A Model of Sky Temperature Estimation at 1.42 GHz using University of Baghdad's Radio Telescope

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Abstract

The objective of this study is to select a suitable observing region at Baghdad location ($44^o\ 22^{'}\ 48^{''}$, $33^o\ 16^{'}\ 30^{''}$) with low interference that may affect frequency of 1.42 GHz. Baghdad University Radio Telescope (BURT) is used in this study to determine a convenient region for observation in Baghdad sky. Different azimuths and elevations were chosen at different observations time. The results of this study showed that the best observations regions were located at azimuth (120°-160°) and (210°-260°). These regions included less sky temperature and estimated to be (42.8 to 163) K. The sky temperature model could be represented as a polynomial of third degree that could fit the behavior of the observation points.

Keywords: 21 cm Line Emission, Sky Temperature, Antenna Temperature.

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نموذج لتقدير درجة حرارة السماء عند التردد 1.42 كيكا هرتز باستعمال التليسكوب الراديوي لجامعة بغداد

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الخلاصة

ان الهدف من هذه الدراسة هو تحديد مناطق جيدة للرصد في سماء بغداد والتي يكون فيها تأثير الضوضاء اقل ما يمكن. وقد تم استخدام التليسكوب الراديوي لجامعة بغداد لتحديد هذه المناطق. تمت الدراسة برصد مناطق مختلفة وواسعة وبارتفاعات مختلفة وفي أوقات عديدة. نتائج هذه الأرصادات أظهرت بأن أفضل المناطق للرصد هي المحصورة بين (120^0 الى 160^0) وكذلك (210^0 الى 260^0). وحسبت درجة حرارة السماء في هذه المناطق بحدود (42.8 الى 163) كلفن، ويمكن ان نمثلها بمتعددة درجات من الدرجة الثالثة والتي توضح لنا سلوك نقاط الرصد.

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1. Introduction

One of the important radio information is the hydrogen line emission at frequency of 1.42 GHz. A neutral hydrogen (Hl) atom has only one proton and one electron. Both particles have quantized total spin (s) of 1/2 and a spin in the z-direction (m) of either 0.5 or -0.5 [1]. When a hydrogen atom makes a transition from the external state into the ground state, a photon is emitted carrying away the energy difference [2]. The emission due to spin-spin coupling with the photon has a wavelength of 21 cm. This line is usually used to study various astronomical

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phenomena, and has different applications in radio astrophysics [3]. Although, this line is considered a unique phenomenon in radio astronomy, but it suffered from the noise.

The noise sources could be classified into two types, artificial and natural sources. The artificial noise is generated due to telecommunication system, while the natural noise is formed due to astronomical sources. Antenna noise temperature is a parameter that explains how much noise an antenna may show in a specific environment. The antenna noise can be classified into two kinds according to source of noise. First type, due to the loss resistance of the antenna itself, and second is the noise the antenna picks up from the neighboring environment. Since any object whose temperature over the absolute zero emits electromagnetic radiation energy. Consequently, each antenna is surrounded by noise sources [4].

Any observing system consists of a receiver, an antenna and a transmission line. All these system components have their contribution to the system noise. The system temperature is a necessary factor in determining the sensitivity and the signal to noise ratio (SNR) of a receiving system. If the antenna has some losses, then the noise temperature consists of two terms. These are the antenna temperature due to the habitat factors around the antenna (T_A), and the temperature due to the tangible temperature of the antenna (T_{AP}) [5].

Several studies were concentrated about the radio noise that associated with the observing system. The most important of these studies is Lanre O. Daniyan (2011). In this study, the sky temperature and antenna temperature of Nsukka city, Nigeria (6^0 $50^{'}$ $09''$ N 7^0 $23^{'}$ $36^{''}$ E) were estimated [6]. Shkelzen C. and Bexhet K. (2011) study the temperature of antenna noise for low earth orbiting satellite ground stations at L and S band [7]. Rodolfo J. Montez, studied the electronic noise calibrator for MIT Haystsck Observatory, and developed a small radio telescope in L-band (1.42 GHz) [8]. In this study, we chose different azimuths and elevations at different observations time. The results of this study showed that the best observations regions are located at azimuth (120°-160°) and (210°-260°).

