APPLICATION OF EFFECTIVE AZIMUTH DIFFERENT FORMULA IN DETERMINING THE *QIBLA* DIRECTION

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Abstract

The sun's shadow and the *Qibla* azimuth are two techniques for figuring out the *Qibla* direction. To obtain *Qibla* direction accuracy while applied to traditional instruments with low accuracy, such istiwa'ayn, the user's accuracy is required. Slamet Hambali's theory of a process angle was inspired by this issue. The effective angle disparity formula, which is based on Slamet Hambali's concept, is discussed in this article along with how it can be used to get effective azimuth variance. This article is based on numerically-based quantitative research using library data. The aim is to comprehend the concept of various effective azimuths and how they are used to identify the direction of the *Qibla*. This article comes to the conclusion that Slamet Hambali's formula for the effective azimuth difference tends to make use of the idea of processing angle by calculating the azimuth difference value with particular aiming hours, azimuth difference value, and processing angle to produce a shooting clock with a different azimuth valuation.

Keywords*: Qibla Direction, Azimuth Disparity, Effective Azimuth, Observation Time.*

Abstrak

Azimut kiblat dan matahari merupakan metode penentuan arah kiblat. Jika diterapkan kepada istrumen klasik dengan ketelitian kecil seperti *istiwā'ayn* maka dibutuhkan ketelitian pengguna untuk mendapatkan akurasi arah kiblat. Problem tersebut memunculkan konsep sudut proses dari Slamet Hambali. Artikel ini membahas konsep rumus beda azimut efektif gagasan Slamet Hambali serta penerapannya dalam menghasilkan nilai beda azimut efektif. Artikel ini berupa penelitian kuantitatif dengan data pustaka dengan pendekatan numerik. Tujuannya untuk mengetahui konsep beda azimut efektif serta penerapannya dalam menentukan arah kiblat. Artikel ini menyimpulkan bahwa rumus beda azimut efektif gagasan Slamet Hambali menggunakan konsep sudut proses dengan menentukan nilai beda azimut dengan jam bidik tertentu kemudian menentukan nilai beda azimut dan menentukan sudut proses sehingga menghasilkan jam bidik yang mempunyai nilai beda azimuth.

Kata Kunci*: Arah Kiblat, Beda Azimuth, Azimuth Efektif, Jam Bidik.*

A. Introduction

Facing the *Qibla* is a valid condition for prayer, both fard and sunnah prayers. It means his prayer becomes invalid if a person prays but does not face the *Qibla*. Therefore, the *Qibla* is something that must be considered. The *Qibla* in question is the direction to the Kaaba inside the Grand Mosque of Mecca. The scholars of fiqh have different opinions regarding the definition of facing the *Qibla*, whether to face the Kaaba physically or simply with the direction.

God also gives human nature as a thinking creature and a cultured creature a mandate as a caliph on earth. As a form of His responsibility, Allah gave two tools to guide humans in finding the truth. The two tools in question are reason and revelation. Both are expected to work hand in hand according to their respective roles proportionally.[1] Therefore, astronomy always develops according to the times, including determining the direction of *Qibla*.

The method of determining the direction of *Qibla* nowadays is very diverse. Among astronomers is the calculation of the *Qibla* azimuth with the concept of spherical trigonometry combined with the sun azimuth reference. This method is widely used by practitioners of astronomy in Indonesia, including in existing community organizations, such as Nahdhatul Ulama and Muhammadiyah. It takes solar data, such as the sun's declination and altitude, to determine its azimuth. This data can be obtained through the table of the reckoning book, ru'yah ephemeris, Ministry of Religion of the Republic of Indonesia, and the Nautika almanac.

The solar data needed to find the sun's azimuth includes solar declination data. The ephemeris data book from the Ministry of Religion of the Republic of Indonesia provides the solar declination data. In addition, the sun's declination can also be calculated using the Meuss algorithm in his book Astronomical Algorithm. The meuss algorithm searches the sun's declination based on the specified date and time. The time in question can be up to the level of seconds, even fractions of a second. So different times produce different solar declination values.

One of the instruments used to determine the direction of *Qibla* is *istiwā'ayni*. The principle is the same as the theodolite. In determining the *Qibla* direction, Aini's uses the

[1] Mahsun, "Rekonstruksi Pemikiran Hukum Islam Melalui Integrasi Metode Klasik Dengan Metode Saintifik Modern," *AL-AHKAM: Jurnal Hukum & Pranata Sosial*, 2015. 4

concept of different azimuths, namely the *Qibla* azimuth and the sun azimuth. This special is considered entirely accurate, but it has several drawbacks, one of which is that it cannot read numerical data up to the order of arcseconds. If the *Qibla* measurement is carried out at any time of the day, the value of the azimuth difference tends to reach the accuracy of arcseconds. To facilitate the use of this feature, data on the adequate azimuth difference is needed, namely the azimuth difference without excess minutes and seconds of arc.

