EDM ZERO CORRECTION CALIBRATION

BY *PETER A. STEEVES, P.Eng.* University of Toronto

When an electromagnetic distance measurement (EDM) device is manufactured, it is difficult to place the electronic center of the instrument exactly on the standing axis of the instrument; therefore, most EDM devices measure all distances too long or too short by a constant amount, usually a few millimetres in magnitude. It is also possible for this so-called zero correction to drift a small amount over long periods of time. Each EDM device has a different zero correction that must be estimated periodically.

This article discusses the survey procedure, derives the least squares mathematical model and describes a computer program for performing an EDM zero correction calibration.

INTRODUCTION

"For some time both government and private survey organizations have recognized the need to ensure that a uniform scale is applied to all EDM measurements. In 1972 the Second National Control Survey Conference, held in Ottawa, recommended that precise calibration base lines be constructed across Canada. It was agreed at that conference that provincial governments construct the base lines and the federal government measure them.

The base lines installed by the Ministry of Natural Resources are being measured by the Geodetic Survey of Canada using a Kern ME-3000 MEKOMETER which is calibrated at regular intervals on the National EDM Precise Calibration Line in Ottawa". [Code, 1979]

PROCEDURE

All possible distances are measured between a series of points situated along a straight line, see Code [1979]. Each measured distance, reduced to the horizontal, represents the sum of:

1. The true distance;
2. The zero correction of the device (at the time of calibration);
3. A random error;
4. A proportional error (wrt distance, function of EDM device);
5. A proportional error (wrt distance, function of error in the estimated refractive index).

The contributions of 4 and 5 cannot be separated in a field test; 4 is minimized through laboratory calibration; 5 can be minimized by obtaining accurate meteorological readings along the path of the electromagnetic radiation.

THE ADJUSTMENT

Figure 1 depicts a precise calibration base line consisting of 4 points (in practice, the minimum number of pillars should be 6) situated along a straight line. Let $x_0 = 0.000$ (held fixed) and x_1, x_2, x_3 be the unknown chainages of the pillars with respect to x_0.

The Mathematical Model

Adjusted Value - Zero Correction - Observed Value - Residual = 0. For the example,

$$\bar{x}_1 - x_0 - \Delta\ell - \ell_1 - v_1 = 0$$
$$\bar{x}_2 - x_0 - \Delta\ell - \ell_2 - v_2 = 0$$
$$\bar{x}_3 - x_0 - \Delta\ell - \ell_3 - v_3 = 0$$
$$\bar{x}_2 - \bar{x}_1 - \Delta\ell - \ell_4 - v_4 = 0$$
$$\bar{x}_3 - \bar{x}_1 - \Delta\ell - \ell_5 - v_5 = 0$$
$$\bar{x}_3 - \bar{x}_2 - \Delta\ell - \ell_6 - v_6 = 0$$

Replacing the unknown chainages by approximate values and a smaller unknown, dx, to estimate and replacing x_0 by 0.000 we have,

$$dx_1 - \Delta\ell + x_1^\circ - \ell_1 - v_1 = 0$$
$$dx_2 - \Delta\ell + x_2^\circ - \ell_2 - v_2 = 0$$
$$dx_3 - \Delta\ell + x_3^\circ - \ell_3 - v_3 = 0$$
$$dx_2 - dx_1 - \Delta\ell + x_2^\circ - x_1^\circ - \ell_4 - v_4 = 0$$
$$dx_3 - dx_1 - \Delta\ell + x_3^\circ - x_1^\circ - \ell_5 - v_5 = 0$$
$$dx_3 - dx_2 - \Delta\ell + x_3^\circ - x_2^\circ - \ell_6 - v_6 = 0$$

