Exp. Theo. NANOTECHNOLOGY 9 (2025) 423-430 https://doi.org/10.56053/9.S.423

Estimated values of missing sky radio brightness temperature observation using numerical method calculation

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Received 11/2/2025, *Received in revised form* 17/3/2025, *Accepted* 11/4/2025, *Published* 15/5/2025

By employing the spline interpolation technique, we are successful in locating the missing value of the sky temperature, which we refer to as Tsky. This investigation made use of a sample of data that is taken from previous work that had been observed at 1.42 GHz using the radio telescope that is located at Baghdad University. For this study, we focused on missing elevations (0-15) degree since the telescope couldn't record data lower than 20 degrees because of the surrounding buildings. According to the findings of this research, we are able to point out that the estimated values of Tsky range from 21 K to 600 K at various azimuth degrees, which range from 120 degree to 220 degree.

Keywords: Sky temperature; Observation; Radio.

1. INTRODUCTION

Radio astronomy tests hypotheses by observing objects that emit radiation at radio frequencies. These telescopes observe radiations received from radio sources [1]. For an emission to be included in the radio spectrum, it must have a wavelength between 0.001 and 30 meters. Monitoring the sources of this spectrum allows discovery of new objects, such as pulsars and quasars that have not previously been detected. Furthermore, the results from evaluating millimeter-wave antenna arrangements [2] have implications to improve high frequency system design in radio astronomy with increased telescope sensitivity, beam control, and spatial resolution in modern observational instruments.

One of the most important forms of spectral emission lines observed by radio astronomers is that of hydrogen radio emission line. Radio energy from atomic Hydrogen is emitted when the atom transitions from its first excited state to its ground state in the 21-cm line of radiation [3]. These changes are triggered by the electron-proton spin-spin interaction, since the parallel spin is more energetic. The photon's rest wavelength is 21 cm and its frequency is 1420.4 MHz. Hydrogen's radiation can penetrate dust clouds at this frequency, although visible light cannot [4].This emission allows astronomers to map neutral hydrogen (HI) and trace the structure and dynamics of galaxies, providing valuable insights into regions that are otherwise obscured in optical wavelengths [5].

The signal-to-noise ratio (SNR) at the input of the receiver provides a measure of how well a communication system works. The system noise is greatly influenced by the electrical circuitry which forms the radio frequency front end. The antenna itself, however, can also be a significant source of background noise in some situations. Depending on the physical origin of the noise there are two types of noise that an antenna has to be considered: antenna noise due to the loss resistance of the antenna (usually referred as internal noise) and noise collected by the antenna from its environment (usually referred as noise power or antenna temperature) [6].The antenna noise temperature contributes to the system noise temperature of a receiving system and may contain atmospheric elements such as water vapour, clouds, and precipitation, as well as solar and cosmic noise [7].

There have been a number of investigations focused on the radio noise that is linked with the observing system. At a radiofrequency of 408 MHz, the absolute value of the background brightness temperature is determined using a big pyramidal "standard gain" horn aerial. Temperature measurements are made and compared directly to the known temperature of the receiver's input resistive load [8]. Based on the brightness temperature distribution and antenna pattern, a rigorous method for determining antenna temperature has been developed. Antenna temperature has been calculated using a proprietary code [9]. Dana et al 2019 [10] studies the contribution of sky temperature Tsky to antenna temperature TA. They also decided to construct a general expression that can be used with contemporary electronically scanned arrays. In this work, we tried to estimate the value of missing sky brightness temperature using previous observations of [11] from Baghdad University Radio Telescope (BURT) at different azimuth (120º - 220º).

