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RFI Mitigation of FAST：Challenge & Solution

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Abstract

The Five-hundred-meter Aperture Spherical radio Telescope is now in the commissioning stage. Due to its extreme sensitivity, it is a great challenge for FAST to mitigate the Radio Frequency Interference (RFI) not only from the telescope itself, but also from the transmitter outside the site. The solutions for RFI mitigation of FAST include the Electromagnetic Compatibility measures of the telescope and the maintenance of radio quiet zones around the site. The new pulsars detected by FAST have indicated the effectiveness of the solutions of RFI mitigation.

1. Introduction

In 2016, the main structure of the Five-hundred-meter Aperture Spherical radio Telescope (FAST) has been completed [1]. Now it is in the commissioning stage, and more than 40 new pulsars have been detected by FAST.

Figure 1. Lateral view of FAST.

Due to its extreme sensitivity and the observing frequency coverage from 70 MHz to 3 GHz, there is a great challenge for FAST to mitigate the Radio Frequency Interference (RFI) not only from the electric and electronic instruments of the telescope, but also from the transmitters around the site. Two main solutions have been proposed during the FAST design stage. One solution is the Electromagnetic Compatibility (EMC) design and measures of the instruments [2], and the other solution is to establish and maintain a Radio Quiet Zone (RQZ) [3] to protect the quiet radio environment around FAST. In the following sections, detailed measures and solutions will be described briefly.

2. EMC Measures

In order to clarify the EMC requirements of the instrument, as the first step, the threshold level of interference detrimental to radio astronomy in ITU-R RA.769 [4] has been chosen for FAST. Moreover, the Electromagnetic Interference (EMI) of the typical instruments such as the actuators, controllers, and total stations has been measured in the anechoic chamber. Based on the different location and operation situations, the EMC requirements have been determined for the individual instruments and systems. Such as, for the actuator, the Shielding Efficiency (SE) of 80 dB has been required. The EMC solutions for several instruments are presented below.

2.1 Actuators

2225 actuators have been installed to shape the reflector of FAST. One advantage to select the current hydraulic actuator for FAST is to simplify the EMC measures of all electronic related parts and reduce the cost. The overall EMC design of the actuator is using shielding cabin to envelope all EMI sources. Meanwhile, the power line filter is used to handle the AC power input, and waveguide tube is designed for the optical fiber cable which is used to transmit control and status signals.

The FAST actuator is manufactured after the EMC design has been completed. Based on the national standard of GJB151A RE102 [5] and patent of invention for FAST

[6], the EMC measurements has been made, and the results show that the SE of more than 80 dB has been obtained for the actuators [7].

Figure 2. EMC measurements of the actuators in the anechoic chamber.

2.2 Cable suspension instrument room

The cable suspension instruments such as motor, drive and controller, winch have been installed at the bottom side of six suspension towers, which are used to suspend the feed cabin to track the cosmic radio sources by using six cables. In order to mitigate the EMIs from these instruments, three zones of the instrument room have been divided to obtain the SE of 120 dB for the electric zone, the SE of 50 dB for the motor zone. The special EMC measures as the comb structure for the motor shaft with high speed has been developed to assure the SE of the motor zone.

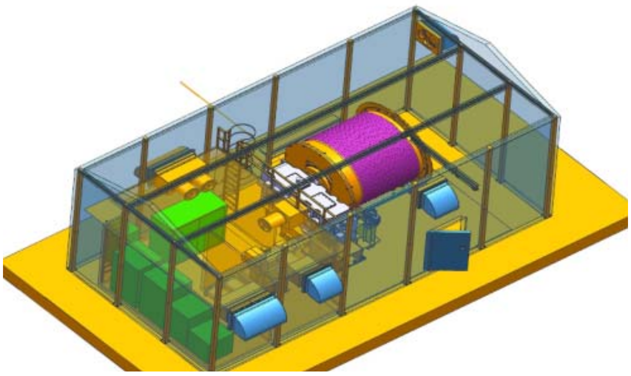

Figure 3. The sketch map of EMC design for the cable suspension instruments room.

