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Spectrum monitor system at QTT site

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Abstract

QTT is a steerable 110 m radio aperture telescope that will be built in Xinjiang province of china, with a frequency range from 150 MHz to 115 GHz. Site RFI levels is clearly an important issue for such a sensitive instrument. Therefore, we have developed an automated highly sensitive and reliable spectrum monitor system for RFI detected and signal characteristic analyzed, a quasi-real-time measured method was employed for long-term spectrum monitoring, and we used the HDF5 data format for RFI data storage and management. This system is working well at QTT site for a long time, we proposed some considerations for how to process and analyze so much RFI data during spectrum monitoring, and the data processing procedures should be updated in the future work to improve RFI analyzed efficiency.

1. Introduction

Qi Tai Telescope (QTT) is a fully steerable 110 m single-dish radio telescope with observing frequency range from 150 MHz to 115 GHz, which will play an important role for fundamental research fields of radio astronomy, such as pulsars, molecular spectral lines, active galactic nuclei, and VLBI observations [1]. QTT is located in the Tianshan mountains at an altitude of 1760 m, with latitude 43°36'4".03 and longitude 89°40'56".99, and at a distance of approximately 46 kilometers from nearby Qi Tai city. QTT base is located in an area of 1.5 × 2 kilometers surrounded by mountains with an altitude ranging from 1860 – 2250m (Fig.1) and a terrain that will be ideal for mitigating external interference signals [2]. The QTT will take a place among the world-leading large-scale scientific facilities.

As we known that Radio frequency interference (RFI) affects large diameter single-dish radio telescope observations greatly. However, RFI is a growing concern for radio astronomers around the world [3]. Even QTT Radio quiet Zone (RQZ) was approved by local government; the QTT RFI environment has the potential to degrade with the local economy and tourism developed. Therefore, it is of great importance to detect and identify sources of RFI so that they may be mitigated immediately. Above all, it is necessary for us to develop and equip a spectrum monitor system for QTT, which we can mitigate interferences timely according to the RFI measured and analyzed.

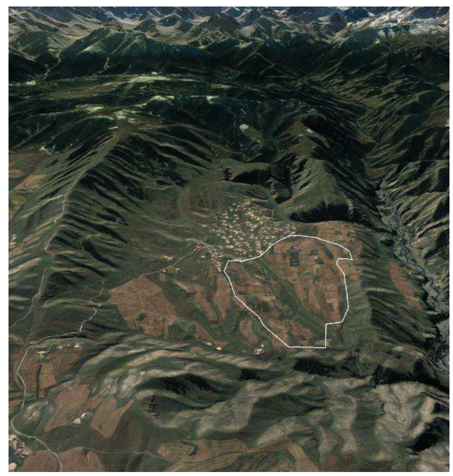


Figure 1. The QTT terrain with white marked area showing the QTT base.

2. Spectrum monitor system

2.1 System design considerations

Spectrum monitor system is a fully system designed to scan from 100 MHz to 12 GHz. The block diagram of RF module for this system is depicted by Fig.2. The diagram shows RFI module comprised of two broadband log-periodic directional antennas (R&S HL033 and R&S HL055) for the detection of signals, and there are six RF paths for frequency band selected (0.1 – 2 GHz, 2 – 6 GHz and 6 – 12 GHz respectively, including measured and calibrated mode); Two standard noise sources (Agilent 346C) were employed for system gain and noise figure measured with Y-factor method [4], which is used to calibrate the raw RFI data; We use five microwave switches for RFI channel selected. Additionally, R&S FSW13 signal analyzer, PC, controllers and DC supply power were installed in a shield cabinet to avoid the RFI themselves.