2. Theoretical Concepts

The concept of the antenna temperature (T_A) could be defined as the temperature of antenna radiation resistance, which equals the resistance temperature. T_A is created due to the relation between the power radiated by the source, which is related to the brightness temperature T_B, and the antenna normalized power pattern P (θ, Φ). Consider a receiving antenna that is pointed to a source brightness distribution B (θ, Φ), the source power radiation is intercepted by the antenna terminals which creates power called antenna power P_A. T_A is associated with P_A at antenna radiometer, and P_A could be given by [9]:

$$P_A = \frac{1}{2}\text{Ae} \iint B(\theta, \emptyset)P(\theta, \emptyset)d\Omega \tag{1}$$

Where ($\theta,\emptyset$) are the azimuth and elevation of the source. A_e is the effective aperture of the radio telescope antenna, and $d\Omega$ is the element solid angle. Utilizing Raleigh-Jeans limit. Therefore, the brightness distribution given by Eq. (1) can be changed by an equivalent T_B, and T_A, as given by the following equation [9]:

$$T_A = \frac{1}{2K}Ae \iint T_B(\theta, \emptyset)P(\theta, \emptyset)d\Omega \tag{2}$$

This means that T_A is equivalent to the convolution between the source brightness temperature and beam power pattern of the radio telescope. Using the Nyquist theorem, T_A can introduce by [10]:

$$T_A = \frac{P_A}{kG\Delta v} \tag{3}$$

Where Δv is the bandwidth frequency of the telescope radiometer in Hz, G is antenna gain.

3. Observations and Data Reduction:

The observations in this work are carried out using Baghdad University Radio Telescope (BURT). This telescope has diameter (D = 3 m), focal length (f = 1.18 m) and f/D ratio is 0.39

[11]. Any radio telescope should be calibrated before any process of observation. This telescope has been calibrated using the sun and the moon as a reference source [12]. This telescope can make daily measurements of the radio signals at the frequency of 1.42GHz. The spectrometer software of this telescope divides the received data into 600 channels of the frequency. These channels are used to obtain the amplitude of the measured power in unit (dBm). The values of this power are divided according to the frequency channels and arrangements as rows data. This power has been obtained after setting the optimum values of spectrometer parameters of the radio telescope. These parameters are span, sweep time, center frequency, Resolution Bandwidth (RBW), and Video Bandwidth (VBW) [13]. The observations date, the BURT antenna position (azimuth and elevation) and the best spectrometer parameters as listed in table (1).

Table 1-Selecting spectrometer parameters values

| Observation date	Antenna position		Input value of spectrometer parameters				
	Azimuth (degree)	Elevation (degree)	Center Freq.(Hz)	Sweep Time (sec.)	Span (Hz)	RBW (Hz)	VBW (Hz)
31-8-2020 30-9-2020	120^0	$20^0,30^0,40^0,50^0,60^0, 70^0,80^0,90^0$	1.42×10^9	30	2×10^7	100	10
4-5-2020 8-9-2020	130^0	$20^0,30^0,40^0,50^0,60^0, 70^0,80^0,90^0$					
2-9-2020 21-10-2020	140^0	$20^0,30^0,40^0,50^0,60^0, 70^0,80^0,90^0$					
10-9-2020 21-10-2020	150^0	$20^0,30^0,40^0,50^0,60^0, 70^0,80^0,90^0$					
10-9-2020 21-10-2020	160^0	$20^0,30^0,40^0,50^0,60^0, 70^0,80^0,90^0$					
6-9-2020 11-10-2020	210^0	$20^0,30^0,40^0,50^0,60^0, 70^0,80^0,90^0$					
31-8-2020 30-9-2020	220^0	$20^0,30^0,40^0,50^0,60^0, 70^0,80^0,90^0$					
21-7-2020 11-10-2020	230^0	$20^0,30^0,40^0,50^0,60^0, 70^0,80^0,90^0$					
22-6-2020 21-7-2020	240^0	$20^0,30^0,40^0,50^0,60^0, 70^0,80^0,90^0$					
4-5-2020 8-9-2020	250^0	$20^0,30^0,40^0,50^0,60^0, 70^0,80^0,90^0$					
22-6-2020 2-9-2020	260^0	$20^0,30^0,40^0,50^0,60^0, 70^0,80^0,90^0$					

