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Evaluation on the performance of single and dual frequency low cost GPS module observation using geodetic antenna

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Abstract

GPS modules have been used for various applications in recent years. Its early development came in parallel with the advancement of Unmanned Aerial Vehicle (UAV) technology. Nowadays, it is also used in in geographic information system (GIS) data acquisition/census, mapping surveys, structure stability monitoring systems and many other applications. GPS modules generally have several positioning features, including standard positioning service (SPS), static positioning, precise point positioning (PPP), post processing kinematic (PPK) and real time kinematic (RTK) GPS. GPS modules in general are only equipped with a microstrip-type antenna or better known as patch antenna. Results from related research show that GPS module with this type of antenna has sub meter accuracy when used for PPK or RTK GPS method. The use of geodetic antennas is very potential to increase GPS position accuracy by up to centimeter level. This paper discusses the evaluation of GPS module measurements with geodetic type antennas for precise positioning using RTK GPS. This paper is focused on the resolution of GPS cycle ambiguity that is often expressed by the term fixing ratio and the accuracy of measurement results obtained. To provide a comprehensive description of the performance of GPS module, in this research two types of GPS module were used; single and dual frequency. Both types of GPS modules were used to conduct simultaneous observation on an open and obstructed observation location.

Keywords: GPS module; PPK, RTK; precise positioning

1. Introduction

The use of GPS modules is increasing in parallel with the increasing need for positioning with reliable accuracy in affordable price. GPS module manufacturers offer products at relatively competitive low prices with attractive features for Its users. Ublox, Skytraq, Emlid, Piksi and Tersus are some of the manufacturers that are becoming widely known by GPS module users in Indonesia. The price of GPS modules varies in the range of 25 USD to 3,500 USD, according to the specifications and features provided.

GPS modules with a price range of 25-60 USD are generally equipped with single frequency sensors and provide only simple features. Positioning system provided in GPS module of this type is usually only in standard positioning service (SPS) or better known as absolute positioning, with accuracy ranging from 3-15 meters. GPS modules of this type are generally used for UAV and USV navigation guides. One of the example of GPS module for UAV / USV navigation guide module is Ublox NEO-6M.

GPS modules with better positioning features such as post processing kinematic GPS, DGPS or RTK GPS have a wider application because they offer better accuracy. This GPS module is available on the market starting at a price of 60 USD. This GPS module is available on the market in several choices, single frequency, dual frequency and multi satellite (including other positioning satellite i.e Glonass, Beidou, QZSS, etc. Example of a GPS module with RTK positioning feature is Skytraq S2525F8-GL-RTK.

Technically, positioning using PPK and RTK will produce position with centimeter level accuracy. This accuracy has been proven can be achieved using geodetic type receivers. Based on research results related to positioning with GPS module, the general accuracy is obtained at the sub meter level, with the measurement solution dominated by float solution although the measurement is done in relatively open place. One of the key factors that leads to those results is the antenna used during observation. Unlike geodetic receivers, GPS modules are generally sold with a built-in microstrip antenna or typically known as patch antenna. This type of antenna (Fig. 1) has a fairly good gain characteristic where signals are uniformly distributed throughout the observation point but very susceptible to bias and errors [1]. Most patch antenna gain is approximately at 30dB with 1-1.5dB of noise.

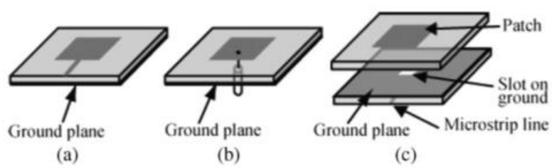

Fig. 1. Several types of microstrip antenna; (a) stripline, (b) coaxial feed and (c) aperture-coupled [1]

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Antenna is one of the important factors affecting the quality of GPS positioning in general and the positioning of PPK and RTK in particular. This paper aims to evaluate the use of geodetic antennas for observation using GPS modules using PPK and RTK methods. The GPS modules used for this research consist of two types, single frequency and dual frequency. The use of two types of GPS modules combined with a geodetic antenna is expected to give an overview of the GPS module's performance when used for measurement. In relation to the implementation of the GPS observation, it has to be underlined that previous research related to this work is entirely carried out in open areas. In this study the measurements are carried out both in open areas and obstructed areas of the building to get a better description of GPS module performance.

