DOI: 10.24996/ijs.2025.66.11.42

ISSN: 0067-2904

The Relation between BURT Radio Telescope Antenna Movement in Horizontal Coordinates Relative to Equatorial Coordinates

Sama Abd-alrazaq Latif*, Kamal M. Abood
Department of Astronomy and Space, College of Science, University of Baghdad, Baghdad, Iraq

Received: 11/6/2024 Accepted: 27/10/2024 Published: 30/11/2025

Abstract
The antenna of the Baghdad University Radio Telescope (BURT), located at Baghdad longitude (44.38°) and latitude (33.275°), is moved according to a horizontal coordinate (Azimuth (Az), Elevation (El)) system. In this paper, the relation between antenna telescope movement is converted to equatorial coordinates (Right Ascension (RA), Declination (DEC)) using a set of conversion equations. MATLAB R2014a is used for programming all equations. Sun data observations for the BURT radio telescope archive are used to investigate the relationship between horizontal and equatorial coordinates. Two sets of data are selected to test and verify this relationship. The first set of data is for sun observation on 7 January 2019 at 10:50 AM, and the second on 13 April 2019 at 11:18 AM. The SunCalc software package (https://www.suncalc.org/) is used to calculate the sun's location (Az, El) in Baghdad's sky. The antenna movement in horizontal coordinates (Az, El) to form a square area equal to 4° square will be converted to equatorial coordinates in the sky region boundary of -24.9313°≤DEC≤ -19.8238° and 19h 17m 2s ≤RA≤19h 37m 20s. In the same way, the antenna movement in horizontal coordinates (Az, El) to form a square area equal to 3° square will be converted to equatorial coordinates in the sky region boundary of 7.3242°≤DEC≤10.6877° and 1h 29m 47s ≤RA≤1h 39m 56s.

Keywords: Horizontal coordinates, Equatorial coordinates, Azimuth, Elevation, Right ascension, Declination [1]

العلاقة بين حركة هوائي التلسكوب الراديوي BURT في الإحداثيات الأفقية نسبة الى الإحداثيات الاستوائية

سما عبدالرزاق لطيف* , كمال محمد عبود
قسم الفلك والفضاء, كلية العلوم, جامعة بغداد, بغداد, العراق

الخلاصة
يتحرك هوائي التلسكوب الراديوي لجامعة بغداد (BURT) الواقع في بغداد على خط الطول (44.38°) وخط عرض (33.275°) وفق نظام الإحداثيات الأفقية ((Azimuth (Az), Elevation (El)). في هذا البحث تم تحويل العلاقة بين حركة هوائي التلسكوب الى الإحداثيات الاستوائية ,Right Ascension (RA) (Declination (DEC)) باستخدام مجموعة من معادلات التحويل. يستخدم MATLAB R2014a لبرمجة

* Email : sama.Abdulrazaq1607a@sc.uobaghdad.edu.iq

جميع المعادلات. تم استخدام بيانات عمليات رصد الشمس لأرشيف التلسكوب الراديوي (BURT) لتحقيق العلاقة بين الإحداثيات الأفقية والاستوائية. تم اختيار مجموعتين من البيانات لاختبار هذه العلاقة والتحقق منها. المجموعة الأولى من البيانات الخاصة برصد الشمس يوم 7 January 2019 الساعة 10:50 صباحاً، والثانية يوم 13 April 2019 الساعة 11:18 صباحاً. يتم استخدام برنامج SunCalc (https://www.suncalc.org/) لحساب موقع الشمس (Az, El) في سماء بغداد. سيتم تحويل حركة الهوائي في الإحداثيات الأفقية (Az, El) لتكوين مساحة مربعة تساوي 4° درجات مربعة إلى إحداثيات استوائية في حدود منطقة السماء البالغة $-24.9313° \leq DEC \leq -19.8238°$ و $19h\ 17m\ 2s \leq RA \leq 19h\ 37m\ 20s$. وبنفس الطريقة, سيتم تحويل حركة الهوائي في الإحداثيات الأفقية (Az, El) لتكوين مساحة مربعة تساوي 3° درجات مربعة إلى إحداثيات استوائية في حدود منطقة السماء البالغة $7.3242° \leq DEC \leq 10.6877°$ و $1h\ 29m\ 47s \leq RA \leq 1h\ 39m\ 56s$.