4. Results and Discussion

Our observations were carried out to estimate the optimum part in the sky that has less sky background noise. This estimation was achieved via pointed BURT to several azimuths' values at different observations. The scanned region was located between 10-300 degree in azimuth angles. Then each azimuth value was observed with eight elevations values. The change in the elevation value was selected from 20 degrees to the 90 degree, and then the sky background noise temperature was computed according to equation (3) for each elevation. The results were demonstrated in Figures 1-11.
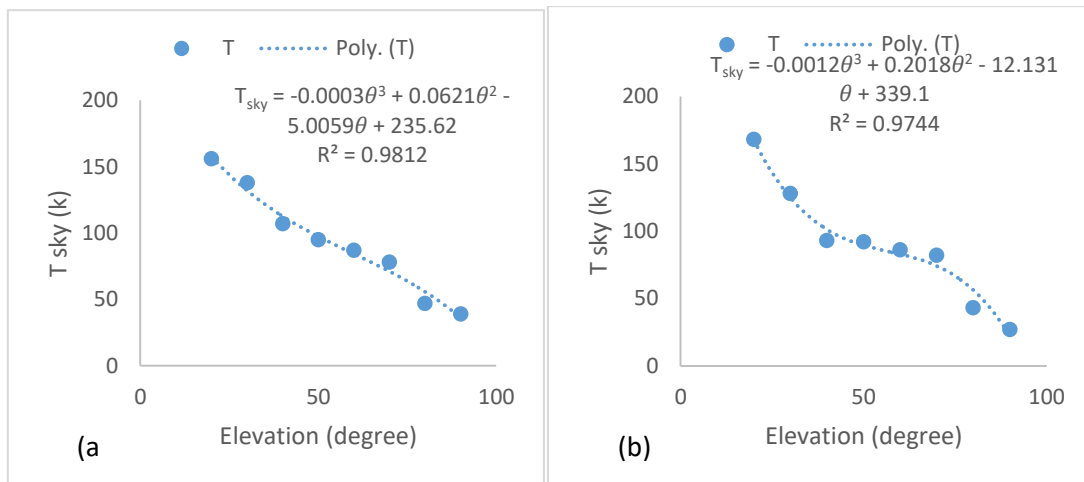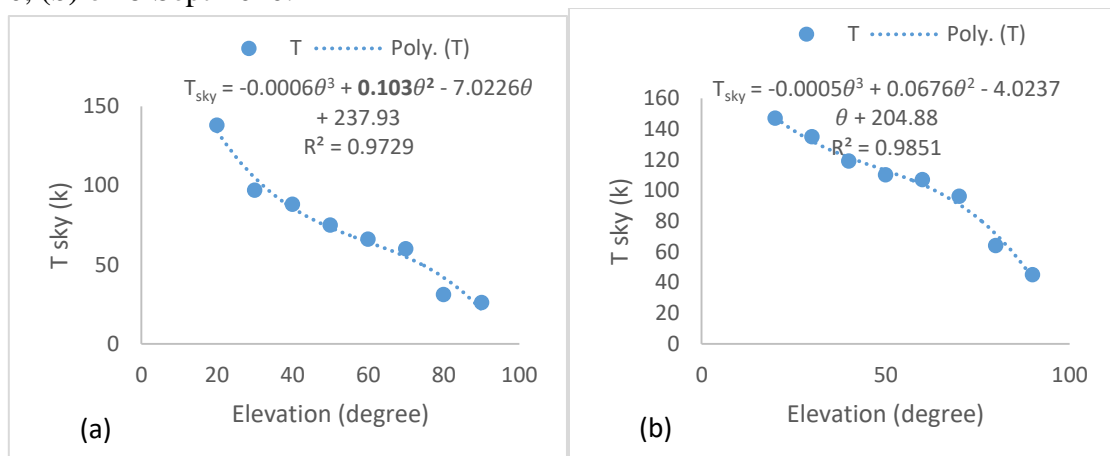
Figure 1- T_{sky} (k) as a function of elevation angle (degree) for azimuth 120°: **(a)** on 31-Aug-2020, **(b)** on 30-Sept-2020.
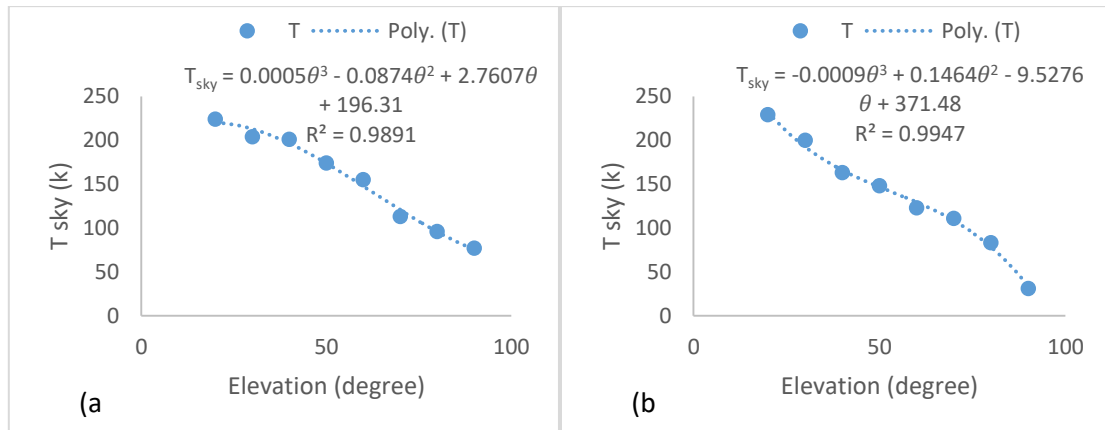
It should be pointed out here that, (R^2) is the norm residual error. The norm residual is a measure of better of fit, where the value closer to one means is the best result.
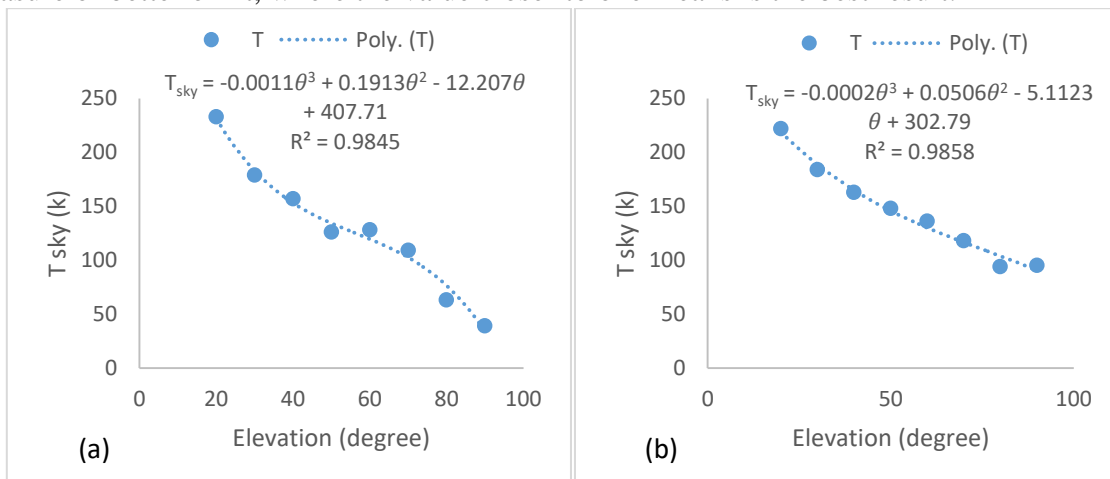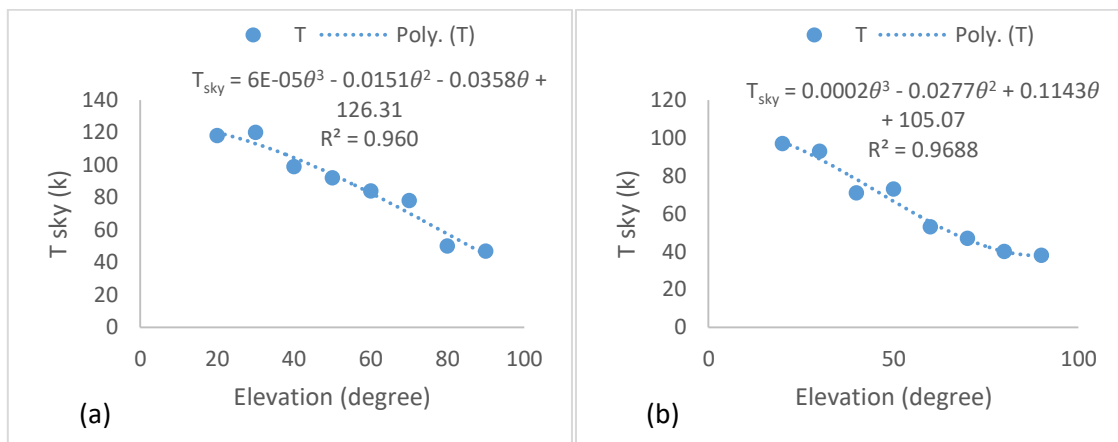

