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Qibla determination through the Sun transit over Ka'ba

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ABSTRACT Astronomical computations show that each year the sun appears exactly overhead Ka'ba on May 28 and July 16. This occurs when the declination of the sun is equivalent to the geographical latitude of Ka'ba. Facing the sun precisely during that moment in time will give the correct direction of the qibla. These twice-a-year phenomena provide excellent opportunities to the Muslims around half the globe to check and confirm their direction of qibla. Solar observations at two locations, namely Telok Kemang and Bukit Malawati on July 16, 2000 have been carried out. The objective of the study is to compare the observed directions of qibla from the two locations during the sun transit over Ka'ba with their corresponding computed values. The observed and computed values of the direction of qibla show a difference of between 3 arcminutes at Telok Kemang and 7 arcminutes in Bukit Malawati.

ABSTRAK Penghitungan astronomi menunjukkan setiap tahun matahari berada tepat di atas Kaabah pada 28 Mei dan 16 Julai. Ini terjadi apabila deklanasi matahari adalah sama dengan latitud geografi Kaabah. Menghadap ke arah matahari tepat pada ketika itu akan memberikan kepada kita arah qiblat yang sebenar. Fenomena dua kali setahun ini memberikan orang Islam yang tinggal separuh dari glob peluang terbaik untuk menyemak dan mengesahkan arah qiblat mereka. Pencerapan matahari pada dua lokasi, iaitu Telok Kemang dan Bukit Malawati pada 16 Julai 2000 telah dapat dilaksanakan. Objektif kajian ini ialah untuk membandingkan arah-arah qiblat yang dicerap dari dua lokasi tersebut semasa matahari transit di atas Kaabah dengan nilai kiraan yang sepadan. Nilai-nilai cerapan dan kiraan untuk arah qiblat menunjukkan terdapat perbezaan 3 arka minit di Telok Kemang dan 7 arka minit di Bukit Malawati.

(Qibla, Transit, Refraction, Zenith, Azimuth)

INTRODUCTION

The knowledge of the direction of qibla is central to Muslims in carrying out specific religious obligations and certain daily tasks. Performing the *solat*, slaughtering of animals, *doa'*, reciting the Holy Quran, constructing mosques and burying the deceased are some of the ritual acts that require proper alignment with the qibla.

The qibla is the direction to the Ka'ba from other place, but what precisely is that direction? In fact this problem received serious attention from some of the most famous scientists including al-Khwarizmi, al-Battani, Abu al-Wafa al- Buzjani, Ibn al-Haitham, al-Biruni and al-Tusi [1]. Significant original contributions to the qibla determination were also made, among others by, Habash al-Hasib, al-Nayrizi, Ibn Yunus, al-Khalili and Ibn al-Shatir [2].

Some of the most important early works on determining the qibla are the following: al-Khwarizmi and al-Battani provide approximate methods using simple geometric construction. Habsah al-Hasib and Ibn al-Haitham supplied exact method that is based on graphical construction. Ibn Yunus and al-Biruni [3] introduced graphical constructions and spherical trigonometric computations. Ibn Yunus and al-Khalili compiled a table containing the qibla angle as a function of longitude difference from Mecca and latitude.

In addition to this computation method, practical methods involving astronomical instruments such as astrolabes and various types of quadrants were used to determine qibla direction. The qibla could be determined by solar observations directly at certain times and derived from observations using spherical trigonometric calculations.

An excellent opportunity to determine qibla direction is by observing the sun when it passes directly over the Ka'ba meridian during local Mecca noon. Based on astronomical computations, we know that each year the sun transits and appears exactly overhead Ka'ba on May 28 and July 16. This occurs when the declination of the sun is equivalent to the geographical latitude of Ka'ba. Imagining that the sun as a vertical extension of a tall tower, anyone facing the sun precisely at the moment of the sun transit over Ka'ba will be in the correct direction of the qibla. Thus, these twice-a-year events provide excellent opportunities to the observers around the world to check and confirm their direction of qibla.

In this paper we explain the basic concepts of the spherical triangle used to derive the time of the sun transit over Ka'ba and also the method for computation of the direction of qibla. The equipment and methodology used in the solar observation are briefly discussed. Finally, the results from the comparison between the observed and computed values of the direction of qibla are given.

