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VSAT Pointing Parameter Calculation Programming with Trigonometry Principles Using NEO6M GPS Module as Coordinate Detection Using C++ Programming Language

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Abstract – *Very Small Aperture Terminal or VSAT is a type of telecommunications technology that uses satellites as a transmission medium. In the VSAT installation process there is a process called pointing, which is the process of directing the VSAT vertically and horizontally in the direction of the target satellite. This is very important to do to get good signal quality, so that the service output from the VSAT is good. The position of the VSAT device on earth, while the satellite is in outer space, creates complexity in the pointing process. The parameters to pay attention to when pointing are the azimuth value, namely the direction formed horizontally between the VSAT device and the point 0 degrees north of the earth, as well as the elevation value, namely the angle formed vertically between the VSAT device and the satellite towards the 0 degree point in the horizon plane. To obtain the azimuth and elevation parameters, previous scientists had written them in a mathematical formula with complex trigonometry elements. By using quantitative methods, this journal summarizes the programming of these formulas using the C++ language. This is useful in the future to determine the suitability of calculation results and can be developed further by direct integration into VSAT devices. This research also uses the NEO6M GPS module which can provide coordinate information because it is needed in calculating the formulation. The results of this research are that C++ can be used to program complex trigonometric mathematical calculations and the accuracy of the programmed parameters can be adjusted according to the type of data used. In conclusion, the C++ language can be used to carry out VSAT pointing parameter calculation programs in collaboration with GPS sensor readings with appropriate results.*

Keywords – *Azimuth; Elevation, Global Positioning System (GPS); Pointing; VSAT.*

I. Introduction

VERY Small Aperture Terminal or VSAT is a type of telecommunications technology that uses satellites as a transmission media [1]. VSAT is a radio frequency transceiver device that has a parabolic antenna [2], VSAT can serve several communication needs including data, voice, image, video and broadcast communications [3]. In the implementation process, VSAT only requires stable electricity and open space. Because of this convenience, VSAT is widely used in Indonesia, where many areas are still not covered by telecommunications networks due to the construction of terrestrial network infrastructure that has not yet reached these areas. The type of VSAT that is widely used is VSAT which uses satellites orbiting in GEO (Geostationary Earth Orbit), this is because the revolution time of the GEO orbit has the same time as the Earth's rotation time. So there is no need for regular pointing.

When installing VSAT, there is an important process, namely pointing. Pointing is the process of directing a VSAT to a satellite. The parameters to pay attention to when pointing are azimuth and elevation. Azimuth is the direction formed horizontally to the point 0 degrees north of the earth, while elevation is the angle formed vertically between the direction of the VSAT to the satellite and the 0 degrees horizon plane [4]. The suitability of azimuth and elevation angles significantly impacts satellite signal reception quality and VSAT service output. Proper antenna positioning through azimuth and elevation angle adjustments is crucial for accurate satellite orbit detection and signal stability [5]. VSAT networks enable two-way internet access and can be deployed globally [6]. Satellite attitude parameters, including pointing accuracy and stability, affect

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image quality in high-resolution telescopes [7]. Tilt and azimuth angles influence photovoltaic system energy production, with optimal positioning essential for maximizing output [8]. Ka-band satellite communications face challenges from rain attenuation, particularly in tropical regions, necessitating accurate prediction models [9]. Neural network models can predict optimal tilt and azimuth angles for solar panels worldwide [10]. Propagation models and adaptive data rate methods can optimize indoor access point placement [11].

Recent research on VSAT and satellite communication systems has focused on improving pointing accuracy and automation. Studies have explored automatic detection systems for satellite orbit positioning using azimuth and elevation angle control [5], and the impact of auto-tracking systems on antenna pointing accuracy [12]. Affordable programmed satellite pointing systems have been developed for propagation experiments [13], while queue theory has been applied to cross-polarization processes in antenna installation [14]. Performance analyses have been conducted for satellite communication systems with randomly located ground users [15] and for free-space optical communications over turbulence channels with pointing errors [16]. The need for automated operations in large distributed satellite systems has been identified [17], and the development of VSAT networks for various applications, including two-way Internet access, has been reviewed [18].

