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A GRAPHICAL METHOD FOR COMPUTING WIND VALUES FROM THE FINNISH RADIOTHEODOLITE RECORD

by

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Abstract

A new method allowing the computation of wind values from recording of the Finnish radiotheodolite in a graphical way is presented.

Theory. The fundamental formula concerning our radiotheodolite (RT) is [1] (Fig. 1)

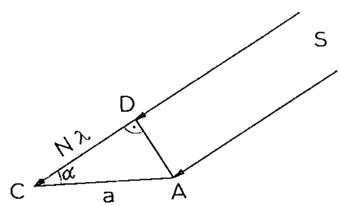

Fig. 1. The basic principle of the radiotheodolite.

(1) $$\cos\alpha = \frac{\lambda}{a} N,$$

where $\alpha =$ the angle between the direction of the incoming radiowave (DC) and the base (CA) which joins the two antennas C and A of the RT antenna system, $a =$ distance CA, $\lambda =$ the wave-length of the radio signal and $N =$ the phase difference of the radio wave at antennas C and A.

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As CA is usually about ten times the wave-length λ, then N is < 10 and contains an integer (period number) and a phase difference which is < 1 (fractional phase difference).

The antenna system consists of two pairs of antennas, CA and CB, which are situated in a horizontal plane perpendicular to each other. Point C is chosen as the origin of the rectangular coordinate system, CA being the x-axis and CB the y-axis. α is the angle of incidence of the radio-wave with CA and β with CB. The corresponding phase differences may be N_x and N_y. Then we have

$$\cos\alpha = \frac{\lambda}{a} N_x, \quad \cos\beta = \frac{\lambda}{a} N_y$$

When h denotes the elevation angle of the radiosonde and A the azimuth angle reckoned positive from CA to CB, then

$$(2) \qquad \begin{cases} \cos\alpha = \cos h \ \cos A = \dfrac{\lambda}{a} N_x, \\ \cos\beta = \cos h \ \sin A = \dfrac{\lambda}{a} N_y. \end{cases}$$

Therefore

$$(3) \qquad \operatorname{tg} A = \frac{N_y}{N_x}$$

and

$$\cos h = \frac{\lambda}{a}\sqrt{N_x^2 + N_y^2}$$

If the corresponding frequency of λ is denoted by f, we have

$$c = f\lambda$$

or $\frac{a}{\lambda} = \frac{a}{c} f$ and we get

$$(4) \qquad \cos h = \frac{\sqrt{N_x^2 + N_y^2}}{\frac{a}{c} f}$$

In this formula, $a = 120$ m according to our usual antenna system and $c = 300$, when f is given in Mc/s and λ in m. The formulas (3) and (4) are the basis of the following graphical computing system of the radio-theodolite records. The recorded quantities are N_x, N_y and f.

We plot in a suitable rectangular coordinate system the recorded points D (N_x, N_y) (»direction points») e.g. for all whole minutes. The radius vector CD is then $= \sqrt{N_x^2 + N_y^2}$ (Fig. 2). Thereafter we draw the $S'D$ perpendicular to CD and, with $\frac{a}{c}f$ as radius, draw an arc which intersects the perpendicular at point S'. According to the formula (4) the elevation angle is then $\wedge S'CD$. When now the geometric height H of the radiosonde is known, we place it, on a suitable scale, perpendicular to CD,

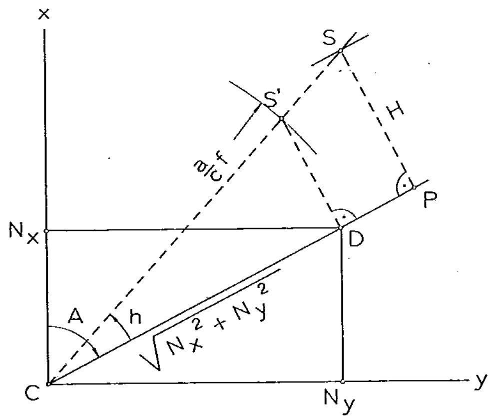

Fig. 2. The principle of the computing method.

between the arms CS' and CD of the angle h. If the height is the distance PS, then the point P represents the projection of the radiosonde on the horizontal xy-plane (the »RS projection point»). Proceeding in this manner for each minute of the RT record, we obtain the horizontal path of the balloon just as in the case of an ordinary pilot balloon.

