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Modern topographic devices and electromagnetic waves: impact on accuracy of measurements

Léopold Degbegnon, Médard C.J. De Souza

University of Abomey-Calavi
01 BP 526 Cotonou, Bénin

Abstract. Precision topographic work is done by the means of classical instruments such as high-precision levels, theodolites and distance-meters. This method gives accuracy results of ±2 mm in altimetry and better than ±5 mm in planimetry, but it requires a lot of expenditures and a long time of execution and more staff. Nowadays, the constellation of the GNSS satellite positioning system and the improvements to electronic tachymeters can provide solutions to gaps in auscultation using conventional measurements. However, these methods also present their weaknesses, resulting by this way from their uses under the high voltage lines. The study of the influence of electromagnetic waves on high-voltage lines on topographic devices allows observations made with a GNSS receiver to be made from an electronic station or total station or with the aid of optical-mechanical theodolite to analyse and interpret the quality of the data obtained on the ground in the Maria Gléta zones in the municipality of Abomey-Calavi and Araromi in the municipality of Sakété. This makes it possible to present the effects of high voltage cables on these measurements and the determinations made in topometry. Very important on measurements at the GNSS receiver and at the total station, the actions of the electromagnetic waves evolve with the variation of the temperature.

Keywords: GNSS receiver, electromagnetic waves, satellite positioning

Introduction

Since the 1950s, the evolution of technology has led to the creation of Electronic Distance Measurement Devices, also known as Instrument of Electronic Measurement of Lengths (IMEL) and electronic tachymeters called total stations. The latter make possible to measure both the distances and the angles, whereas previously the measurement of distances was done by the means of graduated ribbons. The advent of these instruments revolutionized geomatics in general and in a particular way, topometry. It set the way for the introduction of information technology in this field, which is now invested by information and communication technologies [1].

Thus, digital systems such as motorized electronic tachometers and sometimes remote controlled and satellite tracking and positioning are nowadays increasingly used by surveyors-topographers. High voltage lines are suspected of generating electromagnetic waves with adverse effects on the proper functioning of these devices. These adverse effects are caused by the magnetic field they produced. Indeed, the connection of different cable sections or a cable to electronic devices is tricky. For this reason, the general objective of this study is to check and show that the electromagnetic waves affect the topometric electronic devices and their action taints error measurements.

Specifically, we:

— identify the type of error;
— determine the value of the error;
— interpret the results by identifying the precautions to be taken.

After a general overview of the high-voltage power lines of Maria Gléta and Araromi, where the measurements have taken place, this study will exhibit the characteristics of the instruments and methods used to get to the results and their interpretation.

Framework

In the framework of the supply of electric power, the Electricity Community of Benin (CEB), an inter-state institution between Benin and Togo, has set up electrical installations. Some of these installations produce energy while others relay the energy produced by another power plant or purchased from energy producing countries such as Ghana, Nigeria and Côte d'Ivoire. The energy produced in this way is transported by high-voltage (HV) lines to the CEB facilities from which it is supplied to the Benin Electric Power Company (Societe Beninoise d' Energie Electrique — SBEE), whose main function is the distribution of electrical energy in Benin household. These high-voltage power lines generate a corridor named the public domain of HV lines, whose 52 meters right-of-way is set up so as to protect populations from radiation that may come directly from the waves created by electromagnetic fields.

Figure 1. HV line transporting the energy of the Maria Gléta power plant

Source: Agbessi Allen K. Marc.