1. Introduction

A radio telescope is used to investigate the radio waves received by Earth through various celestial objects. Some of these may be well known from optical observations; however, many others were identified only through radio astronomy. The solar system, including the sun, the moon, and the nearby planets, all constitute well-known radio sources [1]. Most telescopes can detect emissions at frequencies ranging from roughly 30 MHz to 300 GHz, and they perform best at wavelengths between 1 and 20 cm. In this paper, we used Sun data from the Baghdad University Radio Telescope (BURT). BURT is a radio telescope located on the roof of the Department of Astronomy and Space, College of Science, University of Baghdad (longitude 44.38°, latitude 33.275°). This telescope has a 3-meter diameter at a frequency of 1.42 GHz, a focal length of 1.18 meters, and an f/D ratio of 0.39 [2] [3].

The antenna of the BURT is moved according to a horizontal coordinate. The horizontal coordinate system is a celestial coordinate system that defines two coordinates: Azimuth and Elevation or Altitude, using the observer's local horizon as its fundamental plane. Azimuth (Az) is an object's angle around the horizon, often measured from the true north and increasing eastward. Az is calculated in degrees (0° to 360°) on the positive scale. Elevation (El), is calculated from the horizon following the vertical line that is moving through the celestial object. El is within limits (+90°, -90°). It is positive (0° to +90°) to the object over the horizon and negative (0° to -90°) to the body that is under the horizon [4]. The equatorial coordinate system contains two coordinates: right ascension and declination. These coordinates are angles extended from the center of the Earth. Right Ascension (RA) is like longitude, measured from west to east affirmatively along the equator from the vernal equinox. The unit of RA is a time unit (hour-minute-second) from 0 to 24 hours (0° to 360° in degree). DEC is the distance northward from the equator (0° to +90°) to the object's location. Declinations that are south of the equator are negative (0° to -90°) [5].

The sun's DEC angle is equal to the angle between its position and the celestial equator as measured along the vast circle that contains the sun and the celestial poles [6]. DEC is positive when the sun's beams are north of the equator and negative when they are south of the equator. During the winter solstice, the sun's beams are -23.5° S of the Earth's equator and +23.5° N of the equator around the summer solstice. The sun's declination is zero during the two equinoxes [7].

2. Theory of converting Az and El to RA and DEC

Conversion from horizontal coordinates (Az, El) to equatorial coordinates (RA, DEC) is done by using the following equations. To find the value of DEC in degrees use the equation below [8]:

$$\sin DEC = \sin El \ \sin \emptyset + cosEl \cos \emptyset \cos Az \tag{1}$$

Where: El represents elevation, Ø the observer's geographical latitude (Ø = 33.275° N), and Az the angle.

To calculate the RA, the date and time of observation must first be converted to Julian Date (JD). Input the date (Year (y), Month (m), and Day (d)) to calculate the Julian date [9] [10]:
To solve the problem of February when m =1 or 2 we take y′= y-1 and m′= m+12.
d = day + UT/24
Where: UT is universal time in hours.

$$JD = B + INT(365.25 \times y) + INT(30.6001 \times (m + 1)) + d + 1720994.5 \tag{2}$$

Where: B is the correction after 1582 October 15 (i.e. in the Gregorian calendar) calculate:
A= INT (y/100)
B= 2- A+ INT (A/4)
T_{UT1} is the number of Julian centuries that elapsed from the epoch J2000.0. It is calculated by the following equation [11]:

$$T_{UT1} = \frac{JD_{UT1} - 2{,}451{,}545}{36{,}525} \tag{3}$$

The θ_{GMST} is Greenwich Mean Sidereal Time in degrees and it’s calculated by the following formula [12]:

$$\theta_{GMST} = \ 67{,}310.54841^{s} + (876{,}600^{h} + \ 8{,}640{,}184.812866^{s}) \ \mathrm{T_{UT1}} \ + 0.093\ 104\ \mathrm{T_{UT1}^{2}} - 6.2 \times 10^{-6}\ \mathrm{T_{UT1}^{3}} \tag{4}$$

The Means Local Sidereal Time (LST) in degrees is calculated through the following formula [12]:

$$LST = \theta_{GMST} + \lambda \tag{5}$$

Where: λ is the longitude = 44.38° E.

