APPLICATION OF REFRACTIONAL EFFECTS IN GEODETIC FRAMEWORK OF IRAQ BY CONTINUOUS TRILATERATION

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1. INTRODUCTION

Terrestrial refraction effect has been of considerable interest to many geodesists for many decades and there is a rich litterature on the subject, of long standing. Due to its local character this problem is still topical. Geodetic determination of how far terrestrial refraction influences geodetic observations is, therefore, very often studied.

"POLSERVICE", the Polish Foreign Trade Enterprise, was charged with a task to establish the network, the general contractor being the State Enterprise for Survey and Cartography, Warsaw, Poland. Works were started in 1974 and the completion of the network is to take place in the middle of 1979. As a result, among others, geodetic network was established, of average distance between points 15 kilometers (the shortest side about 8 km, the longest about 35 km). The structure of the network is as shown on Figure 1, that is all the distances between neighbouring points are measured (there is no deviation from this principle on the total area of Iraq) and, additionally, an angle between two, most clearly seen, directions is measured on each point (deviation from this principle is possible).

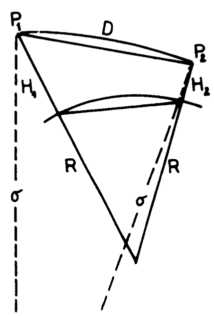

Figure 1. The structure of the network.

E. Tengström and G. Teleki (eds.), Refractional Influences in Astrometry and Geodesy, 267–274.

So far over 8000 sides were measured by AGA model 8 geodimeters, which shows how large is the scope of the works.

2. OPTICAL EFFECTS

During initial observations many interesting remarks about the refraction effects were made. In the evening receding of the horizontal line was being observed and objects on the horizon had shapes unnaturally elongated. This phenomenon occurs during the whole night and early in the morning - later on the profile of objects diminishes and they conceal under the horizon. It happened that light of desert settlements situated at a distance of over 100 km was being observed at night.
A phenomenon of "picture division" is also interesting; the point is that during a very short time in the morning and in the evening, a picture being at a distance of several kilometers is seen double. At the beginning, in the evening a target picture elongates; later on it divides into two and, for example the target is seen distinctly at a higher level, and in less sharp outline, at a lower level. After several minutes this phenomenon disappears. However, very often during the day-time two horizon lines separated by a layer giving the optical illusion of water surface is being observed.

3. COEFFICIENT OF REFRACTION AND ITS EFFECT ON LENGTH OF MEASURED SIDE.

The ratio of the radius of curvature of the ellipsoid (R) to the radius of curvature of the wave path (σ) in a specified point is defined as the accurate coefficient of refraction (see Figure 2):

$$K = \frac{R}{\sigma} \quad (1)$$

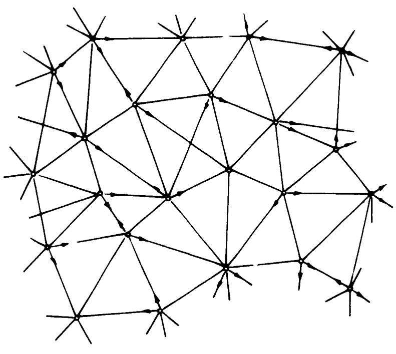

Figure 2.

From several reductions of the measured side, two depend on coefficient of refraction (HOPCKE, 1964):

- correction for path curvature, i.e. the reduction to chord distance (P_1P_2):

$$k_1 = K^2 \cdot \frac{D^3}{24\ R^2} \tag{2}$$

- correction for variation in the velocity for propagation along the line:

$$k_2 = -(K - K^2) \cdot \frac{D^3}{12\ R^2} \tag{3}$$

These corrections can be combined:

$$\text{corr.} = -(2K - K^2) \cdot \frac{D^3}{24\ R^2} \tag{4}$$

Quantities of reduction corrections according to formula (4) for the range of lengths measured in Iraq geodetic network (R = 6 370 km) is indicated on the following table:

K	10 km	15 km	20 km	30 km	35 km
− 0.5	+0.001	+0.004	+0.010		
0.0	0.000	0.000	0.000	0.000	0.000
+ 0.5	−0.001	−0.003	−0.006	−0.021	−0.033
+ 1.0	−0.001	−0.003	−0.008	−0.028	−0.044
+ 1.5	−0.001	−0.003	−0.006	−0.021	−0.033
+ 2.0	0.000	0.000	0.000	0.000	0.000

It results from the above that at distance measured up to 15 kilometers there is always accuracy of $2 \cdot 10^{-7}$ (regardless the accuracy of K); for longer distances, however, not more than 35 kilometers, the error of specifying K quantity, equal to 0.5 does not cause that the reduction error is more than $1 \cdot 10^{-6}$.
Before each measurement of length, simultaneous zenith distance measurements from the two terminals were carried out, enabling accurate introduction of the said reductions. The observations were carried out for laser beam - therefore the coefficient of refraction was specified for helium-neon (HeNe) gas laser beam. For some areas simultaneous zenith distance measurements were repeated after the distance measurement.

4. TERRESTRIAL REFRACTION IN IRAQ

Investigations on terrestrial refraction carried out in Iraq were limited to determinations of refraction coefficient in ground atmospheric layer of 2 - 25 meters. The basic examination depended on 24-hour determination of quantities and changes of refraction coefficient for the South and West Desert area. Eight determinations were made in different places and different seasons of the year.

Figure 3 indicates 3 chosen diagrams of daily changes of refraction coefficient, made on the Iraq Desert area. Due to the homogeneity of basement soil and invariability of weather, the daily changes of refraction coefficient in the middle of the day are very regular during the yearly period.

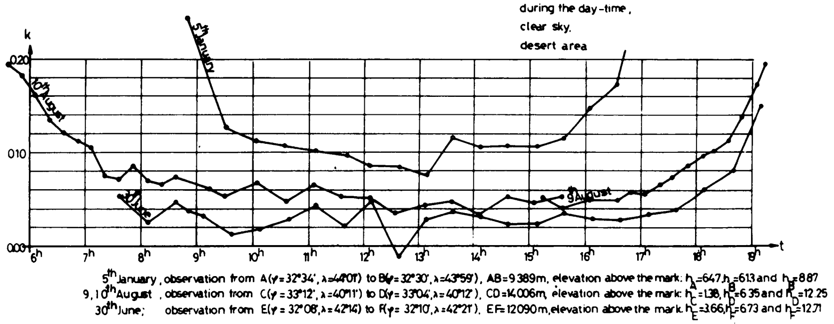

Figure 3. Daily refraction coefficient from non-reciprocal vertical observation when the height difference was known.

The shortest day of the year (22nd December) is characterized by refraction coefficient K = 0.10; the longest day of the year (21st June) K = 0,02. Individual determinations (average from two targets) are marked with circles on the diagram. It was found that there was a constant difference between the determinations or the higher and lower targets equal to about K = 0.03. The determination was made while aiming at the opaque beacons.

Figure 4 specifies three chosen diagrams of 24-hour changes of refraction coefficient. These determinations showed that during the night the refraction coefficient would be most probably K > 0.7. The determinations were made while aiming at lamps, heliotropes and opaque beacons.

Observations as shown in Figure 3 and Figure 4 were made by the method of vertical angle measurement at the known difference of target height and length. While calculating the refraction coefficient, influence of deviation of the vertical was disregarded; its influence on quantity of the coefficient is approximately ± 0.01.

Figure 5 illustrates all determinations of the refraction coefficient calculated for the specified area during the yearly period. Reciprocal observations were made each time for a different side of the specified area (hence 315 determinations were made). These observations were carried out before the measurement by geodimeter.

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They were made at the same time, with accuracy ± 1 minute (when the fixed signal through the radio-telephones was given).

