Design and Implementation of Electromagnetic Radiation Evaluation Software for Electronic Devices: Postprint

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Abstract

Radio astronomy sites contain numerous instruments and equipment with complex electromagnetic environments. Electromagnetic compatibility design, shielding design, and radiation assessment all rely on test-based data processing and analysis, while programmatic approaches represent the only means to improve testing and data analysis efficiency. This paper analyzes the hardware composition, assessment process, software development objectives, and key technical points of electromagnetic radiation assessment systems. Based on software requirements analysis and data transfer, processing, and storage during the assessment process, the design flowchart, data flow diagram, and two-dimensional interpolation algorithm flowchart for the assessment software are presented. The main data characteristics during the electromagnetic radiation assessment process are analyzed, and a data storage and management module based on data sources and databases is developed. Furthermore, using the Microsoft Visual Studio 2010 development platform and through extensive program debugging and interface optimization, the development of the electromagnetic radiation assessment software is completed. The software enables rapid testing, analysis, and evaluation of equipment radiation characteristics, providing an important reference basis for electromagnetic compatibility improvement of radio astronomy sites and compatibility design of radio telescope systems.

Full Text

Preamble

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Software for Electronic Equipment

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Abstract

Radio observatories contain numerous instruments and equipment, creating a complex electromagnetic environment. Electromagnetic compatibility (EMC) design, shielding design, and radiation assessments all rely on test-based data processing and analysis, making automation the only viable means to improve testing and data analysis efficiency. This paper analyzes the hardware composition, evaluation process, software development objectives, and key technical challenges of the electromagnetic radiation evaluation system. Based on software requirements analysis and the data transfer, processing, and storage involved in the evaluation process, the paper presents the software design flowchart, data flow diagram, and two-dimensional interpolation algorithm flowchart. The primary data characteristics in the electromagnetic radiation evaluation process are analyzed, and a data storage and management module based on data sources and databases is developed. Furthermore, using the Microsoft Visual Studio 2010 development platform and through extensive debugging and interface optimization, the electromagnetic radiation evaluation software has been completed. The software enables rapid testing, analysis, and evaluation of equipment radiation characteristics, providing an important reference for EMC improvements at radio observatories and compatibility design of radio telescope systems.

Keywords: electronic equipment; radiation characteristics; measurement and evaluation; software system

1. Introduction

Radio telescopes are extremely sensitive systems. The development and application of broadband high-speed sampling and digital processing technologies, along with the construction of optical observation facilities at observatory sites, have made the electromagnetic environment increasingly complex. The diversity of observation points, continuously increasing signal density, and expanding frequency spectrum all contribute to this complexity. While longer integration times improve telescope sensitivity to astronomical signals, they equally increase sensitivity to radio frequency interference (RFI). The proliferation of high-frequency electronics, digital receivers, and electrical equipment at observatory sites leads to constantly increasing electromagnetic field strengths. Single-dish radio telescopes are particularly vulnerable to interference, which not only affects the quality of certain observations or observation types but also increases data processing complexity and limits overall observatory efficiency. Scientific and rational evaluation of electromagnetic radiation emissions from equipment within observatory sites provides crucial guidance for system EMC design, radio management, and shielding design. Given the large number of electronic devices at radio observatories and the cumbersome nature of electromagnetic radiation testing and evaluation, which consumes substantial manpower and time for testing, data processing, and analysis, programmatic automation represents an effective approach to streamline testing and evaluation while enabling efficient management and analysis of large datasets. The development of electromagnetic radiation evaluation software for electronic equipment is therefore essential for rapid testing and assessment of radiation characteristics.

2. Test System Overview

Given the numerous electronic devices at observatory sites, radiation emission testing must be performed on various equipment. The test system consists of a directional antenna, pre-amplifier, signal analyzer, and computer. The system is calibrated using a standard noise source via a General-Purpose Interface Bus (GPIB) card. [FIGURE:1(a)] shows the physical setup for system calibration. By obtaining power values at typical frequency points with the signal analyzer in both on and off states, system noise and gain are derived through data processing. System noise serves as the sensitivity indicator of the test system and can verify proper system operation. System gain is used to calibrate test data to obtain radiated power at the directional antenna aperture. The directional antenna receives electromagnetic radiation from electronic devices, the pre-amplifier boosts the signal, and the amplified signal enters the signal analyzer. The evaluation software controls the signal analyzer for frequency sweeping and data acquisition, with test data stored in the computer via the GPIB interface.