Rewriting in matrix notation,

$$\begin{bmatrix} 1 & 0 & 0 & -1 \\ 0 & 1 & 0 & -1 \\ 0 & 0 & 1 & -1 \\ -1 & 1 & 0 & -1 \\ -1 & 0 & 1 & -1 \\ 0 & -1 & 1 & -1 \end{bmatrix} \cdot \begin{bmatrix} dx_1 \\ dx_2 \\ dx_3 \\ \Delta\ell \end{bmatrix} + \begin{bmatrix} x_1^\circ - \ell_1 \\ x_2^\circ - \ell_2 \\ x_3^\circ - \ell_3 \\ x_2^\circ - x_1^\circ - \ell_4 \\ x_3^\circ - x_1^\circ - \ell_5 \\ x_3^\circ - x_2^\circ - \ell_6 \end{bmatrix} - \begin{bmatrix} v_1 \\ v_2 \\ v_3 \\ v_4 \\ v_5 \\ v_6 \end{bmatrix} = 0$$

or, $$B\Delta + F^\circ - V = 0$$

The Least Squares Unbiased Estimator for Δ

The least squares criterion states that the "best" estimator $\hat{\Delta}$ of Δ is the estimator which will minimize the sum of the squares of the weighted residuals, that is $\hat{V}^t \Sigma_\ell^{-1} \hat{V} \rightarrow \text{minimum}$

where $\hat{V}$ is the least squares estimator of the residual vector.

Extremal Problems

Minimize $\hat{V}^t \Sigma_\ell^{-1} \hat{V}$

under the constraint $B\hat{\Delta} + F^\circ - \hat{V} = 0$

Using the method of Lagrange [Mikhail, 1976] we obtain:

The least squares estimates

$$\hat{\Delta} = \begin{bmatrix} \hat{dx}_1 \\ \hat{dx}_2 \\ \hat{dx}_3 \\ \hat{\Delta\ell} \end{bmatrix} = -(B^t \Sigma_\ell^{-1} B)^{-1} B^t \Sigma_\ell F^\circ \;;$$

Estimated chainages

$$\begin{bmatrix} \bar{x}_1 \\ \bar{x}_2 \\ \bar{x}_3 \end{bmatrix} = \begin{bmatrix} x_1^\circ \\ x_2^\circ \\ x_3^\circ \end{bmatrix} + \begin{bmatrix} \hat{dx}_1 \\ \hat{dx}_2 \\ \hat{dx}_3 \end{bmatrix} \;;$$

Residuals

$$\begin{bmatrix} \hat{v}_1 \\ \hat{v}_2 \\ \hat{v}_3 \\ \hat{v}_4 \\ \hat{v}_5 \\ \hat{v}_6 \end{bmatrix} = B\hat{\Delta} + F^\circ \;;$$

Variance of unit weight

$$\hat{\sigma}_0^2 = (\hat{V}^t \Sigma_\ell^{-1} \hat{V}) / df$$

where df = number of observations - number of unknowns

Σ_ℓ = variance - covariance matrix of the observations (a diagonal matrix consisting of estimated variances for the observations)

THE APPLE II MICRO COMPUTER PROGRAM

An interactive system has been developed and coded in Applesoft™ Basic for the least squares estimation of the zero correction for electromagnetic distance measurement devices.

The system and the operator converse interactively by means of menus displayed on a cathode ray tube (CRT). The main menu has three options:

a. Enter data;

b. Edit data;

c. Execute the program.

When the operator declares which mode to be used, the computer directs the operator by means of several secondary menus.

With our configuration of micro computer, disk drive and printer, 1 minute and 43 seconds of time is required to execute the program and print out the results.

Figures 2 to 13 depict CRT displays at several stages of the input and data editing modes.

REMARKS

The estimated chainages from the least squares solution can be compared to the precise Mekometer chainages [Code, 1979]; if large proportional differences (wrt distance) are apparent, the EDM device should be sent to the manufacturer for servicing.

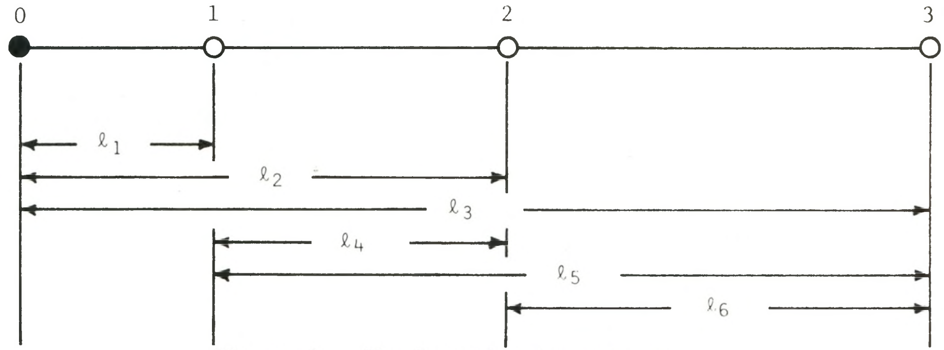

Figure 1. The Baseline Measurements

Micro computers are now available to small surveying companies at moderate prices. Commercial software is available for processing accounts receivable, payrolls, etc. Several commercial coordinate geometry programs are available and several scientific surveying programs will be available from Survey Science, The University of Toronto in the near future.