Utilization GPS module for precise positioning has been developed for almost 1 decade. In 2009, Takasu and Yasuda published RTKLIB program packages [2]. This program can be used to conduct measurements using GPS modules using various precise positioning methods such as static post processing, kinematic post processing as well as real time kinematic GPS [3]. It supports data communications over serial data communication protocol I / O, TCP / IP and NTRIP, using various data correction formats including RTCM 2.3, RTCM 3.1 [4]. The phase ambiguity resolution method used by RTKLIB is Modified Least square AMbiguity Decorrelation Adjustment (MLAMBDA) based on the Least square AMbiguity Decorrelation Adjustment (LAMBDA) method [5]. The first version of RTKLIB was released on January 31, 2009 while the latest version is version 2.4.3 which was released March 31, 2015.

The first experiments by Takasu and Yasuda [1] was conducted by using GPS module Ublox LEI 4T (Fig. 2) and NovAtel GPS-702-GG geodetic antenna (Fig. 3), controlled by BeagleBoard mini computer running Linux OS with ARM Cortex-A8 processor (speed 600MHz). The solution of the positioning obtained from the experiments in general is in centimeter for fixed solution and decimeter for float solution. Fixing ratio of the observation is up to 56.4% in open sky observation area.

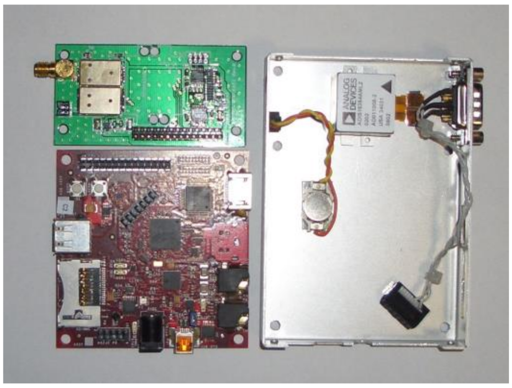

Fig. 2. Low cost RTK positioning developed by Takasu and Yasuda [1]

The RTKLib program has been utilized in the development of precise positioning using GPS modules from several manufacturers with varying specifications. Grieneisen [6] examines the utilization of GPS RTK technology for positioning on small aircraft (micro aerial vehicle). The GPS module used is Ublox LEI 6T with ANN-MS antenna (Fig. 4) which is the default antenna patch of the GPS module. The method used is RTK by using two different base; EUREF (European CORS network) and local base station with data transmission using radio modem. The result of this experiment is dominated by float solution and the accuracy is up to 0.7m (using EUREF) and 0.8m (using local base station).

Fig. 3. NovAtel GPS-702-GG Anntena

Fig. 4. Ublox ANN-MS antenna

RTK positioning using GPS module has also been applied for precise geotagging. The RTKlib source code has been developed into an android app Geotagging + which allows the coordinates of RTK positioning results to be embedded into photo metadata [7][8]. Atunggal et al. comparing geotagging by using built-in GPS chipset on smartphone with geotagging using external GPS module integrated with smartphone. Result from this experiment shows that geotagging using external RTK GPS module integrated with smartphone produce better photo position.

In addition to RTK GPS, RTKLIB usage for precise positioning using precise point positioning (PPP) method has also been reviewed by Wiśniewski et al [9]. In this research, the result of GPS measurement of Ublox LEI 6T module with ANN-MS antenna was processed using PPP method on RTKLib and compared with PPP data from ASG-EUPOS Poland. The accuracy gained in this research is still in the range of 1-2m for open sky observation location.

Evaluation on the accuracy of RTK GPS measurement using GPS module using modified patch antenna has also been conducted by Atunggal et al [10]. The antenna used for the experiment was a patch antenna covered with ground plane. Result of the experiment shows that the use of ground plane can amplify the GPS signal captured by the antenna but not significantly reduce the bias and errors.

Based on all of the aforementioned research related to positioning using GPS module, it is obvious that result from Takasu and Yasuda is better than any other research result. This is due to the use of geodetic antenna for the experiment while other research was conducted by using patch antenna. The use of geodetic antenna hold an important factor in achieving fixed solution.