Indeed, high-voltage electrical installations emit electromagnetic waves from which they generate electric and magnetic fields in a given perimeter. For that reason, living under or near a high-voltage power line can constitute a serious health hazard for residents (figure 1): this is confirmed by the epidemiological study carried out on 60,000 children by Gérald Draper, research director at Oxford University, from 1997 to 2001, and made available to the public in 2005, finding that the risk of leukaemia is 69% higher than the average if one lives within 200 meters from a high voltage line and 23% higher if the distance is between 200 and 600 meters. However, urbanization, one of the consequences of population growth, has now included high-tension lines in urban centers or in the areas undergoing an urbanization process. This is the case of the Benin localities of Maria Gléta where there is a power station and Araromi in the municipality of Sakété where facilities relay the electric power supplied by Nigeria. The power line “Vèdoko — Maria Gléta” in Abomey-Calavi on a distance of about 3 km 100 m from the crossroads Gbègnigan to Maria Gléta and the “Araromi — Ilaje — West” power line to Araromi on a linear line about 1 km 200 m were the subject of this study on the effects of lines on topographic devices. Maria Gléta is a power station located in the municipality of Abomey-Calavi, located in the north-western part of Cotonou, the economic capital of Benin. Araromi is a locality of Sakété municipality, located more in the eastern and northern part of Porto-Novo town, the political capital of Benin. The choice of these two different lines located in various departments was carried out in order to compare the results.

Materials

The present study of the influence of electromagnetic waves of high voltage cables on topographic devices has evaluated the accuracy of the measurements made from various topometric instruments by determining the difference between the different results obtained from the following equipments that was used.

GNSS CHC X 91 receiver. The GNSS receiver is a device that uses satellite signals from American Global positioning systems GPS and Russia GLONASS to calculate its position in X, Y and Z coordinates in the World Geodesic System WGS 84. As for topographic measurements, it operates in couple made of a base and a mobile receiver attached to a radio communicating rod. Figure 2 shows the CHC X91 GNSS receiver that was used to perform the scaling points.

The cost of GPS positioning is closely related to the technique used, which in turn depends primarily on the level of accuracy required. The two main variables that influence costs for the same technique are the time required for each location and the cost of the necessary receivers. As a general rule, the shorter the period of observation required at each point, the less costly the survey will be [2].

Electronic Tachometer (Total Station) LEICA TS06. The electronic tachometer, also called total station as shown in figure 3, consists of an electronic theodolite and a coaxial distance meter. It measures angles and distances using a precision laser beam. A total station is also equipped with computers and memories useful for executing programs, for recording the measurements and for determining the coordinates of the points detected. It works with a reflector to measure distances and can take a reading in less than 5 seconds while measuring a distance of several kilometers.

WILD T2 optico-mechanical theodolite. The theodolite is an instrument for measuring angles and indirect distance measurement consisting essentially of three concurrent axes and two goniometers simply called circles, one of which is horizontal and the other vertical and serves to measure the vertical angles.

Thermometer. The thermometer is the instrument used to measure ambient temperature during operations.

Figure 2. Base and radio as well as the mobile of the receiver GNSS CHC X 91

Source: Adomahou Serge.

Figure 3. Surveying with the total station LEICA TS06

Source: Adomahou Serge.

Processes and methods

1. Setting up of a polygonal canvas constituted of 55 vertices (sealed points) at Abomey-Calavi and 44 points at Sakété.

2. Repeated measurements in planimetry and altimetry with the different devices while raising the ambient temperature and operating time.

3. Numerical processing of data and calculation of deviations.

4. Account of facts or significant actions occurred in the course of operations.

5. Drafting of the daily reports of the work carried out.

The methods used for these measurements are:

— with the GNSS receiver, the real-time kinematic mode;

— with the total station, the radiation with reference collected each time on the previous point;

— with the optico-mechanical theodolite, the procedure with the double-turning method.

The Real Time Kinematic (RTK) mode is the most interesting mode for the automation of construction sites. Indeed, it permits to obtain precisions of the order of a few centimeters on the position at a quite sufficient rate [3].

A total station is an electronic theodolite coupled to an IMEL and having a system for recording and/or transferring information. Whereas the "optico-mechanical" theodolite brings together all "mechanical" reading devices by vernier graduated in comparison with "optico-electronic" devices, also called stations, which are read on a digital display and which often incorporate an electronic distance measuring device. The angle measurement by double turning is a manipulation consisting of a simultaneous half-turn of the bezel and the alidade. This technique of measurement makes it possible to eliminate certain systematic errors and to limit the errors of reading [4].

Results and discussion

Curves of the deviations from 0 between the planimetric coordinates obtained with the different devices.