Figure 2- T_{sky} (k) as a function of elevation angle (degree) for azimuth 130°: **(a)** on 4-May-2020, **(b)** on 8-Sept-2020.
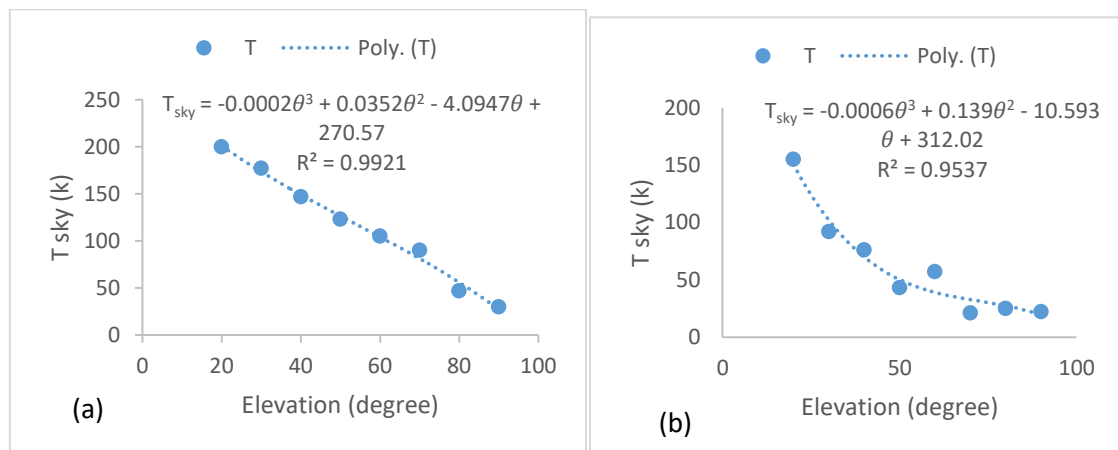