2. Materials and Methods

The research was conducted by executing and reviewing the measurement of GPS module by using geodetic antenna. GPS module used consists of 1 unit of GPS single frequency module and 1 unit of GPS dual frequency module. The use of 2 types of GPS modules is intended to compare the GPS module performance on two different observation location; open sky view area and obstructed area. The hypothesis is that the use of GPS double frequency module and geodetic antenna will have better fixing ratio and accuracy than single frequency GPS module with a geodetic antenna, especially if used in obstructed area.

2.1. Materials and Equipments

Materials and equipments used for this research are as follow:

a. 1 unit single frequency GPS module, Ublox Neo M8T
b. 1 unit dual frequency GPS module, Tersus BX305
c. 1 unit single frequency geodetic antenna, Jinchang JCA228
d. 1 unit dual frequency geodetic antenna, Tersus AX3702
e. 1 unit Android 6.0 smartphone with 2GHz processor and 3GB memory
f. 1 unit personal computer
g. Android application Geotagging+, Lefebure NTRIP Client and Mobile Topographer
h. RTKLib for PC version 2.4.3
i. U-center software for Windows
j. Tersus Geomatics Office software
k. 2G/3G/4G SIM card

2.2. Work Flow

Work flow of the research is presented in Fig. 5.

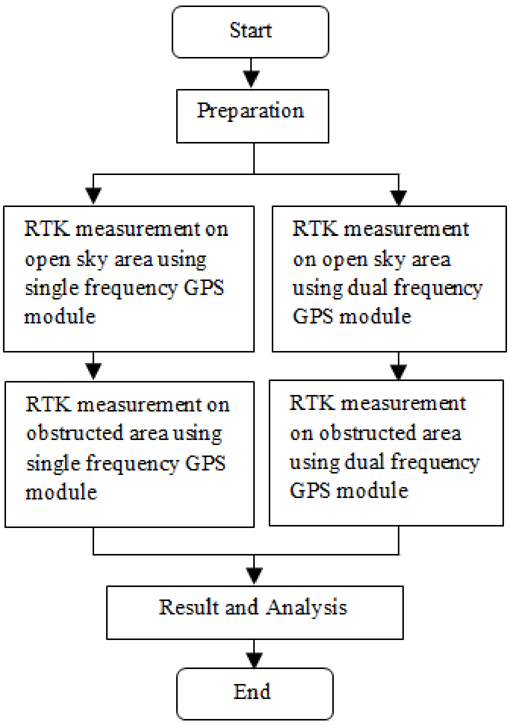

Fig. 5. Research workflow

Experiment on this research is preceded by preparing materials and equipments. The single frequency GPS module (Ublox Neo M8T) is paired with Jinchang JCA228 (Fig. 6). According to the datasheet, this antenna has 40±2dB gain and the noise is less than ≤1.5dB. Setting for this receiver was done by using U-center software. The antenna used for the double frequency GPS module (Tersus BX305) was Tersus AX3702 (Fig. 7). This antenna has 40±2dB gain and ≤2dB noise. Setting for this receiver was done by using Tersus Geomatics Office. In addition to the equipment preparation, a survey to select suitable location for the experiment has also been conducted.

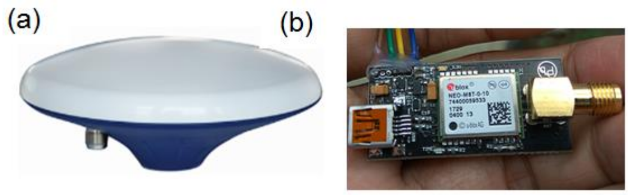

Fig. 6. Single frequency equipments used in the experiment; (a) antenna Jinchang JCA228, (b) receiver Ublox M8T receiver

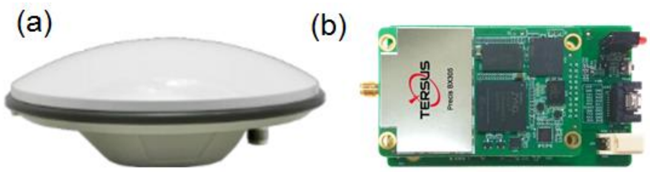

Fig. 7. Dual frequency equipments used in the experiment; (a) antenna Tersus AX3702, (b) receiver Tersus BX305

The experiment was done in the Campus of Universitas Gadjah Mada (UGM). The open sky experiment was done on zero order national pillar N0005 located on the west side of UGM University Club Building (Fig. 8) while the obstructed experiment was done on mapping bench mark (BM) on the north side of Geodetic Engineering Department (Fig. 9).