REFERENCES

Code, R.G. (1979). "Precise Calibration Base Lines in Ontario",

Surveys and Mapping Branch, Ministry of Natural Resources.

Mikhail, E.M. (1976). Observations and Least Squares,

IEP - A Dun-Donnelley Publisher, New York.

Note: A listing and documentation of the zero correction calibration program, coded in Applesoft™ Basic, can be obtained from:

P. A. Steeves, P. Eng.
Department of Survey Science
University of Toronto
Mississauga, Ontario L5L 1C6
CANADA

Please include $5.00 for copying, shipping and handling charges. To receive the program on diskette, please include a 5¼″ diskette.

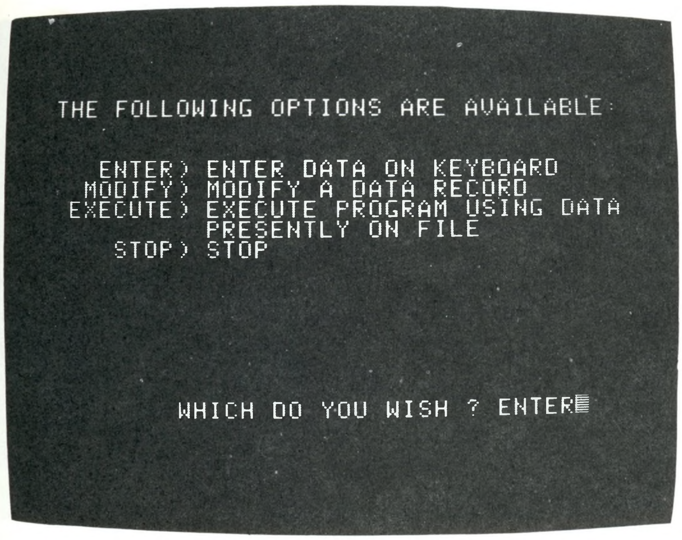

Figure 2. The Program Menu. Operator chose The Enter Program.

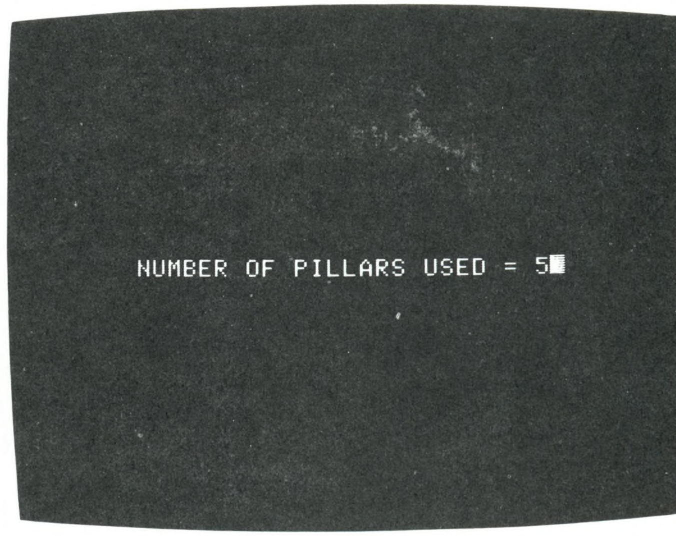

Figure 3. Request for Number of Pillars Used.