The concept of calculating the azimuth difference formula without excess minutes and seconds of arc is to determine the new azimuth difference from the previous azimuth difference with the desired number, which is an integer value without minutes and seconds of arc. The calculation begins by determining the azimuth of the *Qibla* and the sun at a particular hour. Then it will produce the value of the azimuth difference, which is usually the value of this azimuth difference, up to the accuracy of the arcsecond. After the value of the azimuth difference is known, the new azimuth difference value is determined without minutes and seconds. From this new azimuth difference value, look for a new solar azimuth value, referring to the unique azimuth difference. The value of the difference in azimuth is defined as subtracting the azimuth of the *Qibla* and sun. Then the new solar azimuth value is determined by subtracting the *Qibla* azimuth from the unique azimuth difference. From this calculation, the resulting measurement time corresponds to the new azimuth difference—the new measurement time, usually up to the order of seconds.

From the explanation above, it is necessary to know the concept of the effective azimuth difference formula of Slamet Hambali's idea and how it is applied in determining the *Qibla* direction. This study aimed to assess the concept of the azimuth difference formula and its application in deciding the *Qibla* direction. The application of this azimuth difference formula is not only for round values but can also be applied to half-degree values.

Studies regarding the determination of *Qibla* direction are carried out by many researchers. Sayful Mujab (2014), in his study of "*Qibla* in the Perspective of the Schools of Fiqh," explains that the *Qibla* direction is one of the studies in fiqh. The survey of fiqh is a realm where there are many differences of opinion, including the question of *Qibla*. According to Imams other than Shafi'i madhhab, it is required to face the Kaaba physically for those who can see it or meet towards the Kaaba for those who cannot see it. Meanwhile, according to

Imam Shafi'i, there are 2 (two) options, first, the same as the previous opinion, and second, must face the physical Kaaba.

Arimo Bemi Sado (2019), "The Effect of Magnetic Declination on Compass and Earth's Geographic Coordinates on *Qibla* Direction Accuracy." The article explains that the compass is a directional instrument commonly used by the general public. The compass can be used as a *Qibla* direction, but it is weak if it is close to a magnetic object. Compass as a *Qibla* direction indicator can be accurate if it is corrected with magnetic declination correction.

As explained in Ahmad Fadholi's research on "Istiwaain Slamet Hambali, an alternative solution to determine the *Qibla* direction is easy and accurate" (2019). The determination of the *Qibla* direction can use the reference of celestial bodies. But the most often used as a reference is the sun because the sun is the most easily seen celestial body from the earth. Apart from the sun, the stars can also be used as a reference to determine the *Qibla* direction in the wild. It is explained by Samsudin, Ubaidilah, and Masri'ah (2019).

Sampulawa, in his thesis on "Determination of *Qibla* Direction Using Planetary Azimut" (2016). From a distance to earth, stars outside the solar system are more difficult to see. Therefore, determining the *Qibla* direction concerning stars outside the solar system becomes more difficult. Another alternative is using the reference azimuth of the solar system's planets. The planets in question are Mercury, Venus, Mars, Jupiter, and Saturn. The accuracy is better than the sun reference because the observations focus more on the earth's center by referring to the solar system planets. The discussion in this study is still general; namely, the analysis of planetary azimuths and the source of planetary data still need to be detailed.

Slamet Hambali, who was the initiator of the *istiwā'ayni*, in his writing entitled "Test the accuracy of the *Qibla* direction measurement results using Slamet Hambali's *istiwā'ayni*" published by LP2M IAIN Walisongo, (2014)—testing the accuracy of this special at the Great Mosque of Central Java. The results are pretty accurate and can be accounted for, as explained.

Moh. Adieb, in his thesis, explained that this istiwaa could be used by aligning the shadow of the sun aiming with the istiwa' stick and the difference between the *Qibla* zim and the sun azimuth when shooting. This study shows that the contrast produced by this special with a theodolite in determining the *Qibla* direction is still within the tolerance limit, meaning that the difference between the two is not too significant.