2. THEORETICAL CONCEPTS

The amount of disturbing noise power that is transmitted to the receiver by the radio telescope antenna is dependent on the background noise that is present in the sky, the noise that is produced by the atmosphere, the noise that is produced by the side lobes, and the noise that is produced by the losses of the antenna. The power is denoted in terms of the effective antenna noise, which is denoted as T_{sky}, and does not take into account the signal noise power T_A [12, 13]. The expression for the system noise temperature, Tsys, can be found below.

$$T_{sys} = T_{rec} + T_{sky} \tag{1}$$

Where Trec refers to the temperature of the receiver system.

Because a source signal is composed of the same elements as the ambient noise, the only thing that can be said to occur "on-source" is an increase in the band's average power, and the signal's detectability is dependent on the signal-to-noise ratio (SNR) [14], which is given by

$$SNR = \frac{T_A}{T_{sky}} \tag{2}$$

3. DATA

In this work, data are taken from previous study of [11]. In which it is carried out using the radio telescope at Baghdad University with diameter of 3 m, focal length (f) of 1.18 m and f/D ratio is 0.39. According to the basic principle of radio telescope, data has calibrated using reference source as explained in previous work [4]. The daily observations of this telescope record at the frequency of

1.42GHz. There also exist 600 channels of the frequency, which are utilized in determining the amplitude of the power that is being measured. The date of the observations and the telescope position (in terms of azimuth and elevation) are presented in the table 1 below.

Table 1 Properties of observed data from [10].

Observation date	Azimuth (degree)	Elevation (degree)	Frequency
31/8/20	120		
20/5/4	130		
20/9/2	140	$20^0,30^0,40^0,50^0,60^0,70^0,80^0,90^0$	1.42GHz
20/9/10	150		
20/10/11	210		
20/9/30	220		

4. RESULTS AND DISCUSSION

Our study is conducted with the goal of estimating the values of Tsky at the elevations of 0,5,10, 15, 25, 35, 45, 55, 65, 75 and 85 degree that are lacking from observations made with the Baghdad University Radio Telescope at a different in the azimuth value (120^o-220^o). Missing values of data are a common issue that arise in the field of scientific research. Before beginning the analysis of the data for the further studies in radio astronomy, applying a technique known as interpolation can be a useful solution to the problem of completing this missing information. Interpolation is a mathematical method that adjusts a function to your data and uses this function to extrapolate the missing data. Indeed, there are various interpolation techniques are often used in the atmospheric sciences. One of them, spline interpolation, is a type of interpolation in which the interpolant is a spline, which is a special kind of piecewise polynomial. Even though spline interpolation is capable of reproducing the value at all of the curve fitting points, the gradient remains smooth [15]. Table 2 and Fig. (1-6) illustrate the results of the given data (experimental) and theoretical values from spline method of Tsky. It is clear from results below that the theoretical values of Tsky is consistent with the observational data at the elevation of 20, 30,40,50,60,70,80 and 90 degrees. The contribution to the temperature of the antenna that is caused by side lobes that are directed toward the earth will decrease as the antenna's elevation is increased because the radio telescope antenna transmits a disturbing noise power to the receiver, as demonstrated by Eq. (2). Generally, the results below illustrate that Tsky increases with lower elevation angle.

Table 2 Calculated value of T_{sky} from spline interpolation.

Elevation (degree)	Azimuth (120°) T_{sky} (k)	Azimuth (130°) T_{sky} (k)	Azimuth (140°) T_{sky} (k)	Azimuth (150°) T_{sky} (k)	Azimuth (210°) T_{sky} (k)	Azimuth (220°) T_{sky} (k)
0	192	356	387	633	261	387
5	183	336	298	465	262	280
10	173	306	229	348	239	204
15	165	270	177	272	200	153
20	156	233	139	229	156	123
25	147	201	113	209	117	108
30	138	179	98	205	93	103
35	128	167	90	205	84	102
40	117	157	89	202	76	101
45	105	138	90	18	56	97
50	95	126	87	175	42	92
55	90	127	75	166	49	91
60	87	128	66	156	56	88
65	85	122	68	135	38	78
70	78	109	70	113	19	67
75	64	87	59	102	22	61
80	48	64	42	96	24	55
85	40	50	28	90	23	45
90	49	40	27	78	21	23