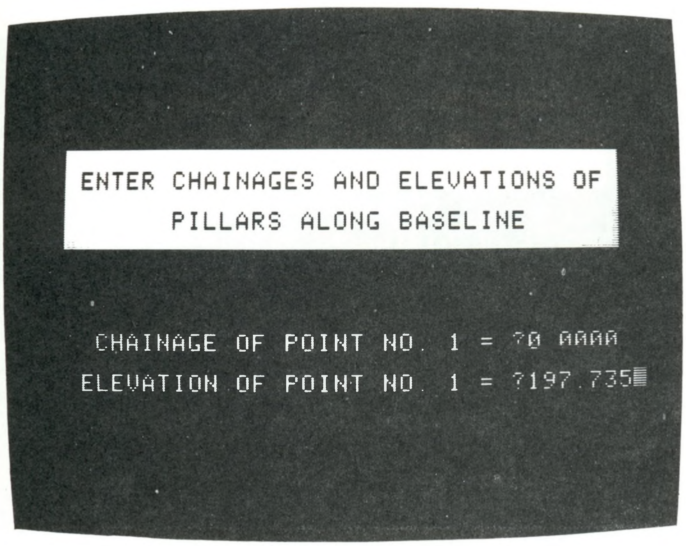

Figure 4. Request for Chainage and Elevation of Pillar 1

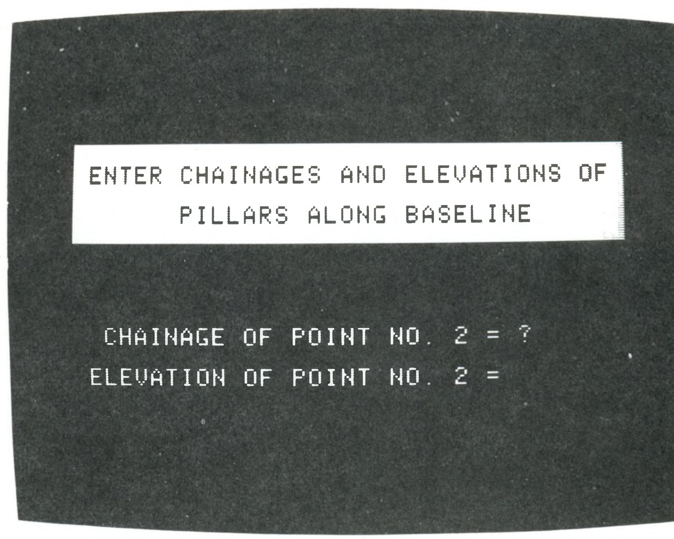

Figure 5. Request for Chainage and Elevation of Pillar 2.

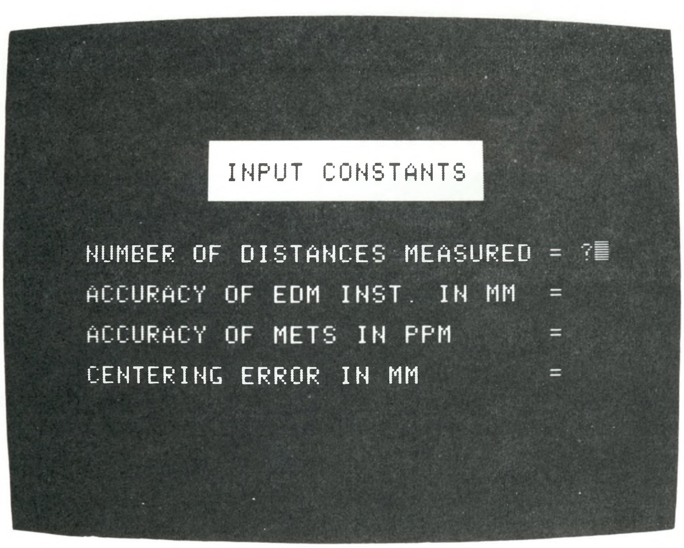

Figure 6. Request for Adjustment Constants.