The signal analyzer is the core instrument of the test system. The R&S FSW26 high-performance signal analyzer is selected, communicating through an Agilent 82357B interface card with GPIB interface. The Agilent VXI Plug & Play driver software and R&S driver software are installed on the computer to enable effective communication between the signal analyzer and GPIB card. The driver software encapsulates universal control commands for the signal analyzer, facilitating program development and debugging for various functions.

Equipment Parameters and Technical Specifications of the Test System

Equipment	Model	Frequency Range	Key Specifications
Directional Antenna	Symmetric Periodic Antenna	0.38–8 GHz	Gain: 5 dBi; Max Input Power: +15 dBm
Pre-amplifier	UVBB2	1 kHz–10 GHz	Gain: 40 dB (typ.); ENR: 14 dB (typ.)
Signal Analyzer	FSW26	0.01–26.5 GHz	DANL: -137 dBc/Hz @ 1 GHz, 10 kHz offset
GPIB Card	82357B	2 Hz–26.5 GHz	GPIB-USB, IEEE 488, VXI Plug & Play

3. Software Requirements Analysis

The evaluation software, integrated with the test system, forms the complete electromagnetic radiation evaluation system. The software must implement communication between the GPIB card and signal analyzer, control the analyzer for frequency sweeping and data storage, process test data and system calibration data (including antenna gain, amplifier gain, and noise source excess noise ratio), and calculate interference level limits at the telescope feed aperture based on specific radio telescope technical specifications and observation requirements, considering path attenuation and telescope gain. The software serves as a critical component of the evaluation system.

Based on test requirements, the software must configure the signal analyzer, control data acquisition, and process and analyze electromagnetic radiation data to assess its impact on radio astronomical observations. The software development must address several key aspects: analyzing data characteristics during evaluation, developing data storage and management modules based on data sources and databases, and ensuring the software interface is simple, user-friendly, and extensible for future optimization.

4. Evaluation Process Framework

The electromagnetic radiation evaluation process for electronic equipment is illustrated in [Figure 2: see original paper]. The primary data sources are the signal analyzer (providing test data and system calibration data) and device manufacturers (providing antenna gain). Interference level limits and path attenuation must be obtained through calculation and analysis. System gain is calculated from system calibration test data, ambient temperature, and noise source excess noise ratio (ENR). Antenna aperture power represents the radiated power from the equipment under test reaching the directional antenna aperture. Based on radio telescope technical specifications and the ITU-R RA.769 recommendation, interference level limits at typical frequency points of the telescope feed aperture are calculated. The angle between the equipment' s radiation signal and the telescope' s main beam axis is estimated to calculate the telescope' s sidelobe gain at typical frequency points. An appropriate radio wave propagation model is selected to calculate path attenuation from the equipment to the telescope feed aperture. Finally, by comparing the electromagnetic radiation test spectrum with telescope interference limits and considering telescope antenna gain and path attenuation, the impact on radio astronomical observations is analyzed.

5. Software Development Objectives

The evaluation software is designed for professional radio astronomy technicians and must implement hardware control, data acquisition/processing, data storage/management, and visualization functions through a simple, user-friendly interface while maintaining extensibility for future optimization.

Functional Modules: 1. **Electromagnetic Radiation Test Module:** Configures the signal analyzer (start frequency, resolution bandwidth, frequency step, integration times) via the interface, inputs test information (personnel, location, device name), and displays/saves test spectra. 2. **System Calibration Module:** Configures the signal analyzer, inputs ambient temperature and noise source ENR during calibration, calculates and displays system noise and gain, and verifies proper system performance. 3. **Interference Level Limit Calculation Module:** Inputs telescope system noise, receiver bandwidth, integration time and other technical parameters to calculate interference level limits at the feed aperture, with data saving and display capabilities. 4. **Path Attenuation Calculation Module:** Inputs the distance from equipment to telescope feed aperture, selects appropriate propagation models, estimates the angle between interference signal and main beam axis, and calculates telescope sidelobe gain. 5. **Electromagnetic Radiation Evaluation Module:** Based on equipment radiation spectra, telescope interference level limits, sidelobe gain, and path attenuation, calculates equipment shielding effectiveness for display and saving. 6. **Data Storage and Management Module:** Stores various data types and manages them through database calls to data sources.