Histograms of the means of the deviations in X and Y obtained with the data of the devices taken two by two.

The variations in the deviations obtained in figures 1, 2, 3 and 4 show that the closer we get to the power plant, the more the deviations observed on the data from the GNSS receiver and the total station increase. As a result, the influence of HV electrical lines on electronic devices intensify as the power plant approaches.

However, figures 5 and 6 showing the histogram of the average on X and Y deviations of the devices taken in pairs demonstrate that the deviation observed on the x-axes is higher than the ones of the y-axes. We then deduce that the electromagnetic loads of HV electric cables influence the x-axe more than the y-axe.

Tables 1 and 2 show that on both sites the amplitudes of the x-axe and y-axe deviations between the GNSS receiver and the total station are higher than those between the total station and the theodolite, which are in fact higher than those GNSS and theodolite. We therefore deduce that the coordinates obtained in X and Y with the total station are less precise than those provided by the GNSS receiver, which are also less precise than those obtained from the surveys of the theodolite.

The amplitudes of the x-axes or y-axes are more important in Abomey-Calavi than in Sakété. This could be explained by the value of the intensity of the electromagnetic field created at this HV line.

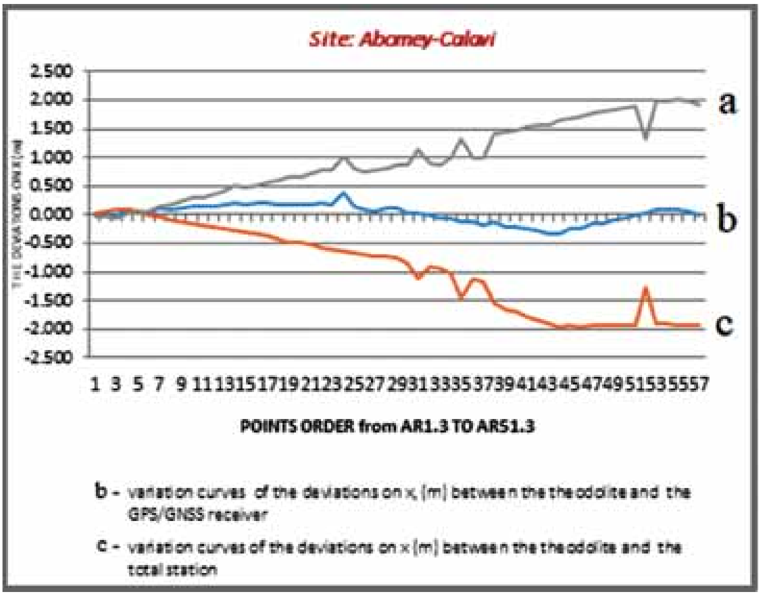

Figure 4. Variation of the abscissas between the coordinates obtained by reading with the devices taken two by two on the first site located at Maria Gléta (municipality of Abomey-Calavi)

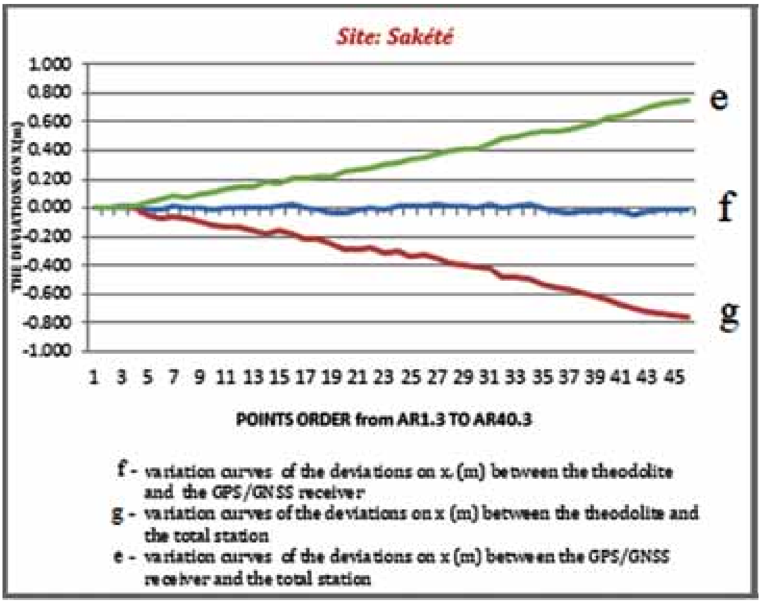

Figure 5. Variation of the abscissa between the coordinates obtained by reading with the devices taken two by two on the second site located at Araromi (Sakété municipality)