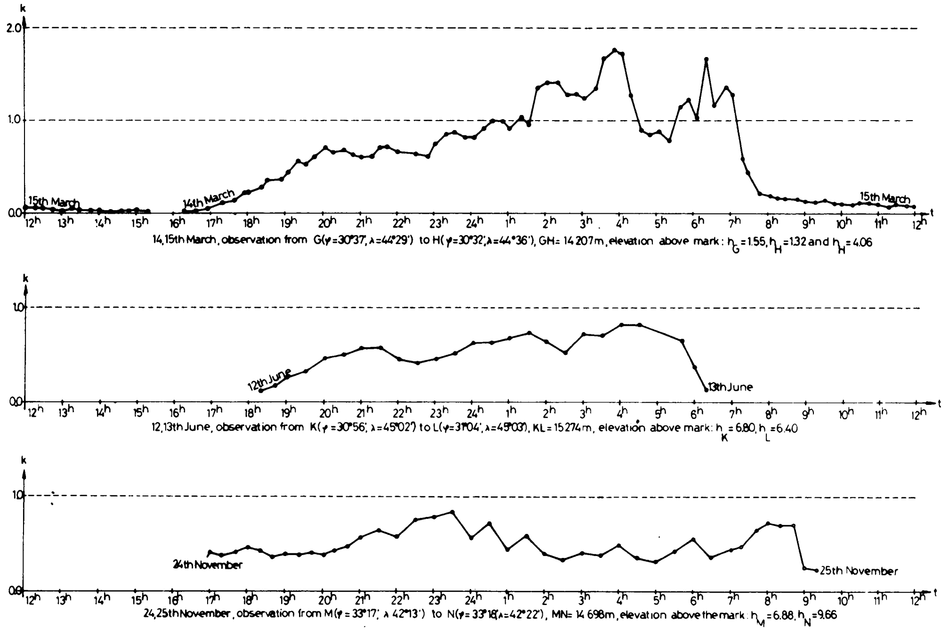

Figure 4. 24-hour changes of refraction coefficient.

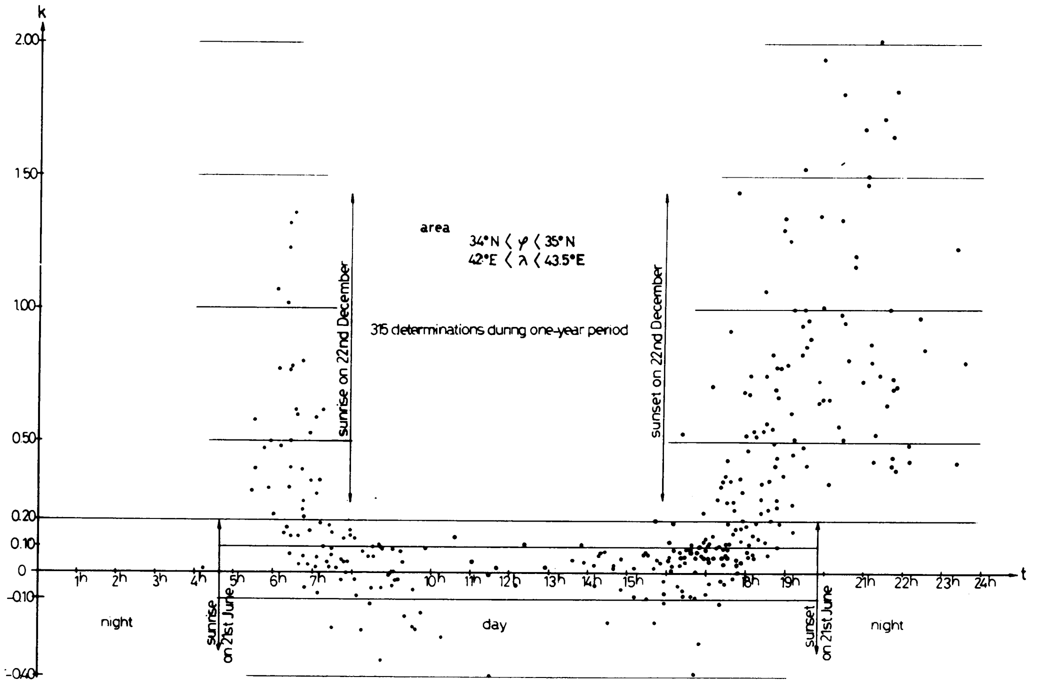

Figure 5. Refraction coefficient from reciprocal zenith angles.