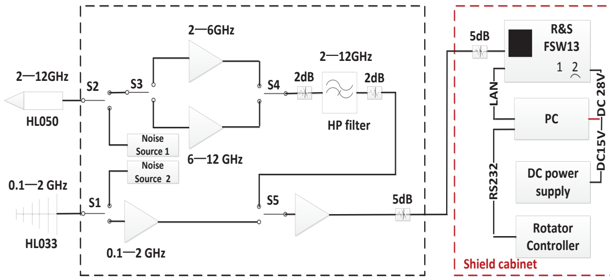


Figure 2. Block diagram of RF & control links

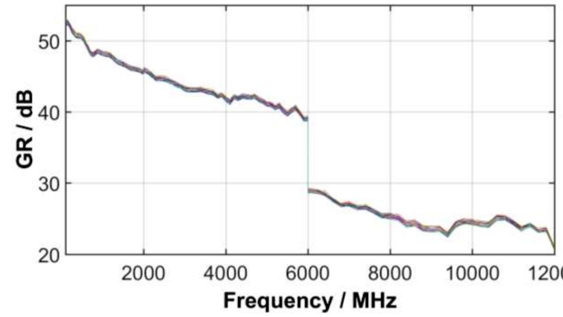
Fig.3 (1) shows the spectrum monitor system applied at QTT site, which is located at an altitude of about 1760 m. The tested antennas are about nine meters high that decreasing the ground spurious RFI affecting the measured results. We used a G5500 rotator for polarizations switched. All microwave devices were mounted in an extremely compacted RF box to improve the sensitivity of the system, as shown in Fig.3 (2), and EMC design for RFI box and control cables were considered as well. Additionally, there are three temperature sensors installed in-side and outside of RF box for analyzing the temperature impacting on tested results. Meanwhile we considered the lighting and grounding designs for this system as well to enhance system reliability.

(1) Spectrum monitor system (2) RF box

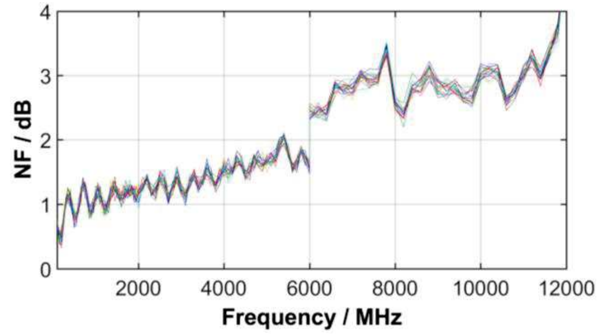
Figure 3. Spectrum monitor system at QTT site; Fig.3 (3) showing all microwave devices equipped in an extremely compacted RFI box

2.2 System performance

Fig.4 shows the performance of the spectrum monitor system, including system gains and system noise figure from 100 MHz – 12 GHz, the parameters were varied with time in one day due to temperature changes. Performance figure presents system gain > 40 dB, system noise figure < 2 dB below 6 GHz, illustrating that the system has a good performance and it is sensitive enough to detect the weak RFI. Furthermore, these parameters were measured for every pointing during spectrum monitoring. Therefore, we can obtain the critical parameters on time ensuring the FRI data tested reliable and accuracy.



(1) System Gain



(2) System Noise figure

Figure 4. Parameters of spectrum monitoring system, Fig.4 (1) shows system gain at 100 MHz – 12 GHz varied with time in one day, Fig.4 (2) shows system noise figure at 100MHz – 12GHz varied with time in one day.

To realize spectrum monitor automatically, we have developed a M&C software with Visual Studio for critical parameters monitoring, system control and RFI data storage, as shown in Fig.5. The interface of this software presents the critical parameters varied with every pointing, including antenna position, environment temperature, temperature in RF-Box, system noise figure, system gain, for which we can obtain RFI data tested are reliable and accuracy.

Figure 5. M & C Software showing the critical parameters monitoring while measuring

3. Spectrum monitor

3.1 Measured method and data streams

A quasi-real-time measured method [5] was employed for spectrum monitor; we set the critical parameters of signal analyzer according to this method. Four detectors applied during spectrum monitoring, including Sample, Peak, RMS and Max hold detectors, it takes two days for one detector, and then repeated. Max hold measured mode is used to capture the transient RFI effectively that we can further analyze the signal characteristic and their impacting on observations. Additionally, It takes one day respectively for Horizontal and vertical polarizations. Every day we will obtain 18 cycles RFI data, every cycle including 6 pointings to achieve a full 360° RFI data.

RFI data streams diagram is shown in Fig.6, we use HDF5 data format for data storage, which is convenient to get the desired data, and it is easy for data processing as well. Every 2 days data will be write in one HDF5 file, including polarization groups, direction groups, frequency band and environment data group, furthermore, the RFI data, system calibration data and the environment data will be recorded in the datasets of the corresponding groups.