Figure 3- T_{sky} (k) as a function of elevation angle (degree) for azimuth 140°: **(a)** on 2-Sept-2020,**(b)** on 21-Oct-2020.
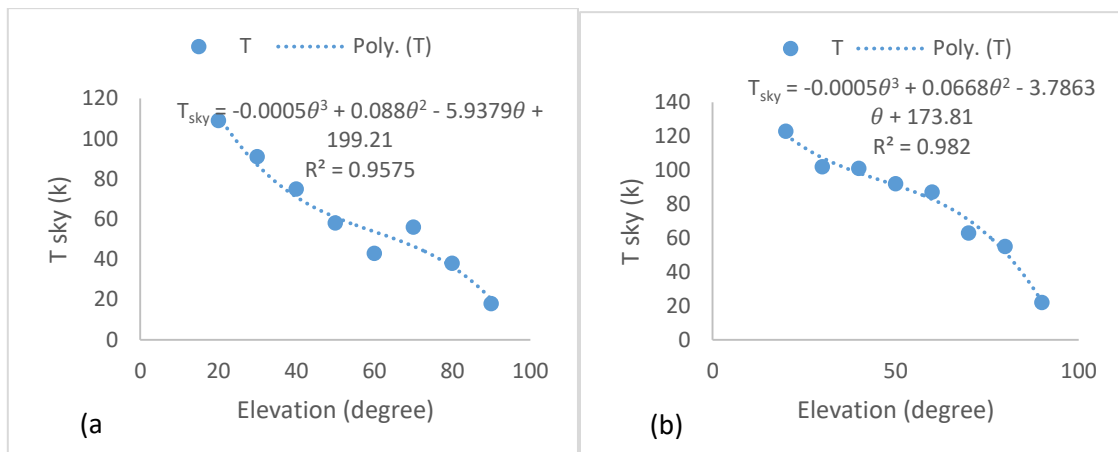
Figure 4-T_{sky} (k) as a function of elevation angle (degree) for azimuth 150°: **(a)** on 10-Sept-2020, **(b)** on 21-Oct-2020.
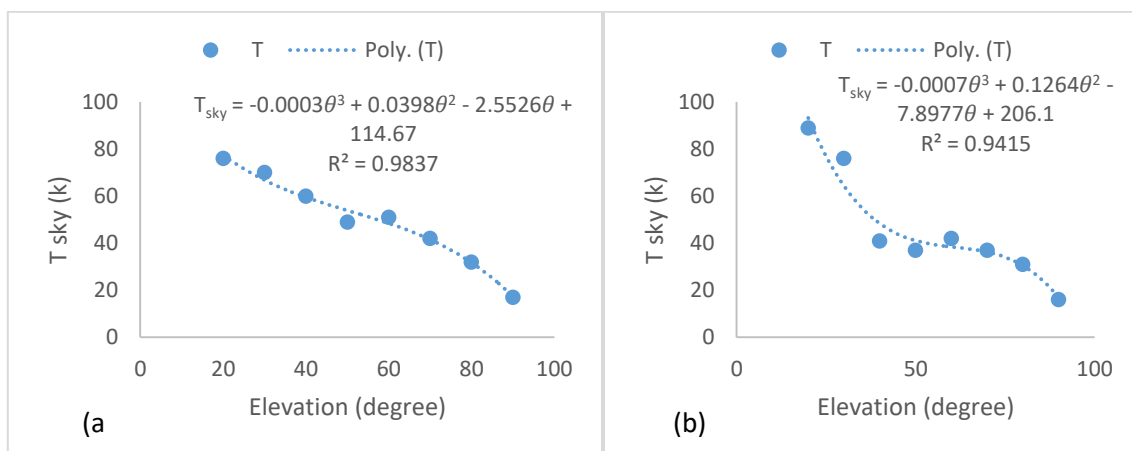