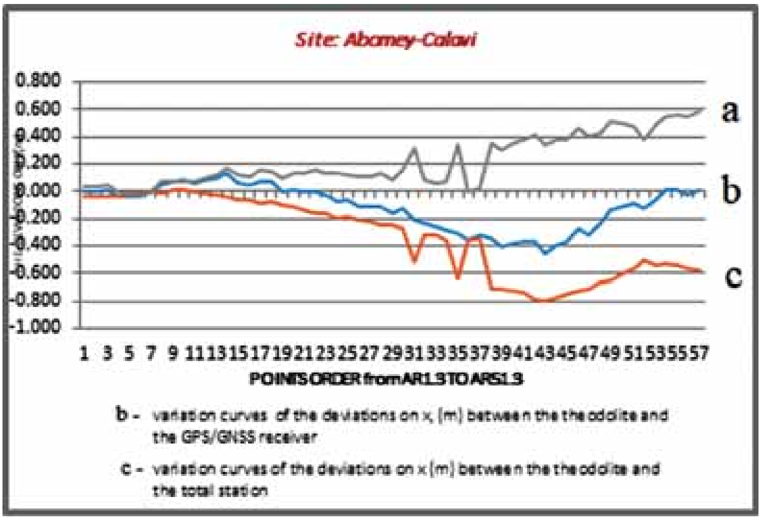

Figure 6. Variation of the deviations on the ordinate between the coordinates obtained by reading with the apparatus taken two by two on the first site located at Maria Gléta (Abomey-Calavi municipality)

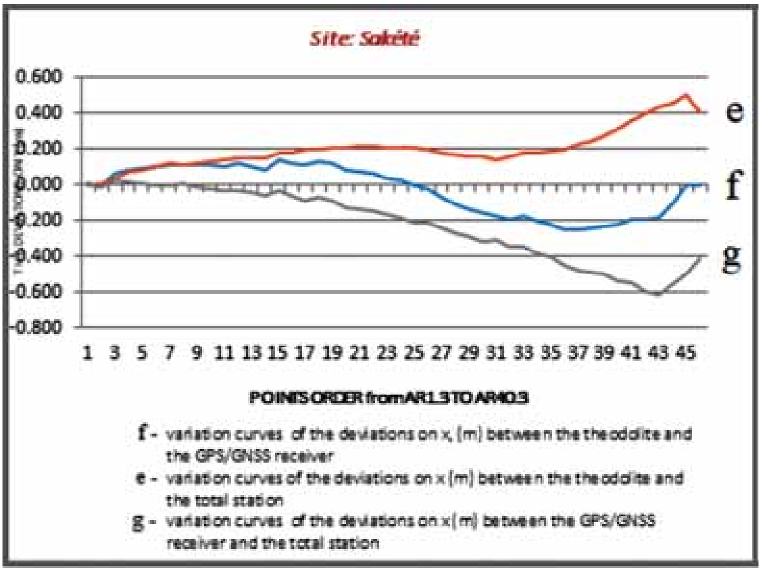

Figure 7. Variation of the deviations on the ordinate between the coordinates obtained by reading with the apparatus taken two by two on the second site located at Araromi (Sakété municipality)

Table 1

Extrema and amplitudes of the deviations in terms of coordinates obtained from the two by two compared devices on the first site of Maria Gléta at Abomey-Calavi

Site	Abomey-Calavi					
Devices	GNSS-Theo*		ST-Theo		GNSS-ST	
Coordinates	X	Y	X	Y	X	Y
Variation of the deviation (m)	–0.348 to 0.381	–0.460 to 0.125	–1.928 to 0.084	–0.799 to 0.005	0.019 to 2.008	–0.025 to 0.586
Amplitude(m)	**0.729**	**0.585**	**2.012**	**0.804**	**1.989**	**0.611**

* *Theo:* theodolite.