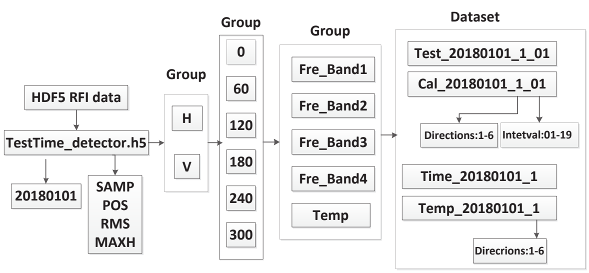


Figure 6. RFI data streams diagram

3.2 RFI analyzed considerations

The goal for spectrum monitoring is to obtain more RFI information, such as RFI source, time, polarization, characteristic, direction, frequency, etc., which we can mitigate the RFI effectively and immediately. Therefore, RFI analyzed with this system considerations are as follows:

(1). For narrow and broadband fixed RFI monitoring and analyzing, the Sample, Peak, RMS detectors and trace averaged measured mode were applied to improve the signal to noise ratio that weak RFI can be detected effectively. The primary work with this measured mode is to locate RFI, analyze RFI source and characteristic, then considering how to mitigate them. Additionally, new RFI should be detected timely that we can deal with them as soon as possible. Though it takes about 13.3 minutes for one pointing's spectrum (12 GHz frequency band) obtained. However, off-line RFI data process procedures lead to new interference can be discovered promptly, so this work should be update.

(2). For Transient RFI, a quasi-real-time monitor method was applied for transient RFI analyzed, that is to say we will obtain a set of spectrums at about 1.3 hours intervals for one direction. Fig.6 presents one direction spectrums varied with time, showing that some RFI only occurred in a certain time period. On the other hand, the max hold measured mode is employed for transient RFI detected and analyzed. Fig.7 shows spectrums obtained with different detectors, RFI coming aviation radio navigation service at 4250 MHz – 4350 MHz frequency band can only be detected with max hold mode.

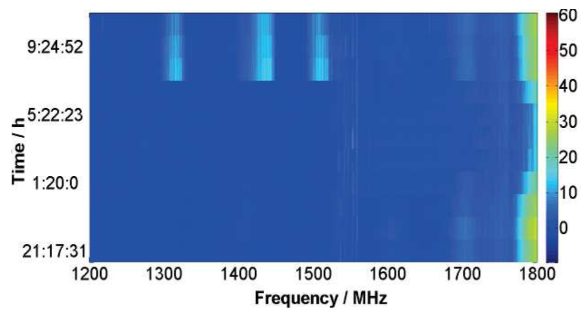


Figure 7. Typical quasi-real-time spectrum showing RFI (at about 1.3 hours intervals) varied with time at 1200-1800 MHz frequency band.

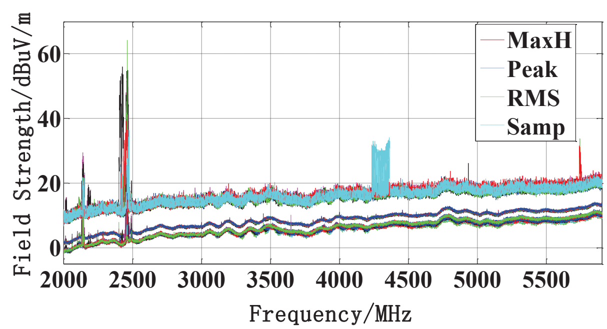


Figure 8. Typical spectrums measured with Max hold, Peak, RMS, Sample detector respectively showing from top to bottom.

(3). We will obtain large RFI data during long-term spectrum monitoring at QTT site. How do we deal with so much data effectively? Therefore, we have developed a data processing program with Matlab platform for data processing, data storage and management, spectrums mapping. Programs developed for spectrums VS with time, direction, detector and polarization etc. are useful, desired RFI data can be effectively fetched and mapping, then we can further analyze RFI by data comparison.

4. Conclusion

Spectrum monitor system at QTT site is reliable, which is sensitive enough to detect the weak RFI. Furthermore, a M&C software was developed for long-term RFI monitoring automatically, we have further developed some programs for spectrum mapping to improve the data processing efficiency. RFI detected and analyzed timely with this system is of great importance for RFI mitigation.

However, there are still some issues for this spectrum monitoring system. And the critical problem is the data processing efficiency; it is means that we cannot obtain the RFI characteristic promptly. So we shall further update this system in the future work, realizing real-time RFI data procession and signal feature statistics.

5. Acknowledgements

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6. References

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