Rini listyaningsih, Slamet Hambali's particular accuracy test in determining the coordinates of a place, Semarang: UIN Walisongo Semarang, (2017). This event can also be used to determine the coordinates of a location as described in Rini listianingsih's research. He explained that this event is an alternative tool to determine the coordinates of the earth, which consists of the latitude and longitude of a place using the shadow of the special stick. The results of measuring the coordinates of sites using this feature are similar to the coordinates shown by GPS. The difference between the two is only on the order of minutes, which is between 0 degrees 0 minutes 41.09 seconds to 0 degrees 8 minutes 12.45 seconds.

Ana Nur Afifah explains this istiwaa, the concept the same as the theodolite, using a different azimuth method. If the *Qibla* direction measurement uses the idea of azimuth difference, carried out at random times, it is likely to produce numbers up to arc second accuracy, so if applied to this unique, the accuracy can be reduced. Therefore, Slamet Hambali made a formula for the difference in azimuth without minutes and seconds. It is what the author examines, namely, determining the adequate azimuth difference with the Android-based Slamet Hambali formula.

B. Method

This study uses a type of qualitative literature research with a normative approach, namely calculating the azimuth difference data with Slamet Hambali's formula. The solar data uses the Jean Meuss calculation method. The primary data source is the adequate azimuth difference data on a specific date resulting from Slamet Hambali's formula. At the same time, the secondary sources are books, astronomy encyclopedias, journals relevant to this research study, and interviews with several figures involved in astronomy and astronomy, including Slamet Hambali. The author uses a descriptive analysis technique by explaining the difference between *Qibla* and solar azimuth. It starts with the *Qibla* calculation using the spherical trigonometry formula. Next examines the origin of the solar declination data, which is essential in determining solar azimuth data. This azimuth difference data is calculated by Slamet Hambali's formula to produce an azimuth difference value close to the degree value without minutes and seconds so that it can make it easier to measure *Qibla* using classical instruments such as this *istiwā'ayni*.

C. Result and Discussion

C.1 *Qibla* Definition

One of the discussions in astronomy is the determination of the *Qibla* direction. The word *Qibla* comes from Arabic, namely *Qibla*, a masdar form of the qabila-yaqbalu-*Qibla*tan which means facing, a reference to face.[2] *Qibla* means direction and everything that is used as a reference to face. Meanwhile, the *Qibla* is the direction the person praying is aiming for, physically and towards the Kaaba.[3] Hadi Bashori explained that *Qibla* means nahiyah as-salah, i.e., the direction to which one prays, which can also be interpreted as a place used as a direction. Meanwhile, in the Encyclopedia of Islamic Law by Abdul Aziz Dahlan, it is explained that the *Qibla* is defined as the building of the Kaaba or the direction that Muslims go in carrying out some worship.[4]

In the history of heavenly religion, two holy places have been designated as Mecca in prayer, namely Baitul Maqdis (Bait al-Muqaddas) in Palestine and Baitullah or Kaaba in the Grand Mosque of Mecca. Until now, Baitul Maqdis is still the Mecca of the Jews. Prophet Muhammad faced the *Qibla* of Baitul Maqdis when he was still in Mecca and Medina for up to sixteen months (or seventeen months). After that, Allah revealed the *Qibla* direction to the Kaaba in the Grand Mosque.[5]

Ahmad Izzuddin's writing, Method of Determining *Qibla* Direction and Its Accuracy, quoted from the Glossary of the Mapping Sciences (t.th.: 153), explains what is meant by direction is a line that shows or delivers to a place without distance information. The explanation above can be applied if the object is a flat plane. However, applying to curved or spherical surfaces like the earth takes work. Additional definitions related to direction are needed when juxtaposed with the *Qibla*, which is on the ground and is shaped like a ball.

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[2] Sayful Mujab, "Kiblat Dalam Perspektif Madzhab-Madzhab Fiqh," *YUDISIA: Jurnal Pemikiran Hukum Dan Hukum Islam* 5 (2016). 318

[3] Ahmad Ghozali Muhammad Fathullah, *Irsyad Al-Murid: Ila Ma'rifat Ilm Al-Falak 'Ala Al-Rashd Al-Jadid* (LanBulan: Al-Mubarok, 2005). 10

[4] Hadi Bashori, *Pengantar Ilmu Falak* (Jakarta: Pustaka Al-Kautsar, 2015). 103

[5] Mujab, "Kiblat Dalam Perspektif Madzhab-Madzhab Fiqh." 318

Qibla direction is defined as the closest distance from a location to the Kaaba through the great circle.[6]