This journal discusses how to convert these mathematical formulas so that they can be programmed computationally using the C++ programming language in the Arduino IDE software [19]. Apart from that, this journal will also discuss the results of detecting location coordinates in the form of longitude and latitude by the NEO6M GPS module, the results of which will be used in the programming. This program is only a conversion of calculations into a computing system, in fact, in the pointing process you have to look at the signal parameters received by the VSAT as the main validation of the feasibility of pointing. By using this pointing model, users do not need to integrate an RF detector device on the VSAT. You only need to look at the signal reception level parameters while pointing. So this program can be used on all types of VSAT GEO.

II. Research Methods

The research methodology carried out in this research uses a quantitative approach, where the author will create a program and conduct trials on several predetermined subjects. The results of the trials are mathematical and can be calculated. The author uses an Arduino Mega 2560 microcontroller, which employs the ATMega 2560 IC as the main processor [20].

To obtain azimuth and elevation parameters, calculations can be performed using the following equations:

i. Azimuth Calculation

$$A' = \arctan\left(\frac{\tan(\phi_v + \phi_s)}{\sin(\theta_v)}\right) \tag{1}$$

Where: ϕ_v = VSAT longitude, ϕ_s = Satellite longitude, and θ_v = VSAT latitude.

The value of A' in this calculation must always be positive. In addition, the latitude position of the VSAT device relative to the equator and the longitude of the satellite coordinates need to be considered [21].

1. VSAT at the north of the equator
   (a) VSAT at the west of the satellite: $A = 180 - A'$
   (b) VSAT at the east of the satellite: $A = 180 + A'$
2. VSAT at the south of the equator
   (a) VSAT at the west of the satellite: $A = A'$
   (b) VSAT at the east of the satellite: $A = 360 - A'$

When programming, note that all variable values must be in radians. Therefore, it is necessary to convert the values of VSAT longitude, VSAT latitude, and satellite longitude from degrees to radians. This conversion is obtained through the following equation:

$$x^\circ \cdot \frac{\pi}{180} = y\,(\text{rad}) \tag{2}$$

One logic that can be used to validate azimuth calculations is as follows:

1. If the satellite longitude is greater than the VSAT longitude, the azimuth direction will be between 0° and 180°.
2. If the satellite longitude is smaller than the VSAT longitude, the azimuth direction will be between 181° and 359°.

ii. Elevation Calculation

$$E = \arctan\left(\frac{\cos\theta_v \cdot \cos(\phi_v - \phi_s) - 0.151}{\sqrt{1 - (\cos\theta_v \cdot \cos(\phi_v - \phi_s))^2}}\right) \tag{3}$$

Where: ϕ_v = VSAT longitude, ϕ_s = Satellite longitude, and θ_v = VSAT latitude.

Likewise, for elevation calculations, the variables used must first be converted into radians:

$$x^\circ \cdot \frac{\pi}{180} = y\,(\text{rad}) \tag{4}$$

The logic for interpreting the elevation results is that the closer the values between the satellite longitude and the VSAT longitude, the greater the elevation value will be, and vice versa.

iii. GPS Detection

Data for VSAT longitude and latitude is obtained via the installed GPS sensor. This component is mandatory because if one or both of these variables are missing, errors may occur, or the data cannot be processed at all. GPS detection in this research uses the NEO6M V2 GPS module with an IC QMC5883L, which employs a patch antenna with a sensitivity of 161 dBm and can perform satellite tracking for up to 22 satellites with 50 channels [22]. In order for the research to proceed according to plan, a clear workflow is required. The workflow can be seen in the following flowchart:

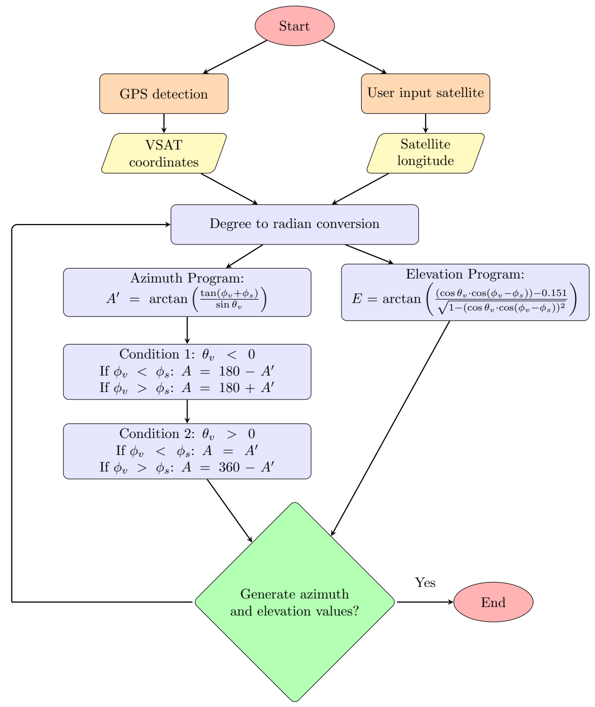

Figure 1: Research Flowchart

III. Results and Discussion

The results part of the research is conducting trials and interpreting the results of these trials. In this research, the trials carried out were broadly divided into two:

i. GPS Detection Test

Tests were carried out with the NEO6M V2 GPS module as a test subject to determine the results of the resulting coordinate detection. To be able to carry out detection, the program is run as follows:

```
while(serial_gps.available()) {
 gps.encode(serial_gps.read());
}
if(gps.location.isUpdated()) {
 Serial.println(gps.location.lat(),6);
 Serial.println(gps.location.lng(),6);
 delay(1000);
}
```

The result of testing:

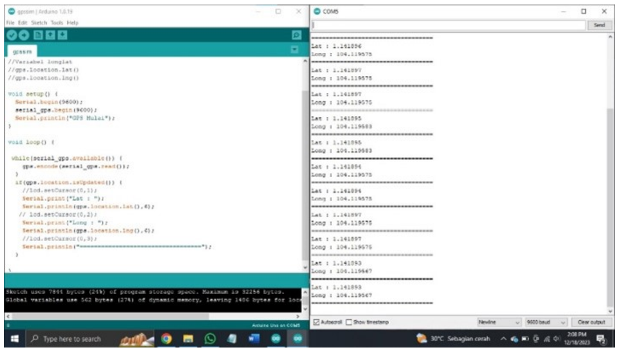

Figure 2: Result of GPS Detection

Testing was also carried out in two conditions, namely indoors and outdoors. This test was carried out to determine the antenna's performance in optimally detecting under what conditions. The following results were obtained:

Table 1: GPS Detection Test Condition

Condition	Detect Time	Result
Indoor		
Sunny	>10 minutes	Not detected
Rainy	>10 minutes	Not detected
Outdoor		
Sunny	1 – 5 minutes	Detected
Rainy	1 – 5 minutes	Detected

The actual placement of the GPS module is indeed outdoors and will be much more optimal in open outdoor conditions rather than inside a building. So the roof/wall will not block the module during the satellite tracking process.

ii. Calculation Programming Test

The trial was carried out by integrating the results of GPS detection, which were then programmed using coding formed from the formula described in the methodology section. To carry out the calculation program, each part of the formula must be derived first and cannot be directly combined in one command. The following program was run for the calculations Azimuth and Elevation:

```
float a = (gps.location.lng() - (longsat));
a = a*(3.14/180);
a = tan(a);
```

```
float b = gps.location.lat();
b = b*(3.14/180);
b = sin(b);

float c = a/b;
c = atan(c);
c = c*(180/3.14);

if (c < 1){
 c = c*(-1);
}

//========VSAT at north========
if (gps.location.lat() > 0){
 if (gps.location.lng() < longsat){
  azimuth = 180 - c;
 }
}
if (gps.location.lat() > 0){
 if (gps.location.lng() > longsat){
  azimuth = 180 + c;
 }
}

//========VSAT at south========
if (gps.location.lat() < 0){
 if (gps.location.lng() < longsat){
  azimuth = c;
 }
}
if (gps.location.lat() < 0){
 if (gps.location.lng() > longsat){
  azimuth = 360 - c;
 }
}
```

The program was tested at two locations, namely locations with coordinates north and south of the equator. This difference affects the latitude value, where locations south of the equator have negative latitude values. The results are as follows:

Table 2: Azimuth Calculation Result

Coordinate	Satellite	Result
Lat : 1.14183°N, Long : 104.11960°E	64° N	268.69°
	146° N	91.23°
Lat : -6.200176°S, Long : 107.012908°E	64° N	276.56°
	146° N	82.44°

```
float l = gps.location.lat()*3.14/180;
float L = (gps.location.lng() - longsat);
L = L*3.14/180;

float b = cos(l);
float c = cos(L);

float x = b*c;
float xa = x - 0.151;
float xb = sqrt(1-sq(x));
float z = xa/xb;
z = atan(z);
elevasi = z*(180/3.14);
```

Elevation testing was only carried out at one location, and the following are the results of the elevation calculation program:

Table 3: Elevation Calculation Result

Coordinate	Satellite	Result
Lat : -6.200176°S, Long : 107.012908°E	64° N	40.03°
	108° N	82.65°
	128° N	64.46°
	146° N	44.45°

The results of the trials show that using the C++ programming language, users can perform arithmetic and trigonometric operations with appropriate commands. The calculation results can be directly compared with other applications that use Python, Java, etc. Additionally, the sensor detection results can also be used as part of the ongoing calculation program.