Figure 5-T_{sky} (k) as a function of elevation angle (degree) for azimuth 160°: **(a)** on 10-Sept-2020, **(b)** on 21-Oct-2020.
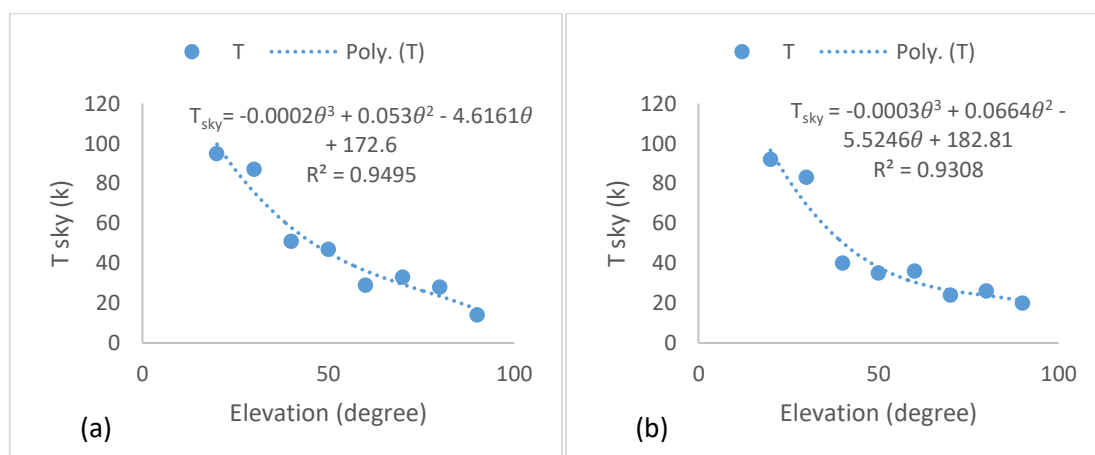

Figure 6- T_{sky} (k) as a function of elevation angle (degree) for azimuth 210°: **(a)** on 6-Sept-2020, **(b)** on 11-Oct-2020.
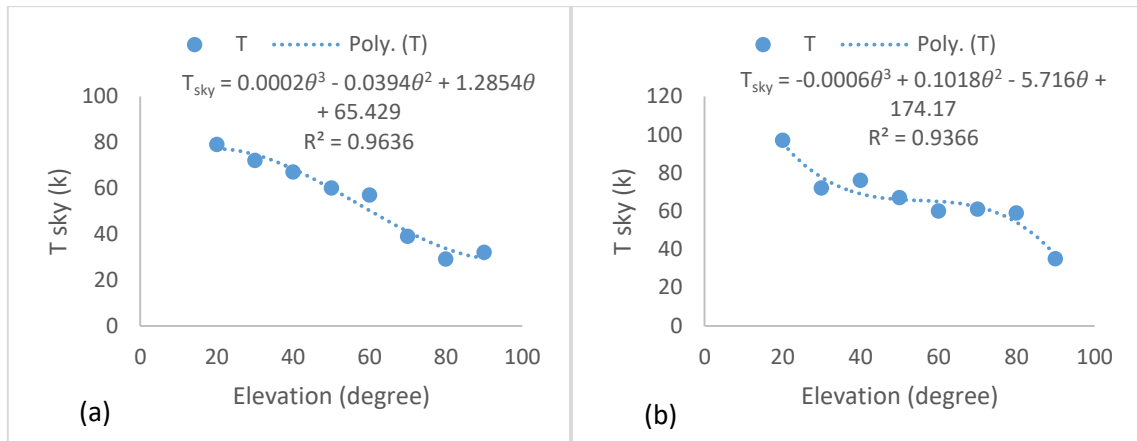
Figure 7-T_{sky} (k) as a function of elevation angle (degree) for azimuth 220°: **(a)** on 31-Aug-2020, **(b)** on 30-Sept-2020.
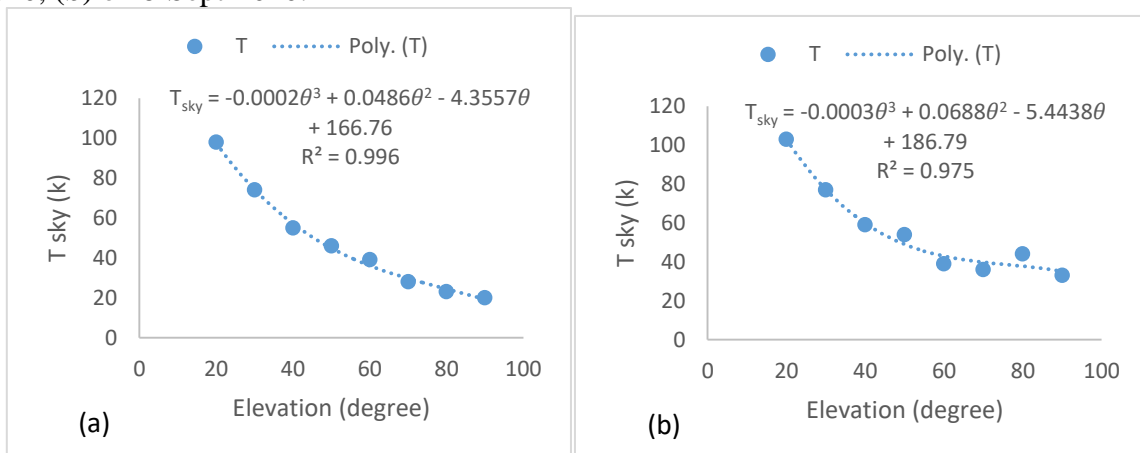