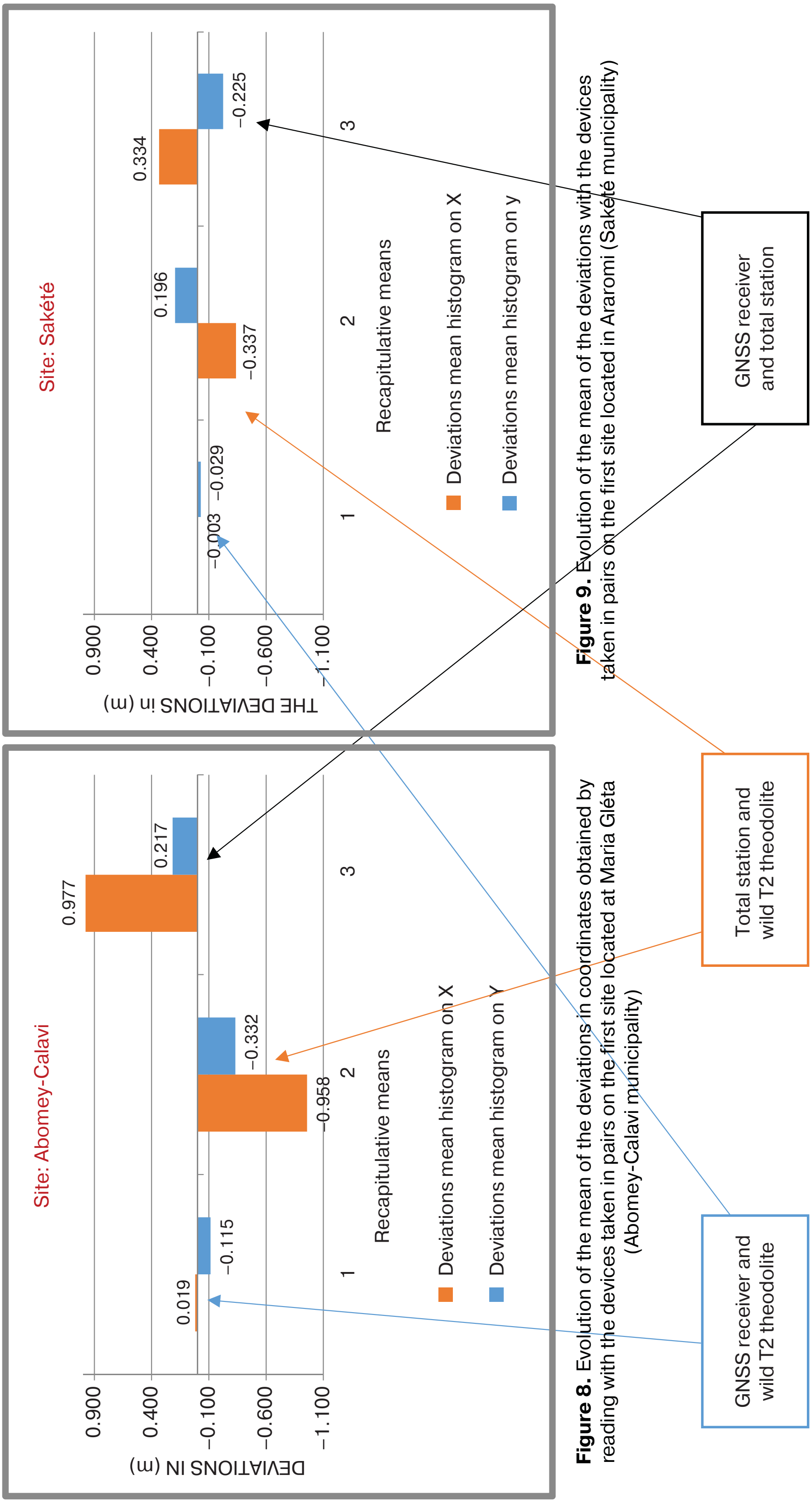

Figure 9. Evolution of the mean of the deviations with the devices taken in pairs on the first site located in Araromi (Sakété municipality)