A Practical Solution of the Method. The computing board consists of an ordinary drawing-board, on which a white polyvinyl-chloride sheet, 120 cm × 70 cm, divided into 5 × 5 cm² squares, has been fitted (Fig. 3). This serves as the (x, y)-coordinate plane for direction points (N_x, N_y) and for the RS projection points. In the middle of its lower long side have been placed 9 »origin sockets» at the corners of the squares. The origin sockets serve as centres of rotation for the »height sector» and the »frequency ruler».

The »height sector», in the form of a quadrant divided into millimeter squares, is placed on the coordinate plane. The height sector can be rotated

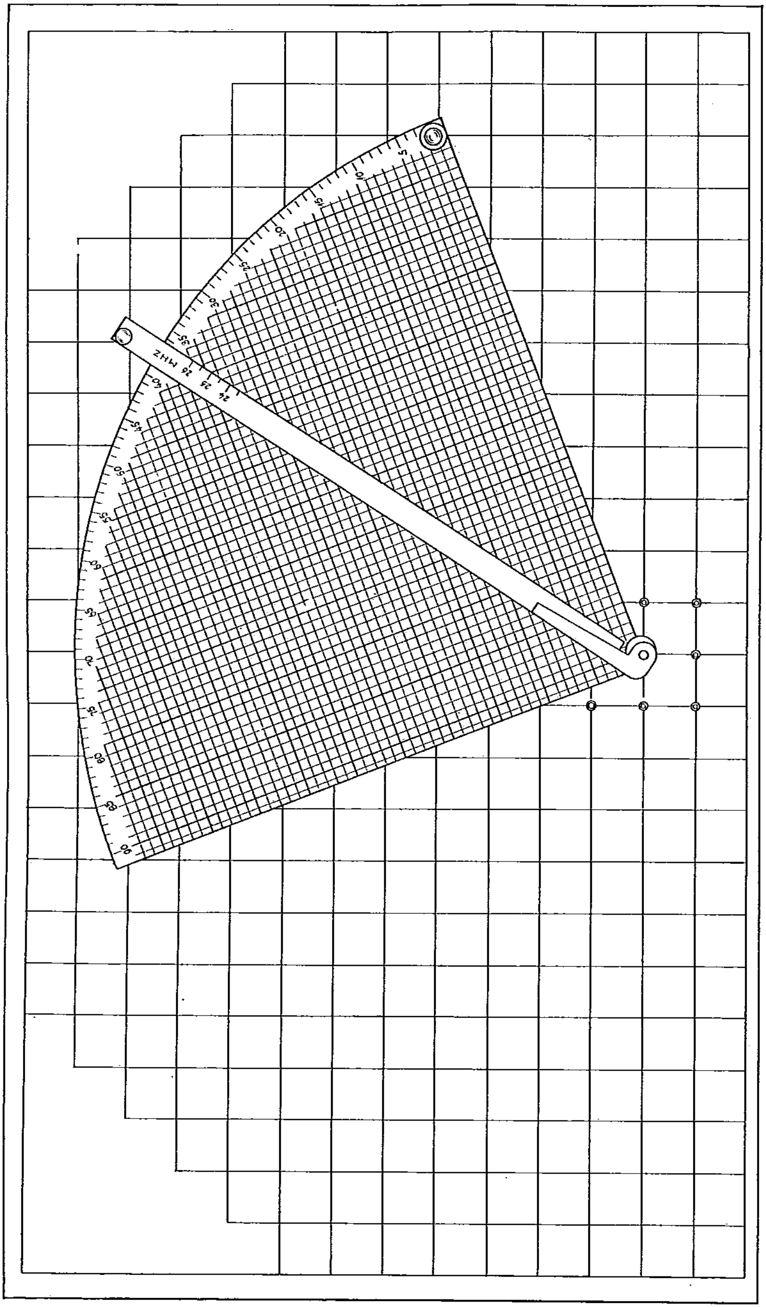

Fig. 3. A practical solution of the computing method.