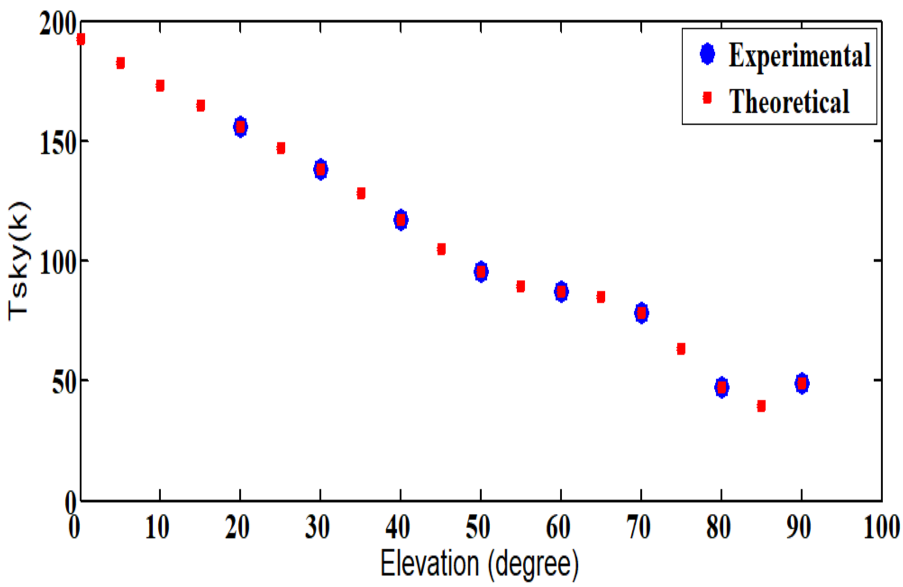

Figure 1 Variation of T_{sky} (k) with elevation angle (degree) for azimuth 120°.

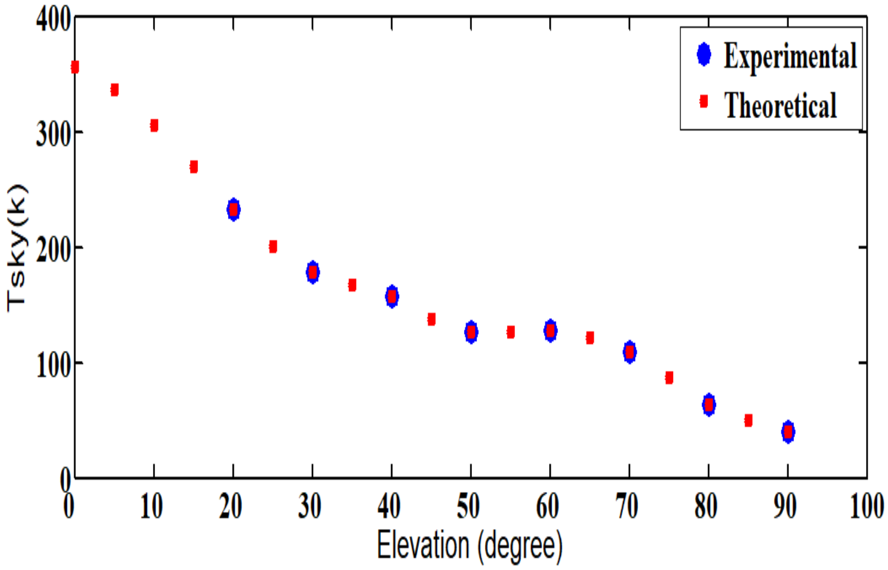

Figure 2 Variation of T_{sky} (k) with elevation angle (degree) for azimuth 130°.

