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The Measurement and Analysis of System Noise Temperatures of the TM65 m Radio Telescope at Low Frequency Bands[†] [⋆]

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Abstract At first, the receiving system of the Tianma 65 m radio telescope (TM65 m in brief) and its noise characteristics at the L, S, C, and X four frequency bands are described. Then, a few measuring methods of system noise temperature are discussed, and the major factors affecting the noise temperature measurement are analyzed, including the errors caused by the non-linearity, feed network insertion loss, mismatch, and so on. With the Y-factor method the noise temperature of the noise source calibrated in the laboratory is verified, indicating that its accuracy attains ∼0.2 K. Finally, the system noise temperatures actually measured at the four frequency bands and an analysis on the result are given.

Key words atmospheric effects—techniques: radio astronomy—cosmic background radiation

1. INTRODUCTION

TM65 m is now the greatest fulled-aperture radio telescope in China, it works at the L, S, C, X, Ku, K, Ka, and Q totally eight frequency bands, covering almost 70% frequency range below 50 GHz, it is also the radio telescope with the broadest frequency coverage in China.

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The radio telescope has a Cassegrain antenna, the aperture of its main reflector is 65 m, with an adaptive surface structure to compensate the gravity deformation for the observations at high frequencies. At present, this antenna has equipped the receivers at the L, S, C, and X four low-frequency bands, in which the S and X bands are of the double-frequency receiver, namely the feed network is common for the two wavebands, others are all of single-frequency feed.

As the microwave receiving system of a radio telescope, it is mainly composed of the antenna/feed part (including the main reflector, sub-reflector, feed, and polarizer), cooled LNA (low noise amplifier), and subsequent frequency conversion chain. Generally the cooled LNA part is called the receiver, in fact, in the design of the TM65 m the feed and polarizer are cooled as well for some frequency bands, and in some literature the feed and polarizer have already been taken as the receiver part, but for convenience of the discussion on the matching between the polarizer and the LNA, this paper defines still the receiver to be the cooled LNA part.

Besides the antenna/feed noise, and receiver noise, the system noise of a radio telescope includes also the noise of atmospheric radiation, and the leakage noise of ground radiation. Generally the total of the noises from the antenna, feed, polarizer, and receiver is used to evaluate the noise performance of the microwave antenna system, because the gain of cooled LNA commonly attains 30 dB, and the noise of subsequent cascade is weakened by a factor of about 1000, hence the influence of subsequent cascade can be neglected.

For the key-important specification of a radio telescope—the system noise temperature, this paper has introduced multiple methods of system noise temperature measurement, and made the estimation on the measuring errors. In this paper, we have made a verification on the calibrated noise source by actual measurements, and finally measured the noise temperatures of the receiving system at the four frequency bands, and made certain analysis and discussions.

2. DESCRIPTION OF MEASURING METHODS

When a radio telescope makes observations, the signal path and the composition of system noise temperature are shown as Fig.1, in this figure T_{300} and T_{77} are the physical temperatures of the 300 K and 77 K black bodies respectively, Γ_A and Γ_R are respectively the reflection coefficients of the polarizer and of the LNA, P_A and P_R are respectively the power transmitted from the polarizer and the power actually received by the LNA. The system temperature is the cascade of noise temperatures of all components in the whole signal path, it can be simply expressed as:

$$T_{\rm sys} = T_{\rm ant} + T_{\rm feed} + T_{\rm R} + T_{\rm sky} + T_{\rm gnd}\,, \tag{1}$$

in which T_{sys} is the noise temperature of the whole antenna system; T_{feed} is the equivalent noise temperature corresponding to the insertion loss of the feed network (including the