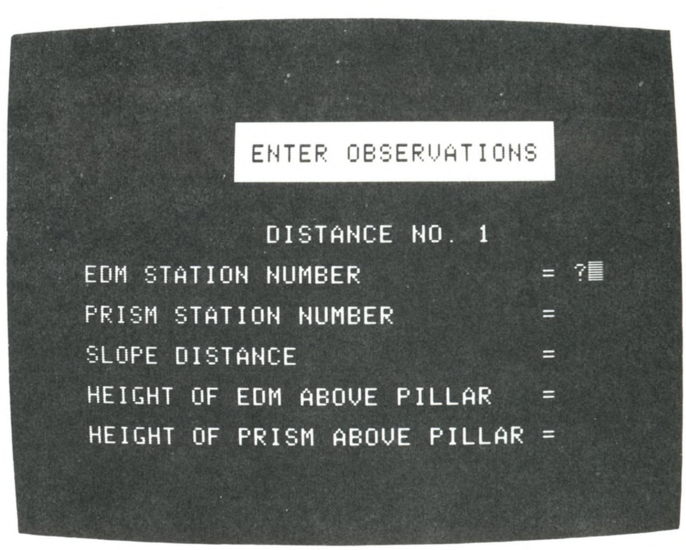

Figure 7. Request for Observations.

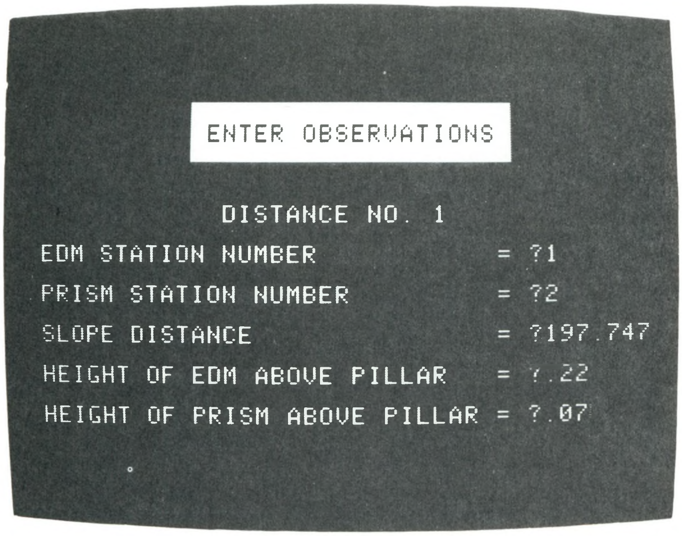

Figure 8. Request for Observations.

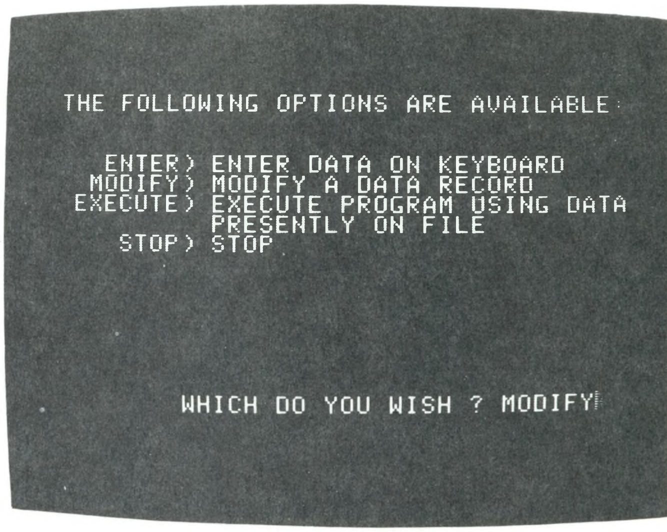

Figure 9. The Program Menu.
Operator chose The Modify Program.

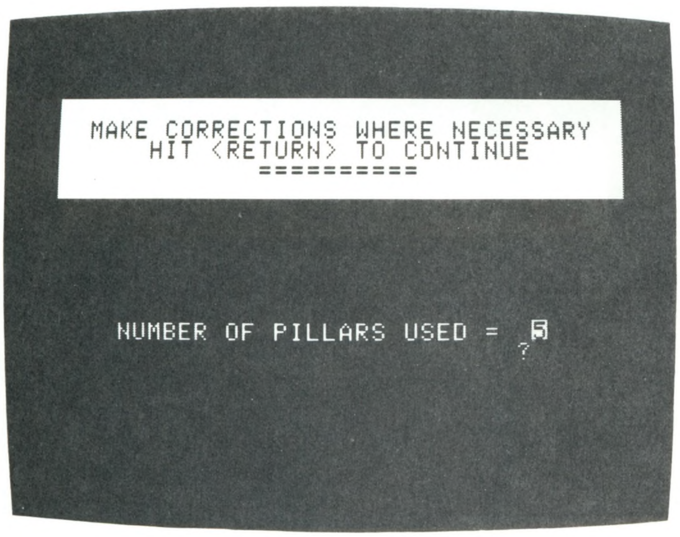

Figure 10. Is the Number of Pillars Correct?