The potential for further development in this research is to optimize the GPS sensor used, ensuring that it can detect location coordinates quickly and accurately. One of the challenges encountered in this research was the GPS sensor occasionally failing, so it is crucial to ensure the GPS is functioning properly before running the calculation program.

IV. Conclusion

The C++ language as a high-level programming language can be used to program arithmetic and trigonometry operations. In this case the implementation is used to create an auto pointing program for VSAT devices. VSAT, which is a telecommunications technology that uses satellite transmission media, certainly has its own challenges in the network development process. One of them is the pointing process which must be appropriate in order to get good signal quality. This program may be further developed to create a VSAT pointing control project or prototype that does not need to use an RF detector so that it can be applied to all types of VSAT GEO devices. The results of this calculation are of course not completely valid, once again it is necessary to look at the results of the signal reception level on the satellite modem to ensure the suitability of the pointing. If using this calculation, it is recommended to add a program for additional manual pointing that is integrated with the motorized device to drive the VSAT.

REFERENCES

[1] B. O. Ekengwu, P. C. Eze, C. N. Asiegbu, S. C. Olisa, and C. F. Udechukwu, "Satellite dish antenna control for distributed mobile telemedicine nodes," *International Journal of Informatics and Communication Technology (IJ-ICT)*, vol. 11, no. 3, p. 206, Dec. 2022. [Online]. Available: https://doi.org/10.11591/ijict.v11i3.pp206-217

[2] J. Seema, S. Rakshanda, and A. Jyoti, "Chhatrapati shivaji maharaj college of engineering, nepti," http://www.practical-home-theater-.

[3] H. Ramonyaga, N. Tjahjamooniarsih, F. W. T. Pontia, J. T. Elektro, and P. T. Elektro, "Analisis performansi very small aperature terminal (vsat) pengiriman data cuaca penerbangan menggunakan computer message switching system (cmss)."

[4] F. Hidayat, J. Wahyudi, and Z. Kurniawati, "Rancangan simulasi auto pointing untuk antena vsat berbasis mikrokontroler," https://journal.ppicurug.ac.id/index.php/snvp, Desember.

[5] B. Herdiana and D. Gunawan, "Automatic Detection System Satellite Orbit Position with a Method of Control Azimuth and Elevation Angles Parabolic Antenna," *Journal of Robotics and Control (JRC)*, vol. 2, no. 6, 2021. [Online]. Available: https://doi.org/10.18196/26131

[6] J. Wilk-Jakubowski, "A review on information systems engineering using vsat networks and their development directions," *Yugoslav journal of operations research*, 2020. [Online]. Available: https://doi.org/10.2298/yjor200215015w

[7] Walid A. Wahballah, F. Eltohamy, and Taher M. Bazan, "Influence of Attitude Parameters on Image Quality of Very High-Resolution Satellite Telescopes," *IEEE Transactions on Aerospace and Electronic Systems*, 2021. [Online]. Available: https://doi.org/10.1109/TAES.2020.3042629

[8] M. Božiková, Matúš Bilčík, Vladimír Madola, T. Szabóová, Ľ. Kubík, J. Lendelová, and V. Cviklovič, "The Effect of Azimuth and Tilt Angle Changes on the Energy Balance of Photovoltaic System Installed in the Southern Slovakia Region," *Applied Sciences*, 2021. [Online]. Available: https://doi.org/10.3390/app11198998

[9] P. M. Kalaivaanan, A. Sali, R. R. Raja Abdullah, S. Yaakob, Mandeep Jit Singh, and A. Al-Saegh, "Evaluation of Ka-Band Rain Attenuation for Satellite Communication in Tropical Regions Through a Measurement of Multiple Antenna Sizes," *IEEE Access*, 2020. [Online]. Available: https://doi.org/10.1109/ACCESS.2020.2966873

[10] Ramez Abdallah, E. Natsheh, A. Juaidi, Sufyan Samara, and F. Manzano-Agugliaro, "A Multi-Level World Comprehensive Neural Network Model for Maximum Annual Solar Irradiation on a Flat Surface," *Energies*, 2020. [Online]. Available: https://doi.org/10.3390/en13236422