The local hour angle (LHA) is the angle formed from the observer’s longitude to the celestial meridian of the object, calculated through these equations [12]:

$$\sin LHA = \frac{\sin Az \ \cos El}{\cos DEC} \tag{6}$$

$$\cos LHA = \frac{\sin El - \sin \emptyset \sin DEC}{\cos \emptyset \ \cos DEC} \tag{7}$$

$$LHA = \tan^{-1} \ (\sin \mathrm{Az} \cos \mathrm{El} \cos \emptyset \ / \sin El - \sin \emptyset \sin DEC) \tag{8}$$

The formula of RA in hours is [12]:

$$RA = LST - LHA \tag{9}$$

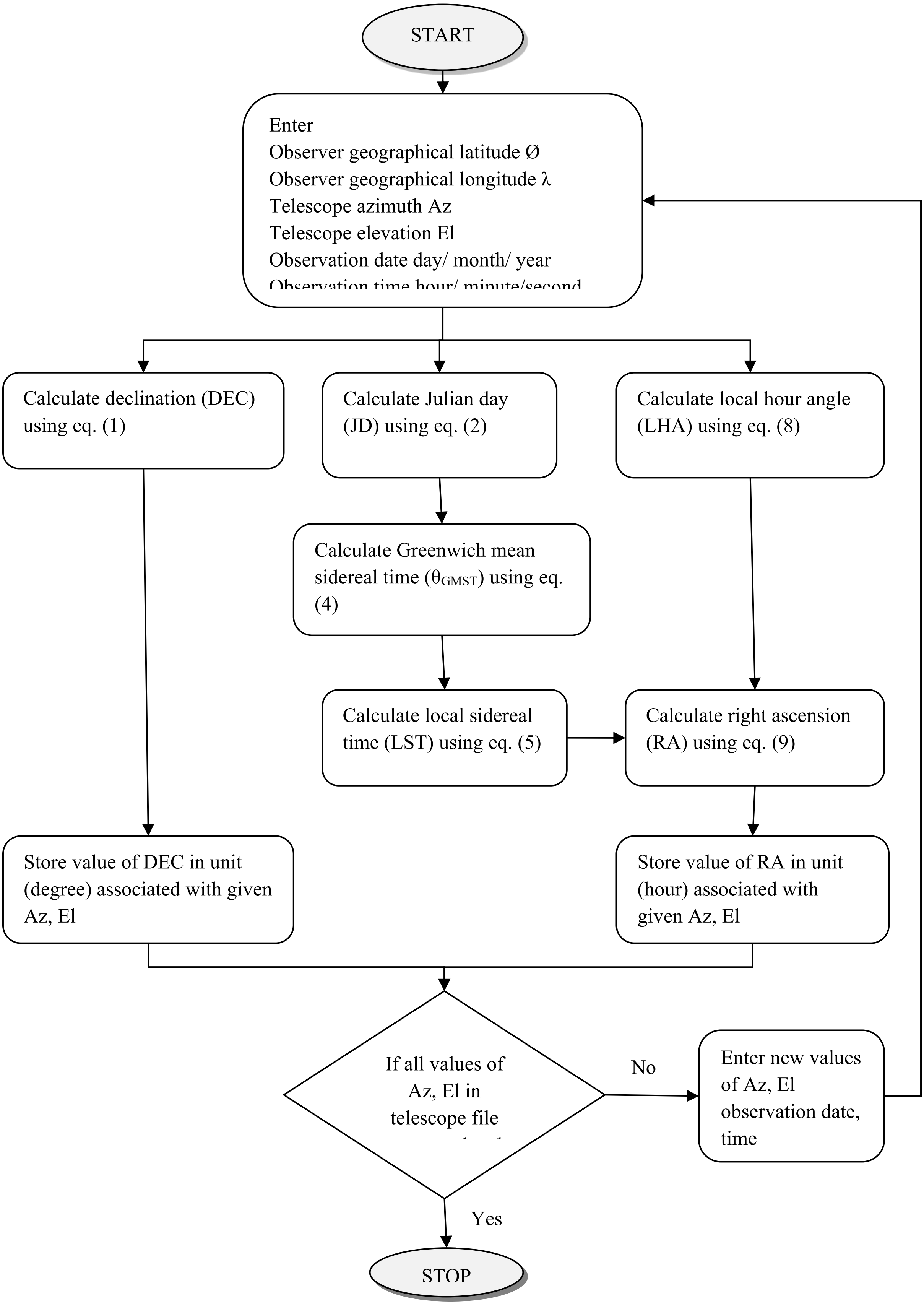

Figure 1: The calculation step of DEC and RA.

3. Data observation

We used Az and El data from the BURT archive for the sun observations on different dates on 7 January 2019 at time 10:50 AM and 13 April 2019 at 11:18 AM, to observe the clear changes in the sun's coordinates and converted them to RA and DEC.

Table 1: The sun's observations on 7 January 2019 at 10:50 AM converted to RA and DEC.