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Laser beam emitted by a geodimeter or its reflection in a reflector was the target. The diagram includes all the observations, which correctness was controlled by trigonometric levelling (the sum of the height differences in the three sides of a triangle). The refraction coefficient from the said determinations concerns helium-neon (HeNe) gas laser beam.

Practical importance of dispersion of light for the used measurements was not ascertained.

5. CONCLUSION

Results of research on terrestrial refraction in atmospheric layer up to 25 meters, reviewed in this paper, had considerable influence on establishment of geodetic network in Iraq.

Owing to high coefficients of refraction it was possible to carry out observations from ground stations (apart from obvious exceptions) hence limiting the necessity to use towers and masts. These had considerable importance for the organization of works in the establishment of such a big network. During a ground reconnaissance, geodimeter lines attainable during the day and those requiring uplifting of the target above the horizon by night terrestrial refraction were determined.

This paper reviews only the influence of terrestrial refraction on the desert area. However, it should be pointed out that while measuring the Marshy area in the Southern region of Iraq, more advantageous results with regard to terrestrial refraction, were attained (higher coefficient of refraction during the night).

Preliminary adjustment for about 40% of the area confirmed high accuracy of measurements - the acquired accuracy was 1 : 650 000 at each point of the network.

Formulas and accuracy of determinations were not included in this paper in order to make it perspicuous. They are well-known by geodesists dealing with this problem.

This article reviews the problem of how the phenomenon of refraction, being generally considered as troublesome for geodesists, occured to be very useful and it was utilized in the establishment of geodetic control in Iraq.

REFERENCES:

HOPCKE, W.: 1964, Uber die Bahnkrümmung elektromagnetischer Wellen und ihren Einfluss auf die Streckenmessungen, Zeitschrift für Vermessungswesen, Vol.6, pp.183-200.

DISCUSSION

T.J. Kukkamäki: I was very pleased to see that in Iraq Mr Pazus has got the same kind of results that we have got here in northern latitudes, when we measured a 900 km long traverse through Finland. We got exactly the same results for k. We used towers, but the towers were only in order to rise the instruments above the treecrowns. From the refractional points of view, the treecrowns are comparable to the ground in Iraq, where the landscape was open. During the daytime k was surprisingly consistent. Trigonometrical height determinations gave good results for these sides with an average length of 30 km and with height differences of ±50 m our results agree with the Iraq results, which means that these results seem to be global.

J. Milewski: In spite of the fact that Iraq represents rather a very special area of atmospheric conditions?

T.J. Kukkamäki: Yes, our results agree well with the Pazus' ones. Have other colleagues any comments to this?

K. Poder: If you are assuming the model of the atmosphere used for deriving the conventional formulae for refractional effects in distance measurements, then you think it is fine, and you have k as the ratio of the curvature of the earth through the curvature of the lightbeam, and you get the curvature correction which roughly and more practically is written in a way which satisfies surveyors' needs, and which also includes some humidity reductions. Now, assume you have a small disturbance near the terminal point where you observe the zenith distances, then you may start by observing that, and your observation indicates that the target is there, due to a small local disturbance, but the major part of the path goes mostly and regularly in free air. In that case the use of k, which also can be put into the formulae, from zenith distances, will give you a very wrong correction. In that case it might be better to take just the classical value of 0.12 or 0.13. If you have that large variation it is a sign that your model is not good enough, and it may be better just to take a more theoretical correction.

J. Milewski: You are right, Mr Poder, as to the distance correction. Theoretically it could arise a disagreement between the real k as average of the whole distance and that obtained from the vertical angles. But we can control how the Hoepke's formula works by the right Edlén's formula for reduction od distance measurements using meteorological parameters. They installed some control stable base points, and at the base points they measured all the time, every day, all the parameters for obtaining the gradient of temperature and of pressure. And the corrections derived from Hoepke's and from Edlén's formulae agreed with each other.

K. Poder: If you use Hoepke's formula you are actually missing a term. Hoepke's formula needs a correction also for the second order derivative of the vertical gradient. This is needed in very sloping lines, and if you use his formula for very sloping lines you will get into troubles. This is important in the case of sloping lines.

T.J. Kukkamäki: So, now you have heard one pessimist and two optimists. Any more pessimists here? If not, we may continue our programme.