[11] F. S. Mukti, P. Dani, D. Arman, V. Sihombing, N. Rahanra, K. Yuliawan, and J. Simatupang, "Integrating Cost-231 Multiwall Propagation and Adaptive Data Rate Method for Access Point Placement Recommendation," *International Journal of Advanced Computer Science and Applications*, vol. 12, no. 4, 2021. [Online]. Available: https://doi.org/10.14569/IJACSA.2021.0120494

[12] S. Bekkar Djelloul Saiah, E. Bensikaddour, A. Kaddouri, R. Belbachir, B. Nasri, and D. E. Baba Hamed, "Analysis of the communication links between the AlSat1b satellite and the ground station: The impact of the Auto Tracking system on antenna pointing accuracy," *International Journal of Satellite Communications and Networking*, vol. 39, no. 5, pp. 486–499, feb 20 2021. [Online]. Available: https://doi.org/10.1002/sat.1396

[13] A. Rocha, S. Mota, L. Cupido, and F. Jorge, "Affordable Programmed Satellite Pointing System for Propagation Experiments," *IEEE Transactions on Instrumentation and Measurement*, vol. 69, no. 6, pp. 2743–2751, 6 2020. [Online]. Available: https://doi.org/10.1109/TIM.2019.2925245

[14] R. Mubarak, S. Budiyanto, P. Wulandari, F. Rahayu, A. Adriansyah, and M. Alaydrus, "A queue theory in the cross-polarization of antenna in satellite communication," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 22, no. 2, p. 884, may 1 2021. [Online]. Available: https://doi.org/10.11591/IJEECS.V22.I2.PP884-892

[15] D.-H. Na, K.-H. Park, Y.-C. Ko, and M.-S. Alouini, "Performance Analysis of Satellite Communication Systems With Randomly Located Ground Users," *IEEE Transactions on Wireless Communications*, vol. 21, no. 1, pp. 621–634, 1 2022. [Online]. Available: https://doi.org/10.1109/TWC.2021.3098540

[16] O. S. Badarneh, R. Derbas, F. S. Almehmadi, F. El Bouanani, and S. Muhaidat, "Performance Analysis of FSO Communications Over F Turbulence Channels With Pointing Errors," *IEEE Communications Letters*, vol. 25, no. 3, pp. 926–930, 3 2021. [Online]. Available: https://doi.org/10.1109/LCOMM.2020.3042489

[17] M. K. Ben-Larbi, K. Flores Pozo, T. Haylok, M. Choi, B. Grzesik, A. Haas, D. Krupke, H. Konstanski, V. Schaus, S. P. Fekete, C. Schurig, and E. Stoll, "Towards the automated operations of large distributed satellite systems. Part 1: Review and paradigm shifts," *Advances in Space Research*, vol. 67, no. 11, pp. 3598–3619, 6 2021. [Online]. Available: https://doi.org/10.1016/j.asr.2020.08.009

[18] J. Wilk-Jakubowski, "A review on information systems engineering using vsat networks and their development directions," *Yugoslav Journal of Operations Research*, vol. 31, no. 3, pp. 409–428, 2021. [Online]. Available: https://doi.org/10.2298/yjor200215015w

[19] M. Fezari and A. A. Dahoud, "Integrated development environment 'ide' for arduino: Introduction to arduino ide," https://www.researchgate.net/publication/328615543, 2018.

[20] M. Yusro, M. Ma'sum, M. Muhamad, and A. Jaenul, "Pengembangan trainer aplikasi multi-sensors (tams) berbasis arduino dan raspberry pi," *Risenologi*, vol. 6, no. 1, pp. 77–85, Apr. 2021. [Online]. Available: https://doi.org/10.47028/j.risenologi.2021.61.150

[21] M. C. Rafael, J. B. Gonçalves, P. P. L. do Prado, and R. Daniel, "Development of an automated system for maneuvering parabolic dish antennas used in satellite communication," 2012.

[22] F. Firdaus and I. Ismail, "Komparasi akurasi global posistion system (gps) receiver u-blox neo-6m dan u-blox neo-m8n pada navigasi quadcopter," *European Journal of Immunology*, vol. 12, pp. 12–15, 2020. [Online]. Available: https://api.semanticscholar.org/CorpusID:218916523