Qibla by Definition

The qibla is the direction between a geographical place to the building of Ka'ba in Mecca, Saudi Arabia. Thus, at a given place one is said to be facing the qibla when one orientates oneself in this direction. For someone who can see the Ka'ba, the qibla is the line of sight to it. However, for someone who is outside the vicinity of Mecca, the concept of geometrical direction is used to determine the qibla.

Here we present several definitions of the direction of qibla as quoted in Abdali [4].

Ibn al-Haitham, *quoted in al-Khatabbi* [5]:

'The qibla is the direction such that when a human observer faces it, it is as if he is looking at the diameter of the earth passing through the Ka'ba. And the ray coming out of his eye in that direction is in the plane of the great circle passing in the direction of his zenith and the point corresponding to [the zenith of] Mecca'

Al-Razi [6]:

'The qibla direction is the intersection point between the circle of horizon and the great circle passing in the direction of our zenith and Mecca's zenith. The qibla angle is the arc on the circle of horizon between the qibla direction and the meridian of our city; and [the angle] between the qibla direction and the equinoctial sunset point [i.e. west] is the complement of the qibla angle.

Figure 1 shows the direction of qibla seen from Kuala Lumpur. The qibla direction is represented by the great circle passing through the two zeniths. It can also be the direction in which an imaginary tall tower over Ka'ba would appear to be seen.

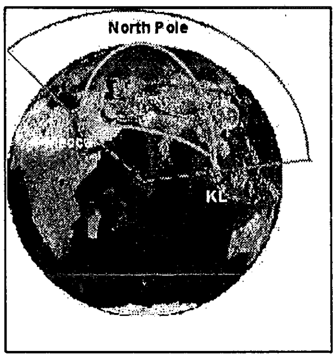


Figure 1. The direction of Qibla is represented by the great circle passing through the two zeniths.

TIME OF SUN TRANSIT OVER KA'BA

Figure 2 is a graphical representation of the moments leading to the sun transit over Ka'ba. When this happens, the sun appears at the zenith with its altitude a equal 90° and the local hour angle LHA as zero. More importantly for this event to occur, the declination δ of the sun must be the same as the latitude, ϕ of Ka'ba as shown in the right figure.

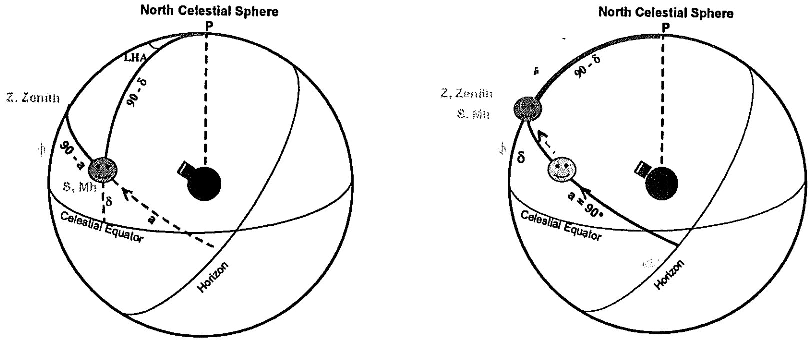


Figure 2 The moments before (left) and during (right) the sun transit over Ka'ba

The use of sun ephemeris enables us to compute and interpolate the positions and times of the Sun all throughout the year. It contains tables that give the positions or coordinate of celestial objects at various future times. Thus, an ephemeris of the sun would provide its future geocentric right ascension and declination in the equatorial system of coordinates with their future corresponding times. In the computation of the time of sun transit over Ka'ba, the Japanese Ephemerides for the year 2000 are used (see Table 1).

Table 1 An extract from the Japanese Ephemerides 2001

	Apparent Declination, δ	**Ephemeris Transit, ET**
15 July 2000	+ 21° 30′ 29.5″	12h 05m 58.6s
16 July 2000	+ 21° 20′ 49.4″	12h 06m 4.09s

The derivation of the date and time of when the sun would appear overhead Ka'ba is as follows:

1. First, using the Japanese Ephemerides 2000, we look up for the date when the declination of the sun is roughly equal to the latitude of Ka'ba, $\delta_{sun} \approx \phi$Ka'ba = +21° 25' 15.6".

This occurs on two occasions throughout the year: May 28 and July 16.