Figure 8- T_{sky} (k) as a function of elevation angle (degree) for azimuth 230°: **(a)** on 21-July-2020, **(b)** on 11-Oct-2020.

Figure 9-T_{sky} (k) as a function of elevation angle (degree) for azimuth 240°: **(a)** on 22-Jun-2020, **(b)** on 21-July-2020.
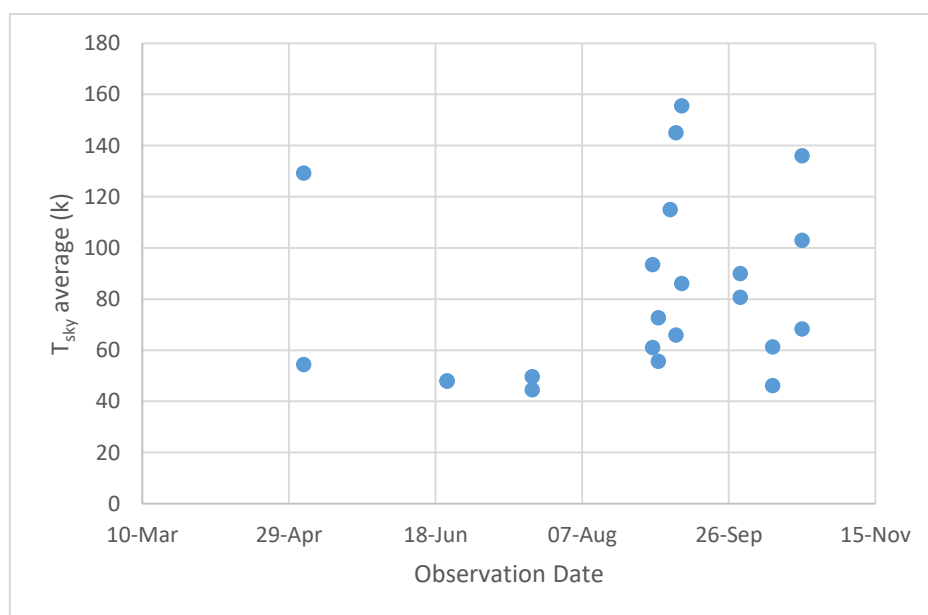
Figure 10-T_{sky} (k) as a function of elevation angle (degree) for azimuth 250°: **(a)** on 4-May-2020, **(b)** on 8-Sept-2020.

Figure 11- T_{sky} (k) as a function of elevation angle (degree) for azimuth 260°: **(a)** on 22-Jun-2020, **(b)** on 2-Sept-2020.

The average values of T_{SKY} during May to October in 2020 have been computed. Then the result is plotted with the observation date, as shown in Figure 12.

Figure 12-T_{sky} average (k) as a function of observation date.

From the Figure 12 the average value of T_{sky} is estimated to be (44.5 to 155.5 K).

5. Conclusions

1- The best observation region in Baghdad University is found at azimuths between (120° to 160°) and (210° to 260°).

2- The sky temperature model could be represented as a polynomial of third degree that could be fitted the behavior of the observation points.

3- The norm residual error (R^2) was computed to verify our model. R is estimated to be varied between (0.996 to 0.9308).

4- The sky temperatures of Baghdad City are estimated to be varied between (44.5 to 155.5) K, as shown in Figure 12.

Acknowledgments

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