chengdu: University of Electronic Science and Technology of China, 2022: 20–90

[24] Wang Jiangqi, Wang Qunjing, Li Guoli, et al. *Electric Drive*, 2013, 43: 39

[25] Liu Qi, Wang Na, Wang Yue, et al. *Chinese Journal of Radio Science*, 2017, 32: 718

[26] Recommendation ITU-R SM. 1753-2. Methods for Measurements of Radio Noise. Geneva: International Telecommunication Union, 2012

[27] Peng Hai. *Electronics World*, 2017, 07: 163

[28] Li Hongbin, He Guangzhong, Guo Qiuting. *Chemical Analysis and Meterage*, 2015, 24: 33

[29] Wang Liyun, Liu Qi, Chen Maozheng, et al. *Acta Astronomica Sinica*, 2019, 60: 40

[30] Liu Qi, Wang Na, Liu Ye, et al. *Scientia Sinica: Physica, Mechanica & Astronomica*, 2019, 49: 95

On-Site EMI Assessment of the NSRT Servo Control System

FAN Yu-ming1 XIANG Bin-bin1 LIU Qi2 CAI Ming-hui2 WANG Na2 ZHANG Chao2
ZHENG Xian-ze2 LI Xiao-feng3 MA Ling2 BAAN Willem A2

(1 School of Mechanical Engineering, Xinjiang University, Urumqi 830017)
(2 Xinjiang Astronomical Observatory, Chinese Academy of Sciences, Urumqi 830011)
(3 China Electronics Technology Group 33rd Research Institute, Taiyuan 030006)

Abstract The servo control system is a critical component of radio telescopes with high electromagnetic emissions. However, the distribution of different equipment across various locations of the telescope poses significant challenges to conducting electromagnetic interference (EMI) measurements under laboratory conditions. This paper addresses these challenges by conducting an on-site EMI assessment of the servo control system at the Nanshan 26-meter Radio Telescope (NSRT), providing technical support for further electromagnetic protection. First, the electromagnetic interference mechanisms of the servo control system were analyzed. Through on-site EMI measurements, data calibration, and environmental noise elimination, radiated emission spectra of different devices were obtained. Furthermore, based on the telescope' s radiation threshold, an Entropy Weight Method (EWM) model was employed to evaluate the electromagnetic interference levels of various devices, determining their radiation levels and shielding requirements. Based on these results, this study further discusses feasible electromagnetic protection schemes and related considerations for the system.

Key words telescopes: radio telescope, instrumentation: servo control system, methods: interference assessment, techniques: electromagnetic compatibility

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