Figure 8. Evolution of the mean of the deviations in coordinates obtained by reading with the devices taken in pairs on the first site located at Maria Gléta (Abomey-Calavi municipality)

Table 2

Extrema and amplitudes of the deviations in terms of coordinates obtained from the two by two compared devices on the second site Araromi site at Sakété

Site	Sakété					
Devices	GNSS-Theo		ST-Theo		GNSS-ST	
Coordinates	X	Y	X	Y	X	Y
Variation of deviations (m)	–0.765 to 0.006	–0.253 to 0.141	–0.765 to 0.006	–0.001 to 0.497	–0.002 to 0.753	–0.612 to 0.026
Amplitude(m)	**0.771**	**0.394**	**0.771**	**0.498**	**0.755**	**0.638**

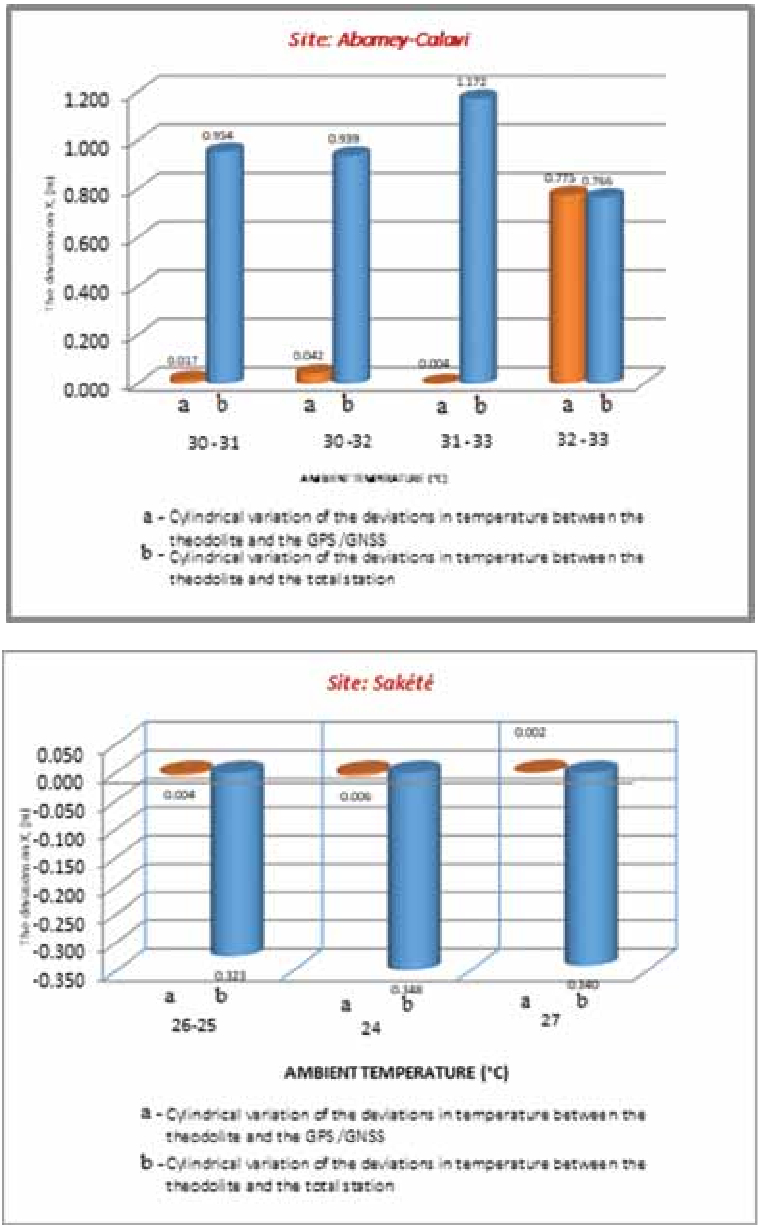

Figure 10. Variations of the mean of the deviations of the tests on X according to the temperature