Qibla's direction is the cardinal direction. According to Ma'rufin Sudibyo, traditionally, there have been four primary cardinal directions: north, east, south, and west. There are also four secondary cardinal directions, namely northeast (located between north and east), southeast (situated between east and south), southwest (located between south and west), and northwest (located between west and north). Furthermore, some add the next level of cardinal directions, namely the tertiary cardinal points, which consist of eight directions, including north-northeast, northeast-east, east-southeast, south-southeast, south-southwest, southwest, west sea, and north-northwest.[7]

C.2 Sun Declination and Equation of Time

One component to determine the sun's azimuth is the sun's declination data of time. The sun's declination is the arc on the circle of time measured from the point of intersection of the time process and the rotation of the equator north or south to the sun's center.[8] When it is north of the equator, the sun's declination is positive, and when it is south of the equator, it is negative. The sun's declination scale is 0 degrees to 23.5 degrees. The equation of time is the difference between the actual solar culmination time and the average solar time. A lowercase e usually symbolizes it. Equation of time, in Arabic, it is called ta'dil al-waqt, while in Indonesian, it is called averaging time.[9]

The value of the sun's declination can be seen in astronomical tables such as in the ephemeris reckoning book of the Ministry of Religion or nautical almanacs. Solar declination data can also be searched through astronomical calculations referring to Julian's Day. Rinto Anugraha explained that the value of the sun's declination is sought through the transformation formula for the geocentric ecliptic coordinates to the geocentric equatorial coordinates.[10]

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[6] Ahmad Izzuddin, *Metode Penentuan Arah Kiblat dan Akurasinya*, (disampaikan di dalam acara AICIS UIN Sunan Ampel Surabaya tahun 2012)

[7] Muh. Ma'rufin Sudibyo, *Sang Nabipun Berputar* (Solo: Tinta Medina, 2011). 111

[8] Encup Supriatna, *Hisab Rukyat Dan Aplikasinya* (Bandung: Refika Aditama, 2007). xii

[9] Susiknan Azhari, *Ensiklopedi Hisab Rukyat* (Yogyakarta: Pustaka Pelajar, 2012). 62

[10] Rinto Anugraha, *Mekanika Benda Langit*, (Bandung: UGM, 2012), hal 56

Meanwhile, Julian day (JD) is defined as the number of days that have passed since Monday, January 1, 4713 BC (before Christ) in the middle of the day, which is 12.00 UT. The term BC is commonly used by historians to describe the time of a historical event. But in calculating time according to astronomical terms, mention the year BC by adding a negative sign before the year. So the year 4713 BC is the same as the year -4712. Usually, the required input is an hour, minute, second, date, month, and year in determining Julian's day. The following equation can calculate the JD.[11],

Y = If month number < 3, so Y = year number – 1
= If month number >= 3, Y = year number
M = If month number <= 3, M = month number +12
= If month number > 3, M = month number
A = If year number > 1582, A = int (year number / 100)
= If year number <= 1582, A = year number
B = If year number > 1582, B = 2 – A + int (A/4)
= If year number <= 1582, B = 0
JD = int (365,25 x (Y + 4716)) + int (30,6001 x (M + 1) + Date + B - 1524,5 + (hour x 3600 + minute x 60 + second) / 86400

Rinto Anugraha explains that to find the value of the sun's declination using the Jean Meuss method, pass the following equations,

- JD
- Delta T
- JDE = JD + Delta T
- T = (JDE-2451545) / 36525
- L0 = 280,46645 + 36000,76983 x T
- M0 = 357,5291 + 35999,0503 x T
- C = (1,9146 – 0,0048 xT) x sin M0 + (0,02-0,0001 x T) x sin (2 x M0) + 0,0003 x sin (3 xM0)
- e = 0,0167086 – 0,0000420 x T
- L = L0 + C
- M = M0 + C
- Omega = 125,04452 – 1934,13626 x T
- E0 = 23,43929111 – 0,01300417 x T
- Delta E = 0,002555554 x cos (Omega) + 0,00015833 x cos (2 x L0)
- E = E0 + Delta E

[11] Ibid

- GST
- LST
- λ = L – 0,00569 – 0,00478 x sin (omega)
- β = 0
- Tan α = (cos E x sin λ) / cos λ
- Tan RA = tan α
- Sin δ = sin E x sin λ
- Deklinasi = atan (tan δ)

The declination value resulting from this equation is between 23.5 degrees to -23.5 degrees. This formula, by Jean Meuss, is called the low-accuracy declination formula, whose results are close to the high-accuracy formula that considers astronomical terms.[12]