Azimuth Az (degree)	Elevation El (degree)	Right Ascension RA (hour- minute - second)	Declination DEC (degree)
153	28	19h 37m 20s	-23.5875
154	28	19h 34m 6s	-23.9474
155	28	19h 30m 32s	-24.2956
156	28	19h 26m 58s	-24.6319
157	28	19h 23m 17s	-24.9561
153	29	19h 35m 40s	-22.6766
154	29	19h 32m 13s	-23.0307
155	29	19h 28m 46s	-23.3732
156	29	19h 25m 16s	-23.7039
157	29	19h 21m 39s	-24.0228
153	30	19h 33m 54s	-21.7646
154	30	19h 30m 32s	-22.1128
155	30	19h 27m 6s	-22.4497
156	30	19h 23m 35s	-22.7749
157	30	19h 20m 5s	-23.0884
153	31	19h 32m 8s	-20.8513
154	31	19h 28m 51s	-21.1939
155	31	19h 25m 25s	-21.5251
156	31	19h 22m 4s	-21.8449
157	31	19h 18m 33s	-22.1531
153	32	19h 30m 26s	-19.9370
154	32	19h 27m 10s	-20.2739
155	32	19h 23m 49s	-20.5996
156	32	19h 20m 30s	-20.9140
157	32	19h 17m 2s	-21.2170

Table 2: The sun's observations on 13 April 2019 at 11:18 AM converted to RA and DEC.

Azimuth Az (degree)	Elevation El (degree)	Right Ascension RA (hour- minute - second)	Declination DEC (degree)
148.07	61.29	1h 39m 56s	8.0685
149.12	61.17	1h 38m 19s	7.7385
150.11	61.17	1h 36m 34s	7.5348
151.12	61.16	1h 34m 48s	7.3242
148.07	62.23	1h 38m 14s	8.9093
149.07	62.19	1h 36m 37s	8.6678
150.06	62.18	1h 34m 57s	8.4609
151.13	62.19	1h 33m 5s	8.2628
148.07	63.21	1h 36m 27s	9.7854
149.12	63.19	1h 34m 46s	9.5583
150.11	63.18	1h 33m 9s	9.3578
151.12	63.19	1h 31m 27s	9.1775
148.07	64.22	1h 34m 37s	10.6877
149.06	64.19	1h 33m 6s	10.4697
150.06	64.18	1h 31m 31s	10.2732
151.12	64.19	1h 29m 47s	10.0898

Table 3: The relation of antenna movement in horizontal coordinates with equatorial coordinates.

Date dd-mm-yy	Local Tim (Am)	Az ,El Area movement (degree^2)	RA , DEC Boundary limits	RA Area movement (hour)	DEC Area movement (degree)
07-01-2019	10:50	4°	19h 17m 2s ≤RA≤19h 37m 20s $-24^{\circ}.9313 \leq DEC \leq -19^{\circ}.8238$	0.3383	5.1075°
13-04-2019	11:18	3°	1h 29m 47s ≤RA≤1h 39m 56s $7^{\circ}.3242 \leq DEC \leq 10^{\circ}.6877$	0.169	3.3635°

4. The sun's position in Baghdad's sky

There are many sites through which we can calculate the location of the sun anywhere on the Earth, and one of these sites is SunCalc (figure 2), through which we calculated the position of the sun in Baghdad University at the coordinates (longitude 44.38° E, latitude 33.275° N) on the date of 7 January 2019, at 10:50 AM, and the date of 13 April 2019, at 11:18 AM.

Table 4: The sun's position at different times by using the link: https://www.suncalc.org/

Date (dd-mm-yy)	Local Tim (AM)	Azimuth Az (degree)	Elevation El (degree)	Right Ascension RA (hour- minute - second)	Declination DEC (degree)
07-01-2019	10:50	158.68°	31.29°	19h 12m 27.37s	-22.390°
13-04-2019	11:18	154.26°	63.58°	1h 25m 34.79s	8.986°

