New Compact Method for Laboratory Testing EDM Instruments

Ragab KHALIL, Egypt

Key words: EDM; total station; Accuracy verification; laboratory calibration, unit length.

SUMMARY

Routine check of EDM instruments is increasingly important. Finding of a suitable testing area, legal access to such areas, time of carrying out the instruments and the costs of permanent installation are problems facing the field calibration. The limited space is main problem facing the laboratory testing of EDM instruments. Some researchers stated that distances between 5 and 100 meters should be measured to test the EDM, so some reflectors have to be mounted outside the laboratory which causes a big change in the atmospheric conditions along the measured distance.

This paper presents a new compact, laboratory method for verification of the accuracy of distance measuring using EDM and total station. This new method complies with the stringent space of the laboratories and no need to mount reflectors outside the laboratory. The mathematical model of this method has been developed and tested theoretically and practically and it gave promising results. The precision of the new method was the same as that of the standard method.

ملخص:

إن المعايرة الدورية للأجهزة المساحية أمرا فى غاية الأهمية لضمان دقة القياسات والحصول على أفضل النتائج أثناء تنفيذ الأعمال. وهناك عقبات رئيسية تواجه عملية المعايرة الحقلية كصعوبة الحصول على منطقة اختبارات مناسبة وشرعية دخول مثل هذه المناطق والوقت المستهلك فى نقل الأجهزة إلى مناطق الاختبار وتكلفة هذه الاعدادات. أما المعايرة المعملية فان أهم مشكلة تواجهها هى محدودية الفراغ المتاح لإجراء الاختبارات وخصوصا عند معايرة أجهزة قياس المسافات الكترونيا حيث يتطلب الأمر قياس مسافات تتراوح بين 5 و 100 متر كما أشار بعض الباحثين، الأمر الذي يضطر القائمين على المعايرة إلى وضع بعض العواكس خارج المعمل وهو ما يسبب اختلافا كبيرا فى الظروف الجوية خلال المسافة المقاسة.

و هذا البحث يعرض طريقة مبتكرة لمعايرة أجهزة قياس المسافات الكترونيا داخل المعمل وذلك بمضاعفة المسافة المتاحة داخل المعمل بالاستعانة بمرآة أو بمجموعة مرايا. تم وضع الأساس الرياضي لهذه الطريقة و تم اختبارها نظرياً و عملياً و أعطت نتائج واعدة حيث كان متوسط الخطأ متساويا فى حالة قياس المسافات باستخدام المرايا او بدونها. هذا البحث تم إجراءه باستخدام مرايا الطبقة العاكسة فيها على السطح الخلفي ويمكن الحصول على نتائج أفضل باستخدام مرايا سطحها العاكس هو السطح الأمامي.

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1. INTRODUCTION

Routine verification of the measuring accuracy of Electronic Distance Measurement (EDM) instruments and nowadays total station is very important. This is of particular concern to contractors to meet the instrument accuracy requirements for a given contract (Dzierzega and Scherrer; 2002). Verification of EDM equipment is concerned with the determination of instrument errors which can then be used to monitor the performance of the instrument (Manual of Survey Practice).

The periodic calibration aims to minimize systematic error (US Army; 2002) and to determine the highest achievable precision using the instrument. (Bossler; 1984) stated that EDM instruments should be calibrated annually, and frequency checks made semiannually. (Becker et al; 2000), (Greenway; 2000), (Heister; 2001) and (Zeiske; 2001) discussed the ISO (International Organization of Standardization) specifications for testing the surveying instruments and they concluded that it is necessary to create uniform, universally-recognized standards for test procedures that can be applied in the field without excessive effort. They also concluded that the issue of standardization increasingly important for surveyors and other professionals. (Becker; 2001) mentioned that the objective for the standards is to specify field procedures to be followed each time the achievable precision for a given surveying instrument used together with its supported equipment has to be determined.

There are two methods for calibrating EDM, the field method and the laboratory method. For the field calibration, EDM must be calibrated over a series of distances representative of the range of the instrument (POB website 2002) known as baseline. The baseline is a permanently marked distance, the length of which is known (Finnish Geodetic Institute). The baselines consist of at least of four marked monuments, all in a straight line over uniformly sloping terrain (Buckner; 1998). These baselines are designed to generate a statistically accurate determination of the errors the EDM (Paiva; 2002). The verification method involves the measurement of a set of segments on the EDM base to determine the existence and magnitude of any errors present (Land information Dept. WAG). The length of the baseline is ranging from 500 and 1400 m (Buckner; 1998), so the field method is suitable for determination of the scale error. The engineering manual of the (US army 2002) stated that establishing a calibration baseline and keeping it in good order can be expensive and time consuming when maintenance is considered.

For the laboratory calibration, a series of distances ranging from five to one hundred meters must be measured. It will be necessary to mount some of the reflectors outside of the laboratory (Dzierzega and Scherrer; 2002).