6. Software Design Framework

Using modular design principles and the Microsoft Visual Studio 2010 development platform, the software architecture is shown in [Figure 3: see original paper]. The design primarily includes system calibration, electromagnetic radiation testing, interference level limit calculation, evaluation, and data storage/management modules. Test system gain and noise, equipment radiation spectra, telescope interference level limits, and shielding effectiveness data are obtained through testing and processing. Test data is stored in source folders and accessed via database calls.

7. Software Flowchart and Data Flow Diagram

The evaluation software integrates system calibration, electromagnetic interference measurement, telescope feed aperture interference level quantification, and evaluation methods. Data transfer and management are critical development aspects.

The software flowchart is shown in [Figure 4: see original paper]. Power data displayed by the spectrum analyzer during testing is processed through interpolation of directional antenna gain, interference level limits, and spatial path attenuation to match data points for computational compatibility. The key variables are: - P_{antenna}: Power at directional antenna aperture - G_{antenna}: Directional antenna gain - G_{system}: System gain - L_{path}: Spatial path attenuation - S_{limit}: Interference level limit - S_{shield}: Shielding effectiveness

The data flow diagram, shown in [Figure 5: see original paper], describes system components and their interconnections, identifying logical inputs/outputs and required processing transformations. Data transfer and management are key development aspects.

Interpolation processing plays a vital role in data handling, requiring multiple interpolation operations to match different datasets. Since the primary data structures are two-dimensional arrays, a two-dimensional interpolation algorithm was developed for frequency and amplitude points. Through extensive debugging and data analysis, an interpolation program was encapsulated as a class file for data preprocessing. The interpolation flowchart is shown in [Figure 6: see original paper]. The process involves: inputting the start frequency (matching the radiation test start frequency), comparing it with the interpolation array' s frequency range, locating the start and end frequency positions, calculating corresponding amplitudes, and performing interpolation between points to obtain the final interpolated 2D array.

8. Data Storage Management Module Design

The testing process generates substantial data including raw measurements, processed data, test logs, and metadata. Effective data transfer requires analyzing data structure characteristics and organizing data conveniently for software operations.

The data storage and management module framework is shown in [Figure 7: see original paper]. Data is accessed via database calls to source files. Storage involves four main folders: system calibration, test system, interference level limits, and device-under-test. Hardware data (antenna gain, noise source ENR) are stored as text files in the test system folder. System calibration data (raw data, processed system gain/noise) and interference level limits are stored in their respective folders. Each test creates a new subfolder in the device-under-test folder, named by "device name + test time" to distinguish multiple tests of the same device. Raw spectrum data, test metadata, and shielding effectiveness spectra are stored in these folders. After each test, metadata is entered into the database along with data source paths for management purposes.

9. Software Interface Design and Implementation

The main evaluation software interface is shown in [Figure 8: see original paper], featuring buttons for radiation emission, system calibration, path attenuation calculation, interference level limit calculation, and emission evaluation. System calibration and radiation testing are integrated into one interface, communicating with the signal analyzer via GPIB. Before testing, system calibration verifies normal noise and gain performance. Abnormal noise indicates potential low-noise amplifier issues or connection problems. Performance degradation requires recalibration to ensure data reliability.

After calibration, equipment radiation testing can proceed. Clicking the processing button enables data handling and storage, with options to view and save processed radiation spectra. The interference level limit calculation interface ([Figure 9: see original paper]) allows input of telescope system noise, receiver bandwidth, and integration time to compute feed aperture limits, which can be displayed and saved. The data management interface ([Figure 10: see original paper]) enables selection of specific test devices, displays test information from the database, and allows viewing of radiation spectra and shielding effectiveness data for effective data management and deletion.

10. Conclusion

To rapidly and effectively evaluate the impact of equipment radiation emissions on radio astronomical observations, this paper presents dedicated evaluation software for radio astronomy applications. The software implements system calibration, equipment radiation characteristic testing, telescope interference level limit calculation, shielding effectiveness evaluation, and data management functions, addressing issues of low manual testing efficiency and cumbersome data processing. Future work will further develop and optimize the evaluation system hardware and software, such as adding radio path attenuation measurement capabilities and optimizing the interference level limit module to enhance system accuracy and reliability, providing important support for radiation assessment and shielding protection at radio observatories.

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