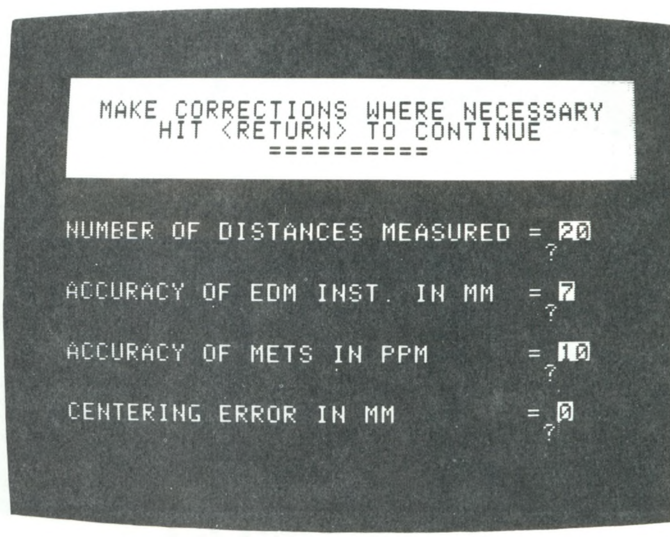

Figure 11. Are the Adjustment Constants Correct?

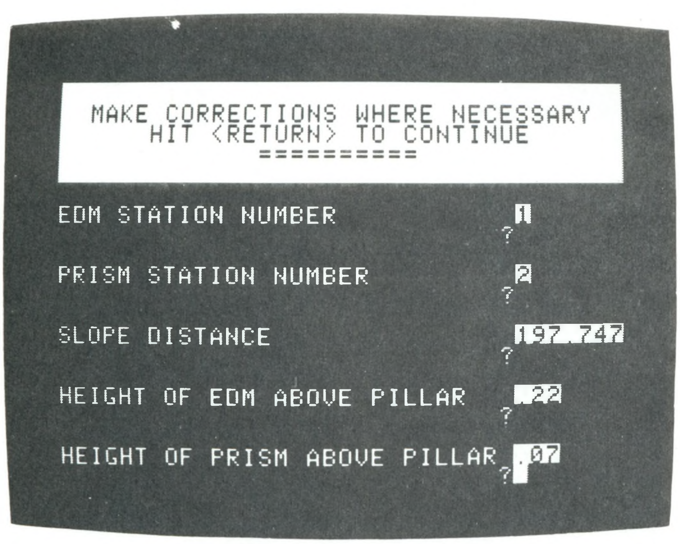

Figure 12. Are the Observations Correct?

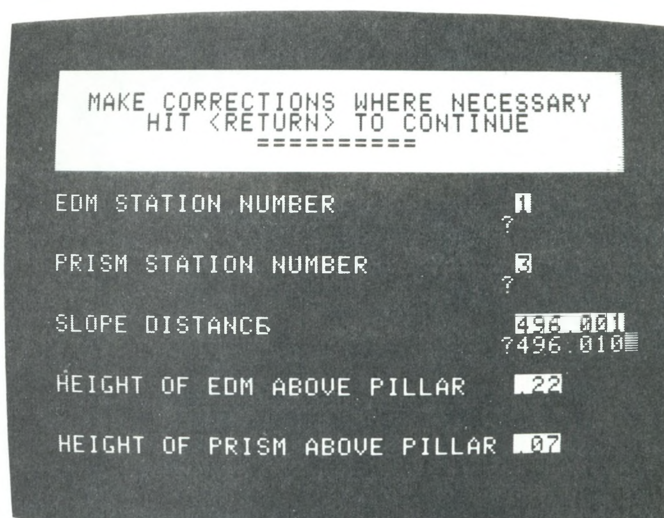

Figure 13. Are the Observations Correct?
The Operator Corrected error in Distance.