Mounting reflectors outside the laboratory has some drawbacks such as the indivisibility obstructions, lack of verification of the measured distance between the EDM and the outside reflector and big change in the atmospheric condition along the measured distance, which is the most important. (Buckner; 1998), (PSM; 2001), (PSM; 2004) and (Kavanagh; 2004) stated that changing of 1°C in the temperature causes a change in the EDM reading of 1 PPM, also changing of 2.54 mm (0.1 inch) in the atmospheric pressure causes an error in the EDM reading of 1 PPM.

This paper presents a new compact laboratory method that overcomes the drawbacks of mounting the reflector outside the laboratory. This new method complies with the limited space of the laboratories and no need to put reflectors outside the laboratory. Several measurements were performed to check the precision of the proposed method.

2. EDM ERRORS

The distances measured by EDM/reflector combination are subject to three types of error, as shown in figure (1).

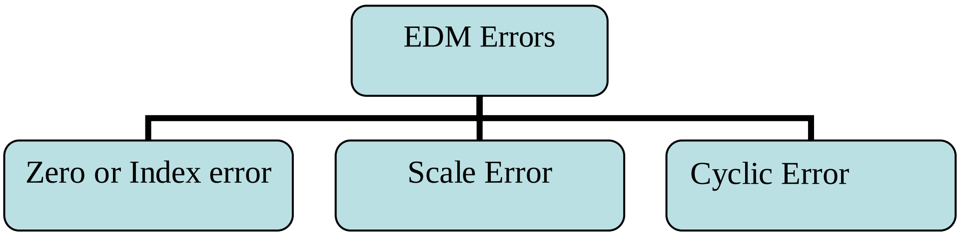


Figure 1: EDM errors.

Zero or Index Error (Additive Constant) is caused by three factors as listed by (land Victoria 2002):

- electrical delays, geometric detours, and eccentricities in the EDM,
- differences between the electronic centre and the mechanical centre of the EDM,
- differences between the optical and mechanical centers of the reflector.

The additive constant or zero/index correction is added to the measured distances to correct for these differences. this error may vary with changes of reflector, so only one reflector should be used for EDM calibration

The scale error describes errors that are linearly proportional to the length of line measured. (Manual of Survey Practice) summarize the reasons of this error in:

- internal frequency errors, including those caused by external temperature and instrument "warm-up" effects,
- un-modeled variations in atmospheric conditions which affect the velocity of propagation,
- non-homogeneous emission/reception patterns from the emitting and receiving diodes (phase inhomogenities).

Cyclic Error (Short Periodic Error) is a function of the actual phase difference measurement by the EDM (Bannister et al 1998). Phase measurement error is caused by unwanted feed through the transmitted signal onto the received signal. Cyclic error is usually sinusoidal in nature with a wavelength equal to the unit length of the EDM. The unit length is the scale on which the EDM measures the distance, and is derived from the fine measuring frequency

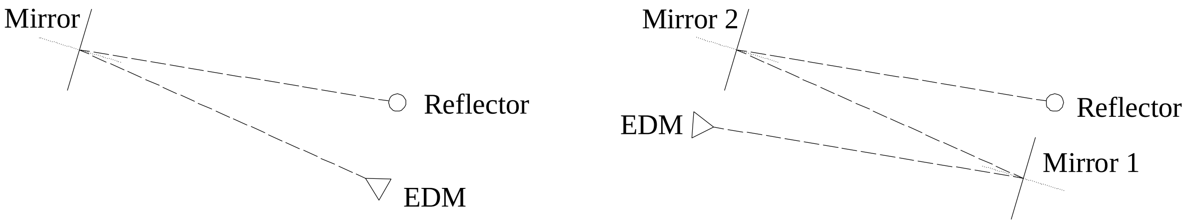
(Land information Dept. WAG). Unit length is equal to one half of the modulation wavelength of an EDM (land Victoria 2002).

The stability of the EDM internal electronics can also vary with age, therefore, the cyclic error can change significantly over time. Cyclic error is inversely proportional to the strength of the returned signal, so its effects will increase with increasing distance (i.e., low signal return strength). Calibration procedures exist to determine the EDM cyclic error that consist of taking bench measurements through one full EDM modulation wavelength, and then comparing these values to known distances and modeling any cyclic trends found in the discrepancies. More details about bench calibration are found in (European synchrotron radiation facility). This procedure requires a specialized calibration baseline designed to detect the presence of cyclic error from the spacing of the measurement intervals (US Army; 2002).

In general, calibration measurements over short distances assist in the determination of the additive constant while longer distances help determine scale error (land Victoria 2002).

3. METHODOLOGY

The idea behind the proposed method is that, since the EDM measures the traveling distance of the modulated wave between the EDM and the reflector, it is not necessary for that distance to be straight, we can duplicate the traveling distance by making it a zigzag line using mirrors. So, we can calibrate the EDM for a distance equal to double the laboratory space by using one mirror as shown in figure (2-a) or to a distance equal to triple the laboratory space by using two mirrors as shown in figure (2-b). This way we can avoid mounting the reflector outside the laboratory.



a) Double the distance
b) Triple the distance

Figure (2): Duplicate the calibrated distance

The EDM used in the experimental work is SOKKIA Total Station SET 600 (No.18520/D21828). The accuracy of the used Total Station, according to its specifications, is ± (3 + 2 ppm x D) for fine measurement with prism. The prism used is SOKKIA standard prism AP11 (constant = -30 mm) mounted on a tribrach with optical plummet. A weather station DAVIS (No. 7440) was used to measure the temperature, atmospheric pressure and humidity during the experimental work.