C.3 *Qibla* Direction

In calculating the *Qibla* direction, several theories can be used. Quoted from the research synopsis from Siti Tatmainul Qulub, there are at least 3 (three) theories for calculating the *Qibla* direction, namely spherical trigonometry, Vincenty, and ellipsoid correction ball triangle. First, the theory of spherical trigonometry. This theory assumes that the earth is perfectly spherical without depressions or bulges. In this theory, the latitude of the place coordinates used is the geocentric latitude. If latitude data is taken from GPS, which is still in geodetic form, it must be converted to geocentric latitude using the following formula approach,

$\text{Tan } \Phi' = b^2 / a^2 \text{ Tan } \Phi$,

Φ' : Geocentric Latitude

Φ : Geodetic Latitude

a : Ellipsoid Long Axis (6378137 m)

b : Ellipsoid Short Axis (6356752,3142 m)

The spherical trigonometric formula approach refers to the concept of the sine equation in a spherical triangle, namely Cotan B = tan K x cos X: sin C – sin X: tan C, with information,

B : *Qibla* Direction

Φ^k : *Kaaba* Latitude

Φ^x : Place latitude

C : Longitude Difference

[12] Rinto Anugraha, *Mekanika Benda Langit*, (Bandung: UGM, 2012), hal 64

The following is an example of the result of calculating the *Qibla* direction using the spherical trigonometry method with latitude transformation (Siti Tatmainul Qulub:2013, 9)

No	City	Geodetic Latitude	Geocentric Latitude	Longitude	*Qibla* Azimuth
1	Semarang	-07° 00" S	-06° 57" 12,96” S	110° 24" E	294° 21" 57,61."
2	Jakarta	-06° 10‟ S	-06° 07‟ 32,52” S	106° 49‟ E	295° 00‟ 00,06”
3	Banda Aceh	05° 35‟ N	05° 32‟ 46,28” N	95° 20‟ E	292° 00‟ 36,29”
4	Jayapura	-02° 28‟ S	-02° 27‟ 00,63” N	140° 38‟ E	291° 13‟ 04,82”

Secondly, vincent's formula. The name of this formula is taken from the figure who invented the procedure, namely Vincenty. This formula considers the earth's shape, which is slightly flattened at the equator, not perfectly round, so the radii of the poles and the equator are not the same. The radius of the earth's equator is 6378137 m, while the radius of the equator is 6356752.3142 m, so it takes the value of the earth's compression (f) through the equation f = (a-b)/a where a = radius of the equator and b = radius pole finger. From this equation, the value is 0.00335281067183099 m (Ahmad Izzuddin: 2012, 110)

The following is the *Qibla* azimuth data using the Vincenty method,

No	City	Geodetic Latitude	Longitude	*Qibla* Azimuth
1	Semarang	-07° 00‟ S	110° 24‟ E	294° 23‟ 4,21”
2	Jakarta	-06° 10‟ S	106° 49‟ E	295° 01‟ 8,76”
3	Banda Aceh	05° 35‟ N	95° 20‟ E	292° 02‟ 58,16”
4	Jayapura	-02° 28" N	140° 38" E	291° 17" 30,6."

Third, by approaching the ellipsoid correction spherical triangle formula (ellipsoid theory). In the third method of determining the *Qibla* direction, the concept is the same as the first method, which uses a spherical trigonometry formula, except that the location coordinates used are adjusted to the coordinates generated from the GPS (Global Positioning System), geographic coordinates. This method is a method that astronomy practitioners in Indonesia have widely used until now. There is a lot of Falak literature in Indonesia that discusses this ellipsoid correction formula. One reason is that this formula is easy to use and straightforward. The accuracy of this third method, when compared with Vincenty's method, differs in the range of 8 arc minutes.

The following results from calculating the *Qibla* direction of the ellipsoid theory.

No	City	Geodetic Latitude	Longitude	***Qibla*** **Azimuth**
1	Semarang	-07° 00" S	110° 24" E	294° 30" 31,74"
2	Jakarta	-06° 10" S	106° 49" E	295° 08" 45,77"
3	Banda Aceh	05° 35" N	95° 20" E	292° 08" 34,3"
4	Jayapura	-02° 28" N	140° 38" E	291° 20" 52,56."