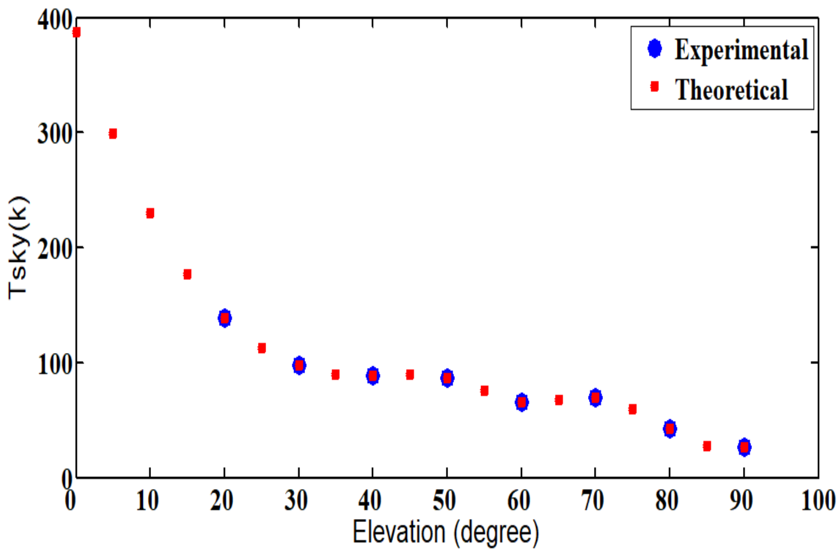

Figure 3 Variation of T_{sky} (k) with elevation angle (degree) for azimuth 140°.

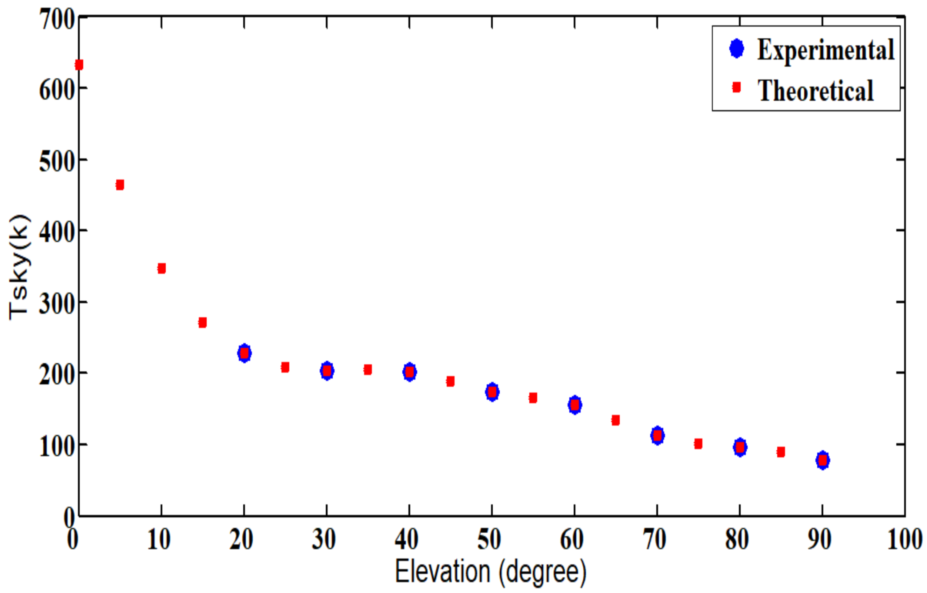

Figure 4 Variation of T_{sky} (k) with elevation angle (degree) for azimuth 150°.