To perform the experimental work I designed two mirror frames to fit over SOKKIA Digital Theodolite that offer optical plummet, leveling and horizontal movement of the mirror surface. The designed frame secures that the reflective surface of the attached mirror coincides with the Theodolite vertical axis as shown in figure (3).

Figure (3): The designed mirrors

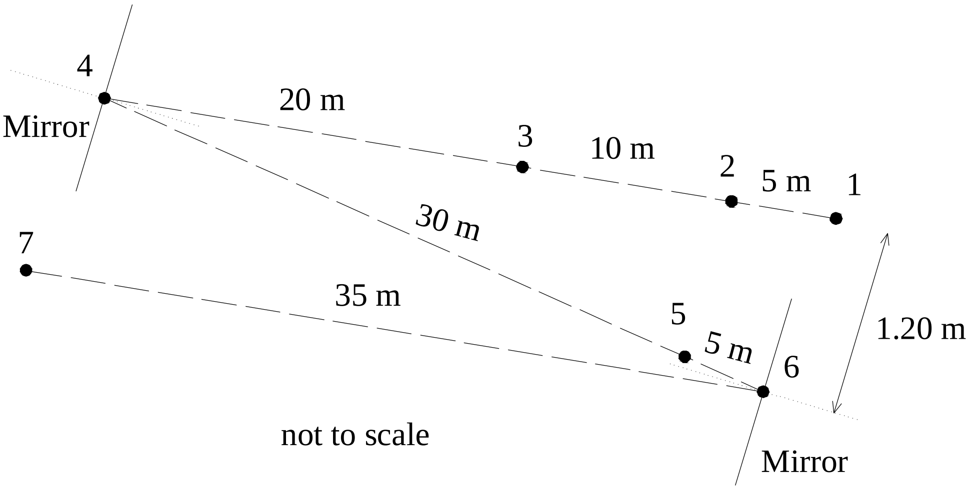


Figure (4): Configuration of the designed baseline

To test the efficiency of the new method, a baseline was design so that the intermediate points were placed at even multiple of the unit length of the EDM instrument to avoid the effects of cyclic error in the calibration process as recommended by (US Army 2002). The unit length of SOKKIA Total Station SET 600 is 5.0 meters (land Victoria 2002). The designed baseline shown in figure (4) consists of three parts. The first part (from point 1 to 4) was used for the standard calibration (without mirrors). The first and the second parts (from point 1 to 6) were used to calibrate the EDM using one mirror over a distance 70 m. The three parts (from point 1 to 7) were used for the calibration over a distance 105 m using two mirrors.

4. MEASURING PROCEDURE

Before starting with the actual measurements the Total Station and the weather station were turned on for 15 minutes. Then the reflector constant, temperature and air pressure are keyed into the instrument. The Total Station and the weather station were kept on during the whole measurements and any changes in the temperature or air pressure are entered into the instrument. Thus, the test yields only the instrument constant. The reflector and the mirrors are setting at the same height as the Total Station.

For the typical calibration the distances 1-2, 1-3, 1-4, 2-3, 2-4 and 3-4 were measured. For calibration using one mirror, the mirror was setting over point No.4 and the reflector over point No.6 and the distances 1-6, 2-6, 3-6 and 5-6 were measured. Then the reflector was setting over point No.1 and the distances 5-1, 3-1 and 2-1 were measured. When calibration using two mirrors was performed, the first mirror was setting over point No.4; the second mirror was setting over point No.6 and the reflector over point No.7. The distances 1-7, 2-7, 3-7 and 5-7 were measured. Then the reflector was setting over point No.1 and the distances 5-1, 3-1 and 2-1 were measured. Each distance was measured ten times and the average was computed.

5. RESULTS

The least squares method explained in (Shepherd; 1987) and (Bannister et al 1998) was applied to get the most probable value of the zero constant for each group of measurements. The values of the zero constant are shown in table 1.

Table 1: the values of zero constant

Calibration method	**Zero constant (mm)**
Typical (over 35 m distance)	4.4
Using one mirror (over 70 m distance)	4.0
Using two mirrors (over 105 m distance)	4.24

A comparison of the results obtained shows the efficiency of the proposed method.

6. CONCLUSIONS

A new compact method to calibrate the EDM in the laboratory has been developed, tested and proved practically. The accuracy of the obtained results shows the efficiency of the proposed method. The accuracy and precision of the proposed method can be improved by using first surface mirror to avoid the possible refraction when using the back surface mirror. It is recommended to use this method to avoid mounting the reflector outside the laboratory.

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CONTACTS

Dr. Ragar Khalil
Lecturer at Civil Engineering Department
Faculty of Engineering
Assiut University
Assiut
EGYPT
Tel. +20882354867
Fax + 2088332553
Email: rkmm99@yahoo.com