2. Next, we perform an interpolation for the value of Ephemeris Transit, ET for δ_{sun} = +21° 25' 15.6"

Here we obtain ET = 12h 06m 1.53s ≈ UT (Universal Time)
ie: Sun Transit Time at Mecca_{UT}

3. Following this, we compute the corresponding Malaysian Standard Time (MST)
   Sun Transit at Mecca_{MST}
   = Sun Transit Time at Mecca_{UT} + (8h - $\lambda_{Ka'ba}$ / 15°)
   = 12h 06m 1.53s + (8h - 39° 49' 29.0"/15°)
   = 17h 26m 43.53s

Hence, the sun is at the meridian of Ka'ba on 16 July 2000 at 5.27 pm (MST).

OBSERVATIONAL TECHNIQUE

On July 16, 2000, the Department of Survey and Mapping Malaysia (DSMM) have carried out solar observations at two locations, namely Telok Kemang and Bukit Malawati. These two locations are part of the 26 official sites for moon crescent sighting for the determination of the beginning of hijri months in Malaysia. The sites have excellent views towards the western sky. The sites also have three survey markers with reference objects (RO's) for back-bearings and survey orientation purposes. The objective of the study is to compare the observed directions of qibla from the two locations during the sun transit over Ka'ba with their corresponding computed values.

The equipment used was Topcon GTS-700 Digital Theodolite with an accuracy of 1"(arcsecond). The solar observational procedure followed the guidelines as outlined in the Survey Regulations 1976 Appendix V. Each observation of 1-minute apart consisted of four pointings to the sun on two circles, as shown in Figure 3. On circle left, the left edge of the sun disc was placed tangentially to the vertical cross hair with the horizontal cross hair bisecting it and the horizontal and vertical readings taken. Using the slow motion screws, the cross hairs were brought to right edge of the sun and the readings were again taken. The procedure was repeated on circle right.

The means of the horizontal and vertical angles gave the position of the centre of the sun. The observation was arranged in such a way that the mean epoch of the solar observation coincided with the time of the sun transit over Ka'ba at 5.27 pm.

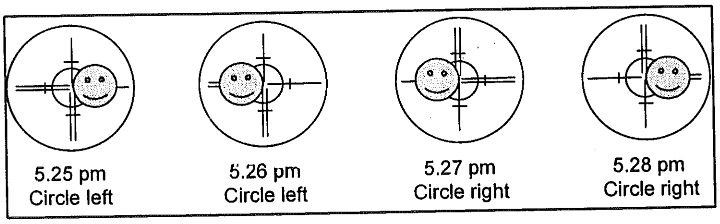


Figure 3 The moments before (left) and during (right) the sun transit over Ka'ba

RESULTS AND ANALYSIS

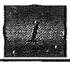
The derivation of the qibla has a simple formulation in spherical trigonometry [7]. A spherical triangle, a three-cornered figure whose sides are arcs of great circles, is used. The direction of qibla is given by the great circle passing through the desired point (A) and the Ka'ba (B). By solving a spherical triangle that has the North Pole, Ka'ba and the desired point at its vertices, the azimuth or the angle subtended by the qibla from the true north, measured clockwise, can be easily computed. The angle between the true north and the qibla, Q can be computed using the formula as follows:

$$Q = Tan^{-1} \frac{Sin(\lambda_A - \lambda_B)}{Tan\phi_B \, Cos\phi_A - Sin\phi_A \, Cos(\lambda_A - \lambda_B)} \quad (4.1)$$

where λ_A is the longitude of point A,
ϕ_A is the latitude of point A,
λ_B is the longitude of Ka'ba, and
ϕ_B is the latitude of Ka'ba.

In (Tables 2 and 3), we show how the computation of the direction of the qibla from two locations, Teluk Kemang and Bukit Malawati are carried out.The results from the solar observation are given in (Table 4). It shows the observed and computed qibla direction from Teluk Kemang and Bukit Malawati [8]. From the table, it can be deduced that differences of between 3 arcminutes to 7 arcminutes were obtained. Although insignificant, the differences in azimuths can be attributed to various factors that have an effect on the solar observation. These include astronomical refraction [9] that is difficult to model especially for equatorial sites and at low elevations, instrumental error, pointing accuracy and clock error. The effects of astronomical refraction, pointing accuracy, instrumental error and clock error should be look into. Investigation on the above parameters will lead to an improved in accuracy of our measurements. Until then we will be very confident of our qibla direction and without any hesitation to perform our duties in obedient to the Almighty. The use of the sun transit over Ka'ba is a means of verifying other methods of determining the qibla. This is to ensure that our qibla direction is very accurate.