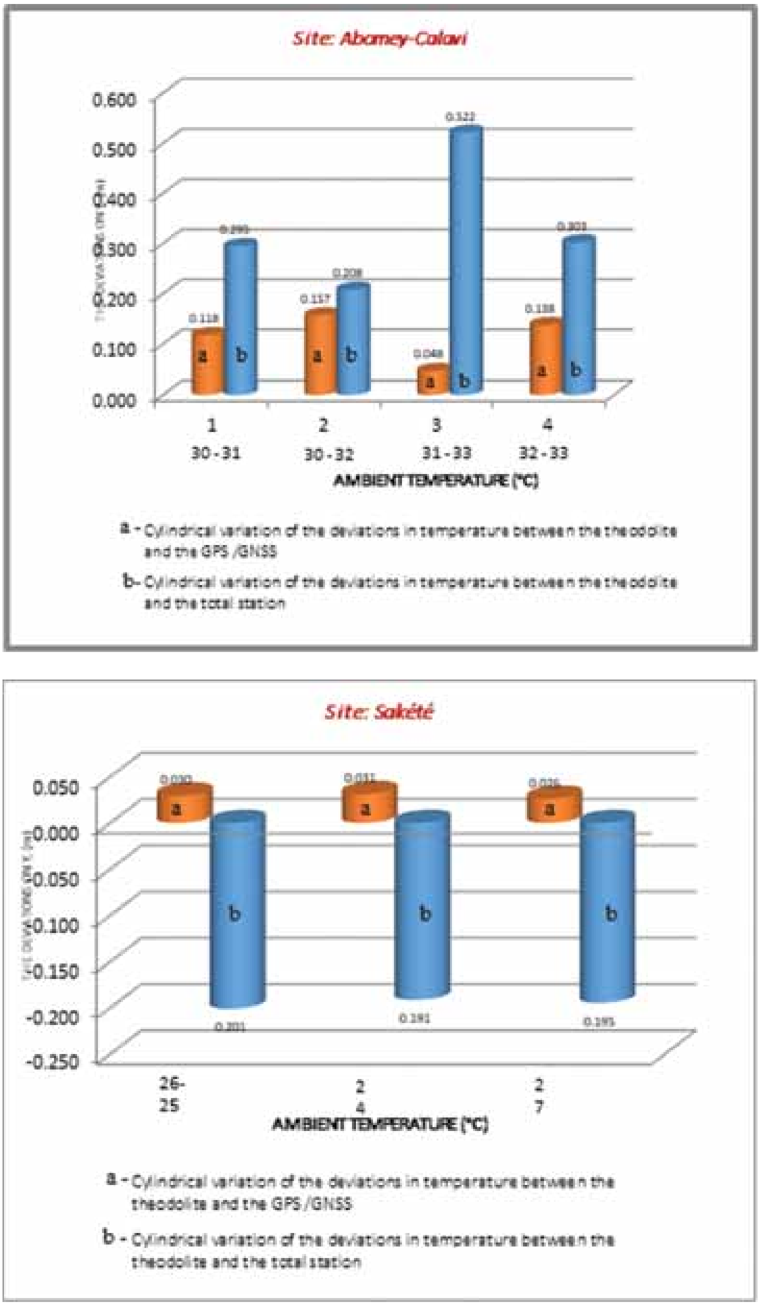

Figure 11. Variations of the mean of the deviation of the tests on Y according to the temperature

The figure 10 on one hand and 11 on the other hand present on X and Y of the deviations of the various tests on the GNSS receiver and the total station according to the temperature compared to the results obtained with the theodolite. Thus, under the same temperature conditions, the difference obtained with the coordinates resulting from the total station is much greater than the one observed with the coordinates generated by the GNSS receiver. This means that the measurements made with the total station under the HV lines are less accurate than those obtained with the GNSS receiver because the electromagnetic waves considerably influence the total station. Then for large-scale works requiring a limited time of execution, the GNSS receiver could be used at a temperature below 27 °C. In addition, the more we set stations with the electronic tachometer, the greater the gap is.

