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EMI apparatus performance of a fully steerable radio telescope

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Abstract

The Electromagnetic Interference (EMI) and Radio Frequency Interference (RFI) caused by the electrical components on a fully steerable radio telescope do require careful attention, imposing interference mitigation measures and adequate shielding of emitting components. It is well known that at low frequency range from 10 KHz up to 200 MHz the EMI effects caused by high voltage switching systems are one of the worst sources of RFI [1]. Typically, the control of AC electrical motors uses electronics control modules that are commonly used to control functions like pulse width modulation (PWM). When these are utilized in compact design environments, like antenna enclosures, the electronic control modules are often assembled under an enclosing cowling and located unavoidably close to a very sensitive radiometer. Therefore, it is desirable to minimize the EMI and RFI in order to achieve the highest sensitivities possible and avoid too complex or unlucky RFI filtering particularly when dealing with detection of faint signals from astronomical sources.

1. Introduction

In order to test the various EMI and RFI effects we built the whole electrical and mechanical systems of the 9-meter radio telescope in Pampilhosa da Serra, Portugal. The telescope was designed originally to fulfill a Galactic survey, as part of GEM project [2]. The GEM surveys require fast scanning capabilities and hence a fast azimuthal rotation (~1rpm) of the antenna. To fulfil the basic requirements of the radio astronomy (RA) survey, the radio telescope was required to achieve a pointing accuracy of 0.1º and be capable of fast scans, with speed up to 6 º/sec in Azimuth.

We applied a number of hardware EMI mitigation techniques including automated pointing components based on [3]. Furthermore, we intend to show the inherent constraints caused by the AC electric motors, inverters, cables and shielding. The expected results of measuring the EMI arising from the AC electric motors will provide quantitative data in terms of the spectral impact of EMI levels (frequency and power). We intend to demonstrate that the steps applied to mitigate the interference on the system will reduce interference significantly and may be of use in other projects.

The steps applied to mitigate the EMI include a combination of filtering, shielding and suppression techniques.

International Telecommunications Union (ITU) regulation and for instance, the United States of America Federal Communications Commission (FCC), states [4] that manufacturers, importers, distributors, and sellers of radio apparatus, interference-causing equipment or radio-sensitive equipment must ensure that the equipment they provide guarantees electromagnetic compatibility (EMC) between other radio apparatus and services such as broadcasting, air traffic control, security services and communications with satellites.

However, for radio astronomical applications, industrial defined standards are often insufficient since the interference levels admitted are inadequate and interference mitigation at the receiver level is further necessary. As such, the primary concern of any RA observatories is RFI [5, 6]. In fact, the first step towards RFI mitigation includes the establishment of radio quiet zones around the radio telescope.

In this paper we quantify the EMI levels in terms of power and frequency and present a detailed survey of mitigations techniques considered. Mainly, we investigate the mitigation of conducted EMI in AC power converters used in the electrical parts of the motorization system of a radio telescope.

2. Description

Fast surveys using elevation over azimuth radio telescopes require precise electrical motors to move the telescope. The radio telescope considered in this study has a three tons of weight, 9-meter diameter and requires an angular accuracy of the order of decimal of a degree. It requires motors with low backlash and high precision control as part of the pointing system of the antenna. The following figure shows a block diagram of a VFD.

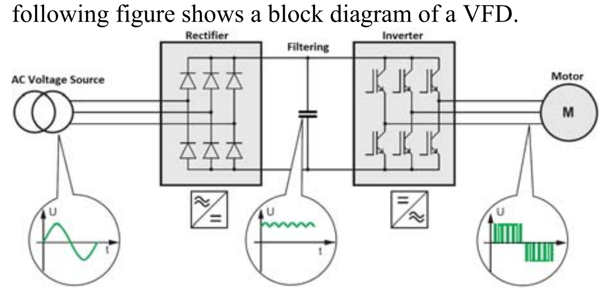

Figure 1. Principle of operation of an inverter or VFD

The components in the inverter are IGBTs. IGBT modules turn on and off several hundreds of volts and several hundreds of Amperes in a few hundred nanoseconds, generating conducting emission and radiated emission due to high dv/dt and di/dt [10]. As such, the several components of the frequency inverter will cause different EMC issues.

To improve the EMC of our electrical system, we apply the following techniques:

1. Place all electrical devices inside a shielded cabinet. A sheet steel cabinet offers excellent shielding against magnetic interference fields
2. All components of the plant must be grounded via low resistance connections both in the low frequency (LF) and high frequency (HF) range.
3. Use shielded cables for interconnections. The shielding effect is improved significantly by using enclosed cable ducts.
4. Use Ferrite filters between VFDs and motors, and supply and VFDs.

3. Implementation

Tests require two steps: i) measure the emission from a device without additional shielding or filtering; and then, establish the shielding and filters in a separate test. Another challenge is that the final test - measuring the emission from the electric circuitry after installation with shielding. ii) test the electromagnetic emission once the radio telescope is fully assembled and operational.

Our EMI testing involves measuring the electromagnetic field strength of the emissions that are unintentionally generated by any product. The test consists on performing radiative and harmonics EMC tests inside an anechoic chamber.

Our setup test consists on a EMI receiver (Rohde & Schwarz ESPC 1 GHz EMI Test Receiver) for frequencies below 1GHz and a radiometer for upper frequencies and integrated capabilities (> 10s).

The ESPC is able to perform accurate interference measurements with pulse repetition frequencies (PRF) to as low as 10 Hz in line with CISPR 16-1 regulations.

Main Features of ESPC 1 GHz

- Test Standards: CISPR 16-1, EN, FCC, VCCI, VDE
- Minimum Frequency: 150kHz
- Maximum Frequency: 1GHz

The radiometer features are:

- Total Power Receiver
- Bandwidth 10 MHz
- IF 140 MHz
- Sensitivity 0,001 dB (for 10 s integration time)
- Short term stability with controlled temperature 10^{-3}
- Long term stability with controlled temperature 10^{-2}

4. Summary

This work describes the combination of techniques applied to mitigate EMI from the power driving system of the GEM radio telescope in Portugal. to It presents a quantitative measure of the EMI of the set of AC electrical motor and respective drivers when shielding and filtering is applied. We take advantage of the new Industry 4.0 standards to improve the power driving system of GEM antenna and much improve its EMI compatibility levels. The testing apparatus measures the EMI caused by all the components of the full steerable radio telescope. The differences with and without shielding and filtering are expected to be considerable in the range of 10 KHz to 300 MHz. The testing with a very sensitive radiometer shows EMI levels to be lower than -150dBm with 10 seconds integration, while the EMI receiver will confirm the compliances with the legal regulations for RA. This experience on new power driving standards enable a significant reduction of EMI caused by AC electrical motors and are expected to be very useful for power driving applications and EMI mitigation in other RA projects.

5. Acknowledgements

Acknowledgements go in here.

7. References

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