C.4 Determining the Effective Azimuth Difference

It would help if you went through several stages to get the value of the azimuth difference without excess minutes and seconds (adequate azimuth difference). 1) calculating *Qibla* direction (B), 2) calculating *Qibla* azimuth (AzK), 3) calculating the order of the Sun (A), 4) calculating Solar azimuth (AzM), and 5) calculating *Qibla* azimuth and Solar azimuth (BA). Difference between *Qibla* azimuth and Solar Azimuth (BA) to the minute and arc second accuracy. The formula for the adequate azimuth difference that Slamet Hambali coined has several steps as follows:

First, calculate the *Qibla* direction at a specific location. *Qibla* direction calculations use spherical trigonometry, geodesy, or ellipsoid correction trigonometry approaches. However, the author uses a third formula approach for practical purposes, namely ellipsoid correction trigonometry. The result of calculating the *Qibla* direction is between 0 and below 90 degrees. If the impact is positive, count from the north; if it is negative, measure from the south.[13]

Second, determine the *Qibla* azimuth, the direction calculated from the true north of a location, clockwise to arrive at the *Qibla* point. *Qibla* azimuth is above 0 degrees to below 360 degrees. To find out the *Qibla* azimuth, you must first know the categorization of the *Qibla* direction, whether it includes the northeast, southeast, southwest, or northwest. After that, the *Qibla* azimuth can be determined by the following equation:

[13] Ana Nur Afifah, Studi Analisis Rumus Menghitung Beda Azimut Kiblat Dan Azimut Matahari Karya Slamet Hambali, Semarang:UIN Walisongo, 2019, 44

- If *Qibla* direction from North to West; So, Azimuth Angle = *Qibla* Azimuth
- If *Qibla* direction from South to East; Azimuth Angle = *Qibla* Azimuth + 180
- If *Qibla* direction from South to West; So, Azimuth Angle = *Qibla* Azimuth - 180
- If *Qibla* direction from North to West; So, Azimuth Angle = 360 - *Qibla* Azimuth

Third, determine the direction of the sun. In principle, the sun's path is almost identical to the *Qibla* direction. Only the variables used are the sun's declination and time angle data. Solar declination data can be obtained from several almanacs, such as data on the ephemeris reckoning of the Ministry of Religion of the Republic of Indonesia or nautical almanacs. In addition, declination data can also be determined using the Jean Meuss approach or the VSOP98 method. The following approximation formula can obtain the solar time angle (t),

t = Abs (LMT[14] + e – (BT^d - BT^x) : 15 – 12) x 15; BT means East Longitude

t = Abs (LMT + e + (BB^d – BB^x) : 15 – 12) x 15; BB means West Longitude

The timing angle is negative if the shot time is before the pass and positive if the shoot time is after the receipt. The time angle value is between 0 and 90 degrees. The sun's declination value (δm) and time angle (t) are used as variables together with latitude (ϕx) in the following sun direction formula:

Cotan A = tan δ^m cos ϕ^x : sin t : - sin ϕ^x : tan t

If the direction of the sun is positive, the sun is in the north. Conversely, if the sun's movement is negative, the sun is in the south. This value of the sun's path becomes a reference for determining the sun's azimuth.

Fourth, determine the azimuth of the sun. Similar to the azimuth of the *Qibla*, the azimuth of the sun is also categorized by direction.

a. If A = North-East (+), then AzM = A. Northeast in question is that the measurement is taken before the particular time', i.e., in the morning, and the sun's declination is positive, i.e., when the sun is north of the location.
b. If A = South-East (-), then AzM = A + 180 . what is meant by southeast is that the measurement is carried out before the special time, i.e., in the morning, and the sun's declination is negative, i.e., when the sun is south of the location.

[14] Local Mean Time

c. If A = South-West (-), then AzM = 180 - A. What is meant by southwest is that the measurement is made after the special time, i.e., in the afternoon, and the sun's declination is negative, i.e., when the sun is south of the location.

d. If A = North-West (+), then AzM = 360 - A. What is meant by northwest is that the measurement is made after the special time, i.e., in the afternoon, and the sun's declination is positive, i.e., when the sun is north of the location.

Fifth, determine the value of the azimuth difference (BA) by subtracting the *Qibla* azimuth value from the sun's azimuth value. If the value of the azimuth difference is negative, it must be increased by 360. In general, when determining the value of the azimuth difference with the free shooting time, the value of the azimuth difference is up to the accuracy of arcseconds. However, with Slamet Hambali's formula, this azimuth difference can be determined by yourself with a rounded value without decimals so that there is no excess of minutes and seconds of arc. So, after finding the azimuth difference obtained from the previous calculation, the next step is to determine the desired new azimuth difference, namely the azimuth difference with a value close to the last difference azimuth value. The new azimuth difference in question is the azimuth difference with a rounded value close to the value of the previous azimuth difference. In the author's view, two kinds of azimuth difference values can be applied for convenience in measuring the *Qibla* direction; the first is the azimuth difference value without excess minutes and arc seconds. The second is the value of the azimuth difference with an excess of half a degree or 30 (thirty) arc minutes.