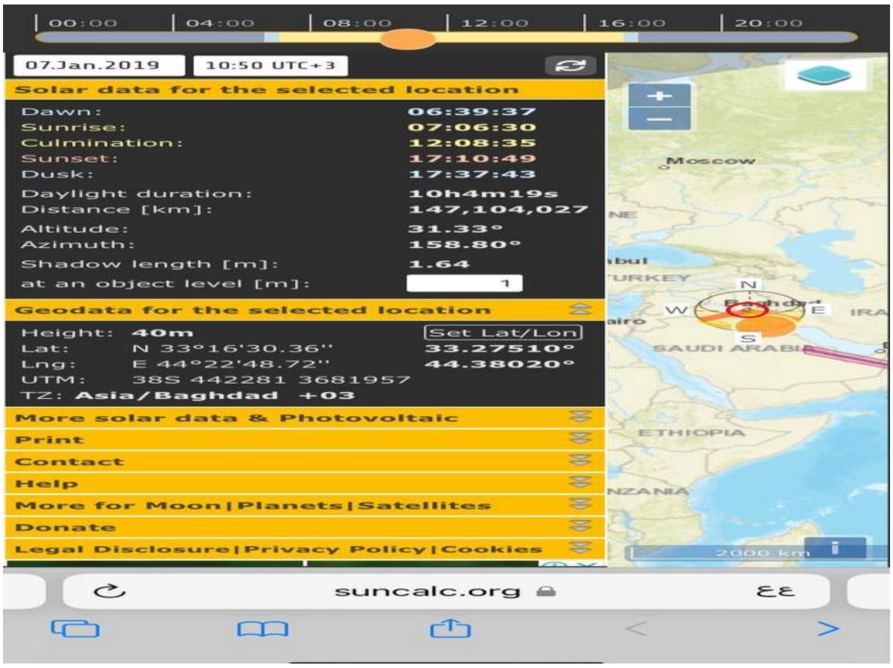

Figure 2: SunCalc website
[https://www.suncalc.org/#/27.6936,97.5195,3/2024.09.14/16:48/1/3].

5. Conclusion

There is no correspondence between the sun coordinates (Az, El), and (DEC, RA) in the result for the same observation date and time. It is due to the time recorded in the archive, which represents the time storage archive file after the telescope has completed all antenna movement coordinate positions (Az, El). Data from the previously published studies of the telescope was taken to correct this correspondence. The antenna movement time has been 14 minutes to complete 25 movements (starting and stopping) points to form a square area of 4 degrees. This time has been subtracted from the storage time file in the telescope archive; the sun position coordinates will be shifted within the sun coordinate limits. Likewise, if we take the file around 16 movements (starting and stopping) points, it takes 9 minutes, and if this time is subtracted from the storage time file in the telescope archive, the sun position coordinates will be shifted within the sun coordinate limits.

The radio BURT telescope (3 meters in diameter) is considered a small radio telescope (SRT); therefore, the sun is considered as a point radio source. The sun's equatorial coordinates (Declination (DEC)) range from -23.5° south of the Earth's equator during the winter solstice to +23.5° north of the equator around the summer solstice. Therefore, the result obtained is satisfactory and within the limit values of these sun’s equatorial coordinates (DEC).

Reference

[1] J. Findlay, "Radio telescopes," *IEEE Transactions on Antennas and Propagation,* vol. 12, no. 7, pp. 853-864, December 1964.

[2] U. E. . Jallod and K. M. Abood, "Characteristics measurement of Baghdad University radio telescope for hydrogen emission line," *AIP Conference Proceedings,* vol. 2190, no. 1, 11 December 2019.

[3] U. E. Jallod and K. M. Abood, " Solar Measurements for 21 cm Wavelength using 3 Meter Radio Telescope," *Electromagnetics Research Letters,* vol. 85, pp. 17-24, 2019.

[4] H. Karttunen and K. Donner, Fundamental Astronomy, fifth ed., New York: Springer Berlin

Heidelberg, 2007.

[5] H. Bradt, Astronomy Methods: A Physical Approach to Astronomical Observations, United Kingdom: Cambridge University Press, 2004.

[6] R. Walraven, "Calculating the position of the sun," *Solar Energy,* vol. 20, no. 5, pp. 393-397, 1978.

[7] S. Ray, "Calculation of sun position and tracking the path of sun for a particular geographical location," *International Journal of Emerging Technology and Advanced Engineering,* vol. 2, no. 9, pp. 81-84, September 2012.

[8] J. Meeus, ASTRONOMICAL ALGORITHMS, SECOND ed., Willmann-Bell, Inc., 1998.

[9] P. Duffett-Smith and J. Zwart, Practical Astronomy with your Calculator or Spreadsheet, fourth ed., Cambridge University Press, 2011.

[10] D. J. Saad, F. M. Abdulla and A. H. Saleh, "Improving the Accuracy of Prayer Times and Calculating Their Change with Geographical Latitudes during the Year 2021 AD," *Iraqi Journal of Science,* vol. 63, no. 9, pp. 4090-4101, 2022.

[11] F. M. Abdulla, "Calculating the variations of sunrise, sunset and day length times for Baghdad city.With comparison to different regions of the world in year 2019," *Iraqi Journal of Science,* vol. 60, no. 12, pp. 2732-2741, 29 12 2019.

[12] D. Vallado, Fundamentals of Astrodynamics and Applications, Springer Science & Business Media, (2001, June 30).