Table 2 Qibla computation for Teluk Kemang

LOCATION:  Baitul Hilal Telok Kemang		NEGERI: Negeri Sembilan
	STATION (A)	KAABAH (B)
LATITUDE	$\varnothing_A$ = 2° 31' U	$\varnothing_B$ = 21° 25' 15."6 U
LONGITUDE	λ_A = 101° 48' T	λ_A = 39° 49' 29."1 T

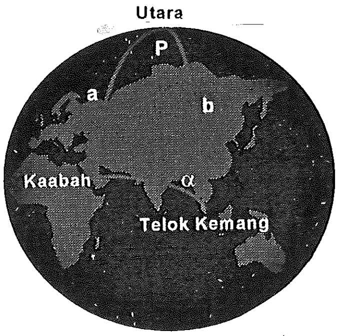
$P = \lambda_A - \lambda_B = 61° 58' 30."9$
$a = 90 - \varnothing_B = 68° 34' 44."4$
$b = 90 - \varnothing_A = 87° 29'$

$$\text{Cot}\,\alpha = (\text{Cot a Sin b} - \text{Cos b Cos P})\ \text{Cosec P}$$
$$= (\text{Tan}\,\varnothing_B \text{Cos}\,\varnothing_A - \text{Sin}\,\varnothing_A \text{Cos}\,\Delta\lambda_{AB})\ \text{Cosec}\,\Delta\lambda_{AB}$$

Tan $\varnothing_B$	=	0.392 318 59	(1)
Cos $\varnothing_A$	=	0.999 035 49	(2)
Sin $\varnothing_A$	=	0.043 910 00	(3)
Cos $\Delta\lambda_{AB}$	=	0.469 852 92	(4)
Cosec $\Delta\lambda_{AB}$	=	1.132 830 35	(5)

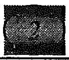
$\text{Cot}\,\alpha = [((1)(2) - (3)(4)) \times (5)] = 0.420\,630\,05$

$\Rightarrow \alpha = 67° 11' 13"$



DIRECTION OF QIBLAT = 360 - α = **292° 48' 47"**

Table 3 Qibla computation for Bukit Malawati

LOCATION:  Baitul Hilal Bukit Malawati		NEGERI: Negeri Selangor
	STATION (A)	KAABAH (B)
LATITUDE	$\varnothing_A$ = 3° 20' U	$\varnothing_B$ = 21° 25' 15."6 U
LONGITUDE	λ_A = 101° 15' T	λ_A = 39° 49' 29."1 T

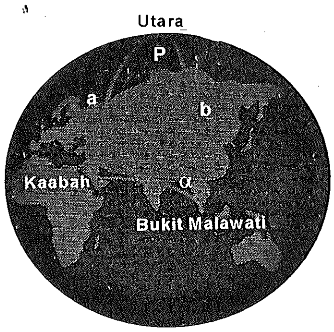
$P = \lambda_A - \lambda_B = 61° 25' 30."9$
$a = 90 - \varnothing_B = 68° 34' 44."4$
$b = 90 - \varnothing_A = 86° 40'$

$$\text{Cot}\,\alpha = (\text{Cot a Sin b} - \text{Cos b Cos P})\ \text{Cosec P}$$
$$= (\text{Tan}\,\varnothing_B \text{Cos}\,\varnothing_A - \text{Sin}\,\varnothing_A \text{Cos}\,\Delta\lambda_{AB})\ \text{Cosec}\,\Delta\lambda_{AB}$$

Tan $\varnothing_B$	=	0.392 318 59	(1)
Cos $\varnothing_A$	=	0.998 308 16	(2)
Sin $\varnothing_A$	=	0.058 144 83	(3)
Cos $\Delta\lambda_{AB}$	=	0.478 304 89	(4)
Cosec $\Delta\lambda_{AB}$	=	1.138 700 76	(5)

$\text{Cot}\,\alpha = [((1)(2) - (3)(4) \times (5)] = 0.414\,309\,329$

$\Rightarrow \alpha = 67° 29' 43"$



DIRECTION OF QIBLAT = 360 - α = **292° 30' 17"**

Table 4. Observed and computed qibla directions July 16, 2000

Location and Observation Epoch	Observed Qibla	Computed Qibla	Difference
Teluk Kemang (5.26 pm)	292^0 45 38	292^0 48 47	-3 09
Bukit Malawati (5.27 pm)	292^0 23 08	292^0 30 17	-7^0 09

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