Sixth, determine the sun's azimuth from the value of the new azimuth difference by subtracting the *Qibla* azimuth from the azimuth difference. If the result is negative, then add 360 degrees so that the effect becomes positive. The results of this solar azimuth need to be categorized in terms of positive or negative notation. If the sun's azimuth is between 90 -180 or 270 - 360 while the latitude of the place is negative (south latitude), the sun's azimuth is given a negative sign (-). If the sun's azimuth is between 0-90 or 180-270 degrees while the latitude of the place is positive (North space), the solar azimuth is given a negative sign. Apart from these categories, the solar azimuth value is considered positive.[15]

[15] Ana Nur Afifah, *Studi Analisis Rumus Menghitung Beda Azimut Kiblat Dan Azimut Matahari Karya Slamet Hambali*, Semarang:UIN Walisongo, 2019, 44

Seventh, Determine the aiming hour according to the desired azimuth difference, namely the round value without excess minutes and arc seconds. In determining this shooting hour, it requires at least the following four equations,

Cotan P = tan AzM sin ϕx

cos (t-p) = cos p tan δ : tan ϕx

t = (t-p) + p

Time = 12 + t: 15 – e + (BTd[16] - BTx):15 or 12 + t : 15 – e – (BBd[17] – BTx):15

With information, "P" is the process angle, "t-p" is the different angle, "t" is the time angle, "BT" is east longitude, and "BB" is west longitude. The results of this viewfinder hour value are in decimal form and can be converted into hours, minutes, and seconds. To ensure the results of this clock's appearance, it is necessary to determine the azimuth difference value based on the latest clock. The trick is to recalculate the difference in azimuth using the first to fifth steps so that it is known whether the value of the difference in azimuth is the same as what is desired, namely spherical material without excess minutes and seconds of arc.[18]

C.5 *Qibla* Direction Deviation[19]

To determine the accuracy of the *Qibla* using the effective azimuth difference method, you can use an indicator of how much deviation the *Qibla* direction is from the Kaaba. The farther the specified location is, the greater the deviation value of the *Qibla* direction. In Indonesia, in general, the deviation of the *Qibla* direction of one degree can deviate by 110 km from the Kaaba.

The first thing that must do in determining the *Qibla* deviation value at a location is the value of the distance from the location to the Kaaba. The distance from the location to the Kaaba, considering the earth's radius, is worth 6378.388 km. In addition, it also feels the difference in longitude between the location and the Kaaba. The equation passed is as follows,

E = BT – BK

M = acos (sin LT x sin LK + cos LT x cos LK x cos E)

KM = M / 360 x 6,283185307 x 6378,388

[16] City's East Longitude

[17] City's West Longitude

[18] Ana Nur Afifah, *Studi Analisis Rumus ...* 44

[19] Anisah Budiwati, *Fiqih Hisab Arah Kiblat: Kajian Pemikiran Khafid dalam Software Mawaqit*, UNISIA, (Yogyakarta:UII, 2014), 107

This equation measures the distance from the location to the Kaaba in kilometers.

After knowing the distance from the location to the Kaaba, we can determine the *Qibla* deviation value. The purpose of determining the *Qibla* deviation is to determine the accuracy of *Qibla* calculation with various methods and how much the variation of the *Qibla* direction value from the Kaaba is. The interpretation of the *Qibla* direction can be calculated using the following equation,

P = KM/sin((180-S)/2) x sin S where "S" is the *Qibla* deviation value in degrees. For example, looking for a deviation of 1 degree from the Kaaba, how many kilometers away, the value of S is 1. If you are looking for variations in arc minutes, you must divide by 60 because 1 degree equals 60 minutes. Similarly, seconds of the arc must be separated by 3600 because 1 degree = 60 minutes of arc, 1 minute of arc = 60 seconds, and 1 degree = 3600 seconds of arc.

a. The Difference in Azimuth without Excess Minutes and Seconds of Arc

The following is the calculation data for the azimuth difference on March 18, 2021, with the coordinates of latitude 6°59' South Latitude and longitude 110°36' East Longitude. 14.00 hrs. The solar declination data and the time equation were obtained from the low-accuracy Jean Meuss method calculation. The resulting data are as follows,