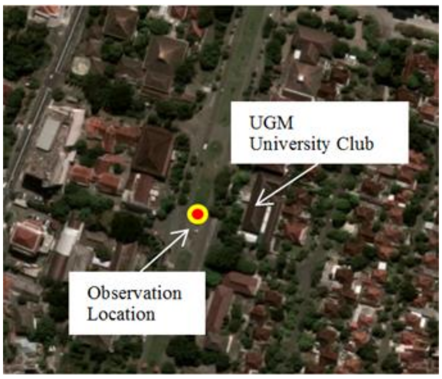

Fig. 8. Location of the open sky experiment

Single frequency GPS module measurements are executed with Android smartphones using Geotagging+ applications while GPS dual frequency module measurements are conducted using Lefebure NTRIP Client and Mobile Topographer applications. Both of the receiver used in the experiment was powered up by using standard USB power bank. Example of complete set of equipments used for the experiment is shown in Fig. 10.

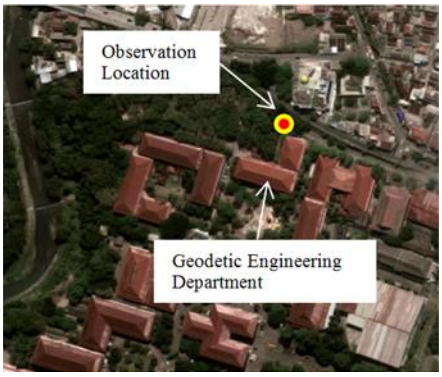

Fig. 9. Location of the obstructed experiment

Fig. 10. Equipments used in the experiment

Measurements for each observation location (open sky area and obstructed area) were executed simultaneously using single frequency GPS module and dual frequency GPS module. The duration of the observation is approximately one hour. To ensure that ambiguity resolution from those two receivers use the same algorithm, both of the measurement was stored into the memory of the Android smartphone and then processed using RTKPost program from the RTKLib program package. Result of RTK positioning from RTKPost is then evaluated by focusing on the success rate of getting fixed RTK solution or often called fixing ratio, along with the accuracy of the measurement.

3. Results and Discussion

Measurements using single frequency and dual frequency GPS modules have been conducted in the study area. In general, measurements using dual frequency GPS module produce better fixing ratio and accuracy than single frequency GPS module.

3.1. Result of Single Frequency and Dual Frequency GPS Modules Observations on Open Sky Area

The results of single frequency GPS module measurement in open sky area are presented in Table 1. In open sky area the fixing ratio value is 68.2% with Root Mean Square Error (RMSE) of 0.04356m, 0.06451m and 0.12539m for the Easting (E-W), Northing (N-S) and Up (U-D) component as presented in Table 1. The plot of the RTK solution of horizontal position components can be seen in Fig. 11.

Table 1. Statistic of single frequency observation on open sky area

Fixing Ratio	RMSE		
	E-W (m)	N - S (m)	U - D (m)
68.20%	0.04356	0.06451	0.12539

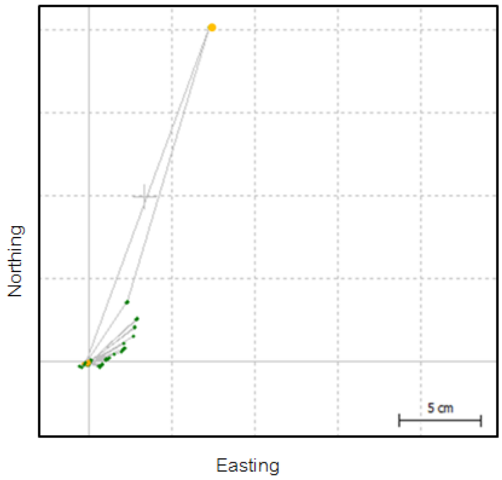

Fig. 11. Plot of the RTK horizontal position components from single frequency GPS module observation on open sky area

The results of dual frequency GPS module measurement in open sky area are presented in Table 2. In open sky area the fixing ratio value is 81% with RMSE of 0.04356m, 0.03087m, 0.03624m and 0.07225m for the Easting (E-W), Northing (N-S) and Up (U-D) component as presented in Table 2. The plot of the RTK solution of horizontal position components can be seen in Fig. 12.