round an origin socket and moved somewhat in the direction of the right-hand side of the sector.

The »frequency ruler» is situated on the height sector. It can also be rotated round the same centre as the height sector, but it cannot be moved in the direction of the ruler. The ruler is provided with a scale for $\frac{a}{c}f$ numbered in megacycles.

Both the height sector and the frequency ruler are connected to the coordinate plane by means of a plug, which has been put into one of the abovementioned origin sockets. The middle socket is mostly used.

To begin with, the axes corresponding to the phase difference components N_x and N_y are chosen in accordance with the course the radiosonde is likely to take, so as to enable us to draw the path of the radiosonde in the coordinate plane.

For the determination of the period number of N_x and N_y two other antenna pairs, C_1A_1 and C_1B_1, called search antennas, are used. The distances C_1A_1 and C_1B_1 between the search antennas are both about one wavelength: $a_1 = \frac{a}{10} = 12$ m. In this antenna system the phase differences N_{x1} and N_{y1} are between -1 and $+1$. Ten times N_{x1} and N_{y1} give the simultaneous total phase differences N_x and N_y in the main antenna system. In this way the integers (the period numbers) of N_x and N_y are determined. The 5-cm coordinate lines correspond to these period numbers. Proceeding from these period lines we now plot the direction points (N_x, N_y) on the coordinate plane, taking the corresponding fractional phase differences from the RT record by means of a scale as numbers or by means of a pair of compasses.

The individual direction point indicates as such the RS azimuth with regard to the antenna coordination.

The elevation angle of the RS is reached as follows:

The height sector is placed so that its right-hand side and one of the cm-lines starting at right angles from the side pass through the direction point. The frequency ruler is turned so that the said cm-line intersects the frequency scale of the ruler at the recorded frequency reading f. The angle between the right-hand side of the height sector and the frequency ruler is then the elevation angle h of the sonde.

Now to get the RS projection point we place its geometric height H, which is determined either from the PTU sounding or by means of the rate of ascent, between the two arms of the elevation angle perpendicular to the right-hand side of the height sector. For this purpose we reckon the height at right angles from this side of the height sector using as unit, 5 cm, 2 cm or 1 cm corresponding to 1 km of the actual height. When the intersection point of the height line (which is prallel to the right-hand side of the height sector) with the frequency ruler is moved perpendicularly down to the right-hand side of the height sector and pricked on the coordinate plane, we have there the projection point of the radiosonde.

The resulting points now form the RS projection curve, also called the horizontal path of the RS, the scale being the same as for the height H. From this curve the wind is determined in the usual way.

This computer is designed on the assumption that the antenna bases CA and CB are at right angles to each other and that both distances CA and CB are 120 m. If the antennas have been placed in another way, the net of the coordinate plane must be changed correspondingly.

When the plotting of the direction points begins, the middle origin point is made use of. Is it found later on that an error of one period (5 cm) has occurred in N_x or N_y, the matter can be corrected by moving the origin correspondingly. The marked points are easily removed from the coordinate sheet after the computation.

If desired, transparent paper can be spread out on the coordinate plane. It is also advantageous to cover with paper the unused origin sockets. The direction points and the RS projection points should be distinguished from each other by means of some suitable marking.

Should the direction points extend beyond the coordinate plane, the names and signs of the axes are to be changed so that the points fall in this plane again. This change must be borne in mind when taking the wind directions.

REFERENCES

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