It is therefore clear that the electromagnetic waves of high-voltage power lines affect the accuracy of measurements made with topographical devices such as the GNSS receiver and the total station. Then the most suitable device for work under the high voltage lines is the optical-mechanical theodolite because it does not produce an electromagnetic field that could interfere with the one of the cables in such a way that the deviation on the measurements carried out with it is minimal. Of course, GNSS can be used by choosing the suitable moment.

Conclusion

The advent of modern devices brings more precision and speed in the execution of topographical works [5]. However, the use of these electronic devices is conditioned by the environment. This is the result of given study on the influence of electromagnetic waves of high-voltage cables on topographical devices. Thus, the use of devices such as GNSS receivers and the electronic tachometer in an environment where electromagnetic waves are important should be discouraged for precision work. In case of exceptional circumstances, the GNSS receiver can be used at times when the ambient temperature is less than 27 ° C to lessen this influence and to reduce the resulting errors.

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Bio Notes:
Léopold Degbegnon — Doctor-Engineer in Geodesy, Department of Civil Engineering of Abomey-Calavi Polytechnic, Abomey-Calavi University, Benin. *Research interests*: electromagnetic waves, satellite positioning. *Contact information*: e-mail: leopolddegbegnon@yahoo.fr

Médard C.J. De Souza — Geometer Engineer, Department of Civil Engineering of Abomey-Calavi Polytechnic, Abomey-Calavi University, Benin. *Research interests*: electromagnetic waves, satellite positioning. *Contact information*: e-mail: meldjulio@gmail.com

Научная статья

Влияние электромагнитных волн на точность измерений современных топографических устройств

Л. Дегбегнон, М.С.Ж. Де Соуза

Университет Абомей-Калави, Бенин
01 BP 526 Cotonou, Bénin

Точные топографические работы выполняются посредством таких классических инструментов, как высокоточный уровень, угломер и дальномер. С их помощью можно получить результаты с точностью до ±2 мм при измерении высот (альтиметрии) и до ±5 при измерении площадей (планиметрии). Но этот способ является затратным с точки зрения финансов, времени и количества персонала. Сегодня система спутниковой навигации ГНСС совместно с усовершенствованными моделями электронных тахиметров может решить проблему устранения пробелов при измерении территорий стандартными методами. Тем не менее и данные методы не являются совершенными, имея сбои в работе при использовании под высоковольтными сетями. Изучение влияния электромагнитных волн высоковольтных линий на топографические устройства позволяет проводить наблюдения при помощи спутникового приемника (GNSS-приемник) и электростанции, общей станции (total station) или при помощи оптико-механического теодолита с целью интерпретации и анализа качества данных, полученных на земле в зонах Мария Глета (Maria Gléta) муниципалитета Абомей-Калави (Abomey-Calavi) и Арароми (Araromi) муниципалитета Сакете (Sakété). В результате можно определить степень влияния высоковольтных кабелей на качество выполняемых в топометрии измерений. При проведении измерений GNSS-приемником и общей станцией (total station) важно учитывать, что активность электромагнитных волн зависит от изменения температур.

Ключевые слова: GNSS-приемник, электромагнитные волны, спутниковая навигация

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Сведения об авторах:
Дегбенон Леопольд — кандидат технических наук, профессор кафедры гражданского строительства, Университет Абомей-Калави (Бенин). *Область научных интересов*: электромагнитные волны, спутниковая навигация. *Контактная информация*: e-mail: leopolddegbegnon@yahoo.fr

Де Суза Медард С.Ж. — инженер-геодезист кафедры гражданского строительства, Университет Абомей-Калави (Бенин). *Область научных интересов*: электромагнитные волны, спутниковая навигация. *Контактная информация*: e-mail: meldjulio@gmail.com