Table 2. Statistic of single frequency observation on open sky area

Fixing Ratio	RMSE		
	E-W (m)	N - S (m)	U - D (m)
81.00%	0.03087	0.03624	0.07225

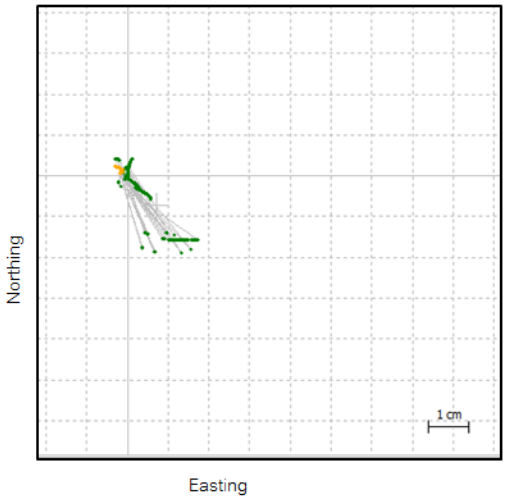

Fig. 12. Plot of the RTK horizontal position components from dual frequency GPS module observation on open sky area

From the results presented in Figs. 11 and 12, it can be seen that dual frequency GPS module has better fixing ratio and RMSE than single frequency GPS module. Measurement from single frequency GPS module produced some float solutions where position precision were at the decimeter level. This solution refers to RTK solution at the beginning of the observation where the phase ambiguity resolution is still based on very few data and the solution was not convergent. Measurement from dual frequency GPS module also produced some float solutions, but the accuracy of its position is still in centimeter level. This shows that the linear combination from the dual frequency data produce better RTK solution.

3.2. Result of Single Frequency and Dual Frequency GPS Modules Observations on Obstructed Area

The results of single frequency GPS module measurement in obstructed area are presented in Table 3. In obstructed area the fixing ratio value is 0% with RMSE of 0.28723m, 0.06229m and 0.30661 for the Easting (E-W), Northing (N-S) and Up (U-D) component as presented in Table 3. The plot of the RTK solution of horizontal position components can be seen in Fig.13.

Table 3. Statistic of single frequency observation on obstructed area

Fixing Ratio	RMSE		
	E-W (m)	N - S (m)	U - D (m)
0%	0.28723	0.06229	0.30661

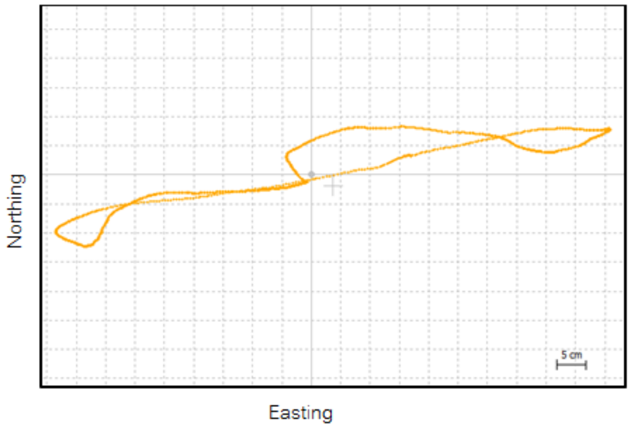

Fig. 13. Plot of the RTK horizontal position components from single frequency GPS module observation on obstructed area

The results of dual frequency GPS module measurement in obstructed area are presented in Table 4. In obstructed area the fixing ratio value is 72.8% with RMSE of 0.06928m, 0.03931m and 0.13978m for the Easting (E-W), Northing (N-S) and Up (U-D) component as presented in Table 4. The plot of the RTK solution of horizontal position components can be seen in Fig. 14.