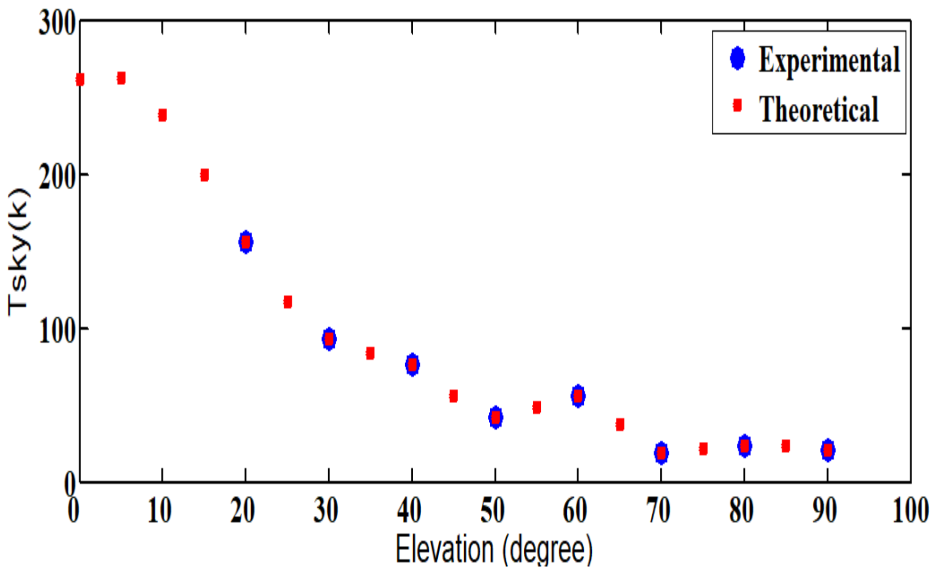

Figure 5 Variation of T_{sky} (k) with elevation angle (degree) for azimuth 210°.

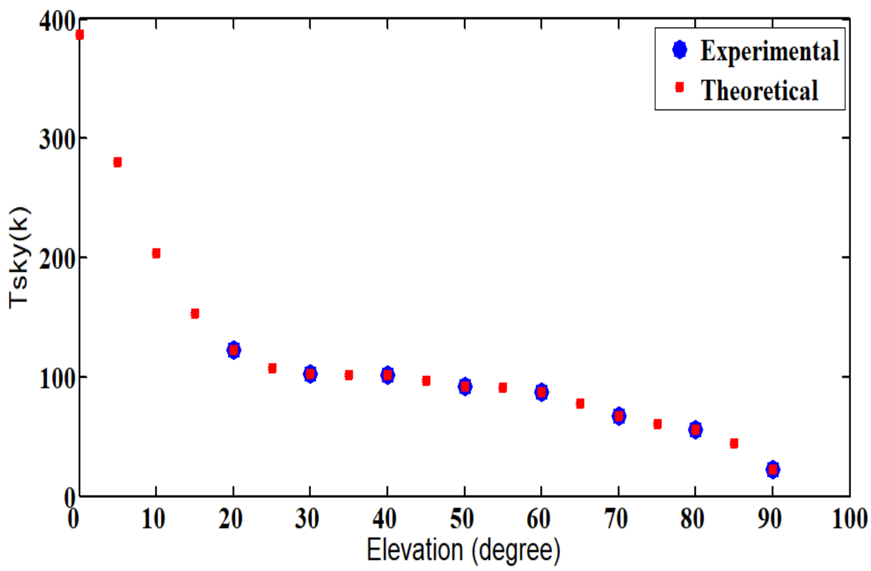

Figure 6 Variation of T_{sky} (k) elevation angle (degree) for azimuth 220°.

5. CONCLUSIONS

In this study, we attempted to estimate the missing values of sky temperature at various elevation degrees using a sample of data that was taken from the Baghdad University Radio Telescope at a number of different azimuths using a variety of observations. Due to the presence of nearby buildings, this telescope was unable to collect data below an elevation of 20 degrees. Thus, spline interpolation was the method that we used for this work because it provides the most accurate estimation for points that have not yet been measured. As a result, we were successful in determining the unknown values of Tsky that were missing from the observations that spanned an azimuth range of 120 to 220 degrees.

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