Qibla Direction	:	65° 32' 30.9"
Qibla Azimuth	:	294° 27' 29.1"
Sun Direction	:	81° 04' 54.3"
Sun Azimuth	:	278° 55' 05.7"
Azimuth Difference	:	15° 32' 23.4"
New Azimuth Angel	:	16° 00' 00.0"
Time	:	14: 05: 26.8 Local Time

The data shows that the *Qibla* azimuth is 294° 27' 29.1" and the sun's azimuth is 278° 55' 05.7". In contrast, the value of the difference in azimuth is 15° 32' 23.4", which is obtained by subtracting the azimuth of the *Qibla* from the azimuth of the sun. The value of the azimuth difference still has the advantage of minutes and seconds with a relatively large number. Then determine the rounded value of the azimuth difference, which is close to the previous value.

In this case, the value of 16 degrees is determined, which is then processed with the stages of the process angle to produce a new shooting clock, namely 14: 05: 26.8 local time.

It is then reviewed from the new clock, whether it produces the desired value, by calculating the azimuth difference based on the new watch. The resulting azimuth difference value is 15° 59' 51.2". This value is quite close to the expected value of 16 degrees. If calculated, the difference between the two is only 8.8 arc seconds. According to the author, this value is so small that it doesn't affect the *Qibla* direction. It is known that the distance between the location and the Kaaba is 8342.368895 km. With this distance, it can see that the *Qibla* direction deviation value of 8.8 arc seconds is 0.356112524 km or about 356 meters from the Kaaba.

b. The difference between azimuth and half-degree excess

The following is the calculation data for the azimuth difference on March 18, 2021, with the coordinates of latitude 6°59' South Latitude and longitude 110°36' East Longitude. The solar declination data and the time equation were obtained from the low-accuracy Jean Meuss method calculation. The resulting data are as follows.

Qibla Direction	:	65° 32' 30.9"
Qibla Azimuth	:	294° 27' 29.1"
Sun Direction	:	80° 25' 02.6"
Sun Azimuth	:	279° 34' 57.4"
Azimuth Difference	:	14° 52' 31.7"
New Azimuth	:	15° 30' 00.0"
Time	:	14: 07: 09.2 Local Time

The data above shows that the *Qibla* azimuth is 294° 27' 29.1" and the sun's azimuth is 278° 55' 05.7". In comparison, the value of the difference in azimuth is 14° 52' 31.7", which is obtained by subtracting the azimuth of the *Qibla* from the azimuth of the sun. The value of the azimuth difference still has the advantage of minutes and seconds with a relatively large number. Then determine the rounded value of the azimuth difference, which is close to the previous value. In this case, the value of 15 degrees 30 minutes of arc is determined, which is then processed with the process angle stages to produce a new shooting clock, namely 14: 07: 09.2 Local Time.

It is then reviewed from the new clock, whether it produces the desired value, by calculating the azimuth difference based on the new watch. The resulting azimuth difference value is 15° 29' 48.6". This value is quite close to the expected value of 15 degrees 30 arc minutes. If calculated, the difference between the two is only 11.4 arc seconds. According to the author, this value is so small that it doesn't affect the *Qibla* direction. It is known that the distance between the location and the Kaaba is 8342.368895 km. With this distance, it can see that the *Qibla* direction deviation value of 8.8 arc seconds is 0.459684315 km or about 459 meters from the Kaaba.

D. Conclusion

From the explanation above, the writer draws two conclusions. First, the concept of the effective azimuth difference formula by Slamet Hambali recalculates the aiming hour by entering the desired azimuth difference input. The expected azimuth difference is a rounded value of degrees or degrees with an excess of half a degree. The primary step is to calculate the process angle to find a new clock with a rounded azimuth difference value. With this azimuth difference value, it can be easier to determine the *Qibla* direction using classical instruments such as *istiwā'ayni* and another option for measuring the *Qibla* direction.

Second, the application of this formula is not only to find the value of the azimuth difference without excess minutes and seconds of arc but can be used to find the value of degrees with an excess of half a degree or 30 arc minutes to find the adequate azimuth difference. The results are still accurate; although there is a difference between the desired azimuth difference value and the azimuth difference resulting from the formula, the difference is minimal. When applied to deviations from the Kaaba, this difference is only in the range of 300 to 400 meters. This value is still within the reasonable limits of the *Qibla* deviation.

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