Table 4. Statistic of dual frequency observation on obstructed area

Fixing Ratio	RMSE of Fixed Solutions		
	E-W (m)	N - S (m)	U - D (m)
72.80%	0.06928	0.03931	0.13978

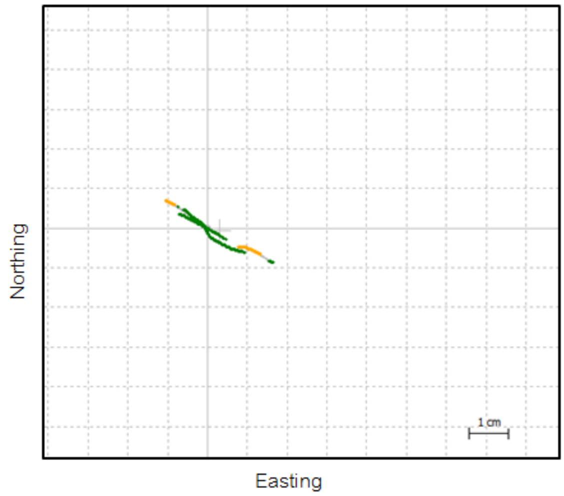

Fig. 14. Plot of the RTK horizontal position components from single frequency GPS module observation on obstructed area

From the results presented in Table 3 and Fig. 13, it can be seen that in obstructed area, the performance of single frequency GPS module is still far from optimal. This can be seen from the RTK solutions that are entirely float and measurement precision only at the decimeter level. At the same location, dual frequency GPS module has a much better performance. Dual frequency GPS module produce better fixing ratio and the measurement accuracy is at centimeter level. The use of linear combination of data from L1 and L2 is proven in supporting phase ambiguity resolution.

4. Conclusion

From the results of the experiment in this research, it can be concluded that RTK measurement using single frequency GPS module and geodetic antenna produce a good fixing ratio and accuracy on open sky area. On obstructed area, the performance of single frequency GPS module is far from optimal where solution tends to be float and the accuracy is in decimeter level. RTK measurement using dual frequency GPS module produce better fixing ratio and accuracy on both study areas. The fixing ratio is above 70% and the accuracy is in centimeter level. Therefore, the performance of a dual frequency GPS module with geodetic antenna proved to be better than single frequency GPS module with geodetic antenna.

It has to be underlined that the results analyzed in this paper is only for the horizontal position of the RTK solution. Further investigation to study the vertical component of coordinates from RTK measurements not to be done in the future.

References

1. K.F. Lee and K.F. Tong, *Microstrip patch antennas - basic characteristics and some recent advances*, Proceeding of the IEEE. 100 (2012) 2169-2180.
2. T. Takasu and A. Yasuda, *Development of the low-cost RTK-GPS receiver with an open source program package RTKLIB, International Symposium on GPS/GNSS, International Convention Center Jeju, Korea, 2009, pp. 4-6.*

3. T. Takasu, *RTKLIB: open source program package for RTK-GPS, FOSS4G 2009, Tokyo, Japan, 2009.*
4. Y. Heo, T. Yan, S. Lim and C. Rizos, *International standard GNSS real-time data formats and protocols, IGNSS Symposium, Queensland, Australia, 2009.*
5. X.W. Chang, X. Yang and T. Zhou, *MLAMBDA: a modified LAMBDA method for integer least-squares estimation,* Journal of Geodesy. 79 (2005) 01-22.
6. Grieneisen, D., *Real time kinematic GPS for micro aerial vehicle*, Semester Thesis, SwissFederal Institute of Technology, Swiss, 2012.
7. D. Atunggal, N.A. Ausi, B. Ma'ruf and C.A. Rokhmana, *Pembuatan aplikasi android geotagging+ untuk geotagging teliti: aplikasi geotagging dan modul GPS RTK terintegrasi untuk akuisisi data GIS, sensus dan pendataan lainnya, FIT ISI 2017, Riau, Indonesia, 2017.*
8. Peyréga, M., *Link to functionnal dev tree and APK for 2.4.3b26 with lapack, https://github.com/eltorio/RtkGps/issues/11, 2017*.
9. B. Wiśniewski, K. Bruniecki, M. Moszyński, *Evaluation of RTKLIB's positioning accuracy using low-cost GNSS receiver and ASG-EUPOS*, The International Journal on Marine Navigation and Safety of Sea Transportation. 7 (2011) 79-85.
10. Atunggal, D., Basith, A., Rokhmana, C. A., Pratiwi, D. M. *Studi awal penggunaan modul GPS murah untuk pengukuran RTK NTRIP, FIT ISI 2015, Malang, Indonesia, 2015.*