2.3 Feed cabin

The feed cabin is one of the key instruments of FAST. 7 sets of receivers have been divided into three groups and installed at the lower platform of the Stewart platform in the cabin individually. Due to the requirement of the movable lower platform and SE of the cover, the steel shell with soft shielding cloth has been constructed [8]. Inside the cabin, various electric instruments have been installed. Two shielded rooms have been built to envelope the strong EMI sources. The special measures for the legs of the Stewart platform have also been used to mitigate the EMI for the legs. According to the EMC measurements of the feed cabin, the SE of more than 120 dB has been achieved.

Figure 4. The photo of the feed cabin of FAST.

2.4 Total station

More than 20 total stations have been used to measure the shape of the reflector and position of the feed. The strong EMIs have been detected from them. Several measures have been considered to mitigate the EMIs. The shielded cabin with servo system for the total station has been developed. Another choice is the shielded cabin with wave-guide window made by 3D printing. The test and SE measurement shows that these two prototypes could both provide the SE of more than 80 dB.

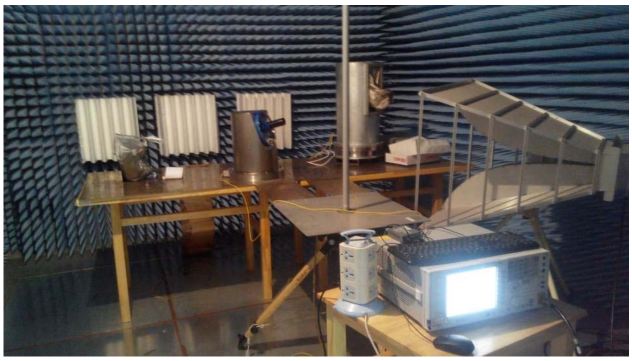

Figure 5. The SE measurements of one shielded cabin of the total station in the anechoic chamber

2.5 10 KV power filter

The 10 KV power filter has been required to be installed at the shielded power transformer substation to assure the SE of at least 90 dB. The ceramic capacitor has been selected to provide better reliability comparing to the thin film capacitor. The structure of the filter has also been designed by using the steel tube to decrease the electromagnetic coupling. The filters have been designed, tested and installed at the site successively.

Figure 6. The photo of the 10 KV power filter installed at the shielded transformer substation.

3. RQZ maintenance

In 2013, a Radio Quiet Zone (RQZ) with radius of 30 km has been established to protect the quiet radio environment around the FAST site. The typical RFI sources in the RQZ have been identified based on the routine RFI measurements and observing data, such as mobile stations. The seven mobile stations have been closed in the restricted zone of FAST RQZ with radius of 5 km. More than 20 mobile stations have been required to lower the power of the transmitter and adjust the direction of the antennas. Moreover, an air radio restricted zone with radius of 30 km has been developed in 2017. Two air routes have been moved outside the air restricted zone. The comparison of the measurement results before and after two air routes adjustment is shown in the Figure 7.

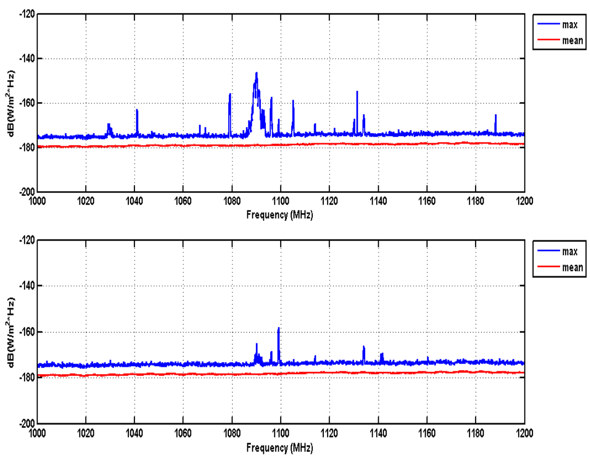

Figure 7. The results of the RFI measurement before and after two air routes adjustment (up map: before; down map: after).

4. Conclusion

Since 2016, most EMC measures of FAST have been implemented and operated. The regular sampling measurements of the instruments have also been carried out. The results show that the SE of the shielded cabins and rooms change little after taking some rectification measures. Till now, no apparent RFIs from the instruments with EMC measures have been detected, which indicates the validity of EMC solution. Moreover, the maintenance of FAST RQZs has contributed to protect the quiet radio environment around FAST site effectively. In addition, considering the rapid development of local society, the study of RFI mitigation technology is also ongoing.

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