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A SIMPLE METHOD FOR THE COMPUTATION OF WIND VALUES FROM THE FINNISH RADIO THEODOLITE RECORD

by

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In connection with the theory of the Finnish radiotheodolite, VÄISÄLÄ (1) has presented a numerical method for the computation of wind values from the observations made with the radiotheodolite. Later, VÄISÄLÄ and WILSKA (2) have developed a graphical method for the same purpose. At Ilmala observatory, where experiments have been carried out with the radiotheodolite during the years 1953 to 1956, a simple procedure for the computation of wind values, presented in this paper, has been worked out.

The radiotheodolite is employed to measure the difference in phase between the signals arriving at two fixed aerials. Two such pairs of aerials are used, placed at right angles to each other and in the same horizontal plane. At the same time as the phase differences N_x and N_y are recorded on a chart moved by a clockwork mechanism, a record of the frequency f of the wave emitted by the radiosonde is also obtained. From these quantities, the azimuth (Fig. 1) and elevation angles (A and h, respectively) of the radiosonde can be determined:

$$tg\, A = \frac{N_y}{N_x}, \tag{1}$$

$$\cos h = \frac{c}{f \cdot a} \sqrt{N_x^2 + N_y^2}\,, \tag{2}$$

where a is the spacing of the aerials in both pairs of aerials, and c is the velocity of propagation of electromagnetic waves (the velocity of light).

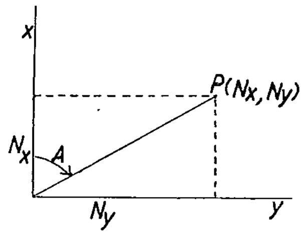

Fig. 1.

Since $a = 120$ m and f, as a rule, is lower than 25.0 Mc/s, N_x and N_y may obtain values smaller than 10. The observed quantities N_x and N_y can thus be plotted on a grid with the N_x and N_y axes at right angles and the number of grid squares, counted from the origin, equalling 10. In this grid, the lines of constant angle of elevation are concentric circles with the point $N_x = N_y = 0$ as centre (and corresponding to $h = 90°$). These concentric circles may be replaced by a scale in terms of the angle of elevation, marked on a rule, which can be rotated about the origin.

According to equation (2), the value of the elevation angle is also dependent on f in addition to N_x and N_y. It is therefore necessary to calculate the elevation angle scale for a fixed value of f. Since the wave close to 24.0 Mc/s emitted by the radiosonde is employed in these measurements, this particular frequency has been used as a basis for the graduation. Let h_0 denote the angle of elevation calculated in this manner, and f_0, N_{x_0} and N_{y_0} the corresponding observed quantities. When the observed frequency deviates to the values f_1 and the other quantities are h_1, N_{x1} and N_{y1}, we have, on the strength of (2),:

$$\frac{\cos h_1}{\cos h_0} = \frac{c}{f_1 \cdot a} \cdot \frac{f_0 a \sqrt{N_{x_1}^2 + N_{y_1}^2}}{c \sqrt{N_{x_0}^2 + N_{y_0}^2}} \quad \text{and}$$

$$\frac{\cos h_1}{\cos h_0} = \frac{f_0}{f_1} \cdot \frac{\sqrt{N_{x_1}^2 + N_{y_1}^2}}{\sqrt{N_{x_0}^2 + N_{y_0}^2}} .$$

If now $h_1 = h_0$, then

$$\sqrt{N_{x_1}^2 + N_{y_1}^2} = \frac{f_1}{f_0} \sqrt{N_{x_0}^2 + N_{y_0}^2} . \tag{3}$$

In this relation, $\sqrt{N_{x_0}^2 + N_{y_0}^2}$ is the distance from the origin obtained at the frequency f_0, i.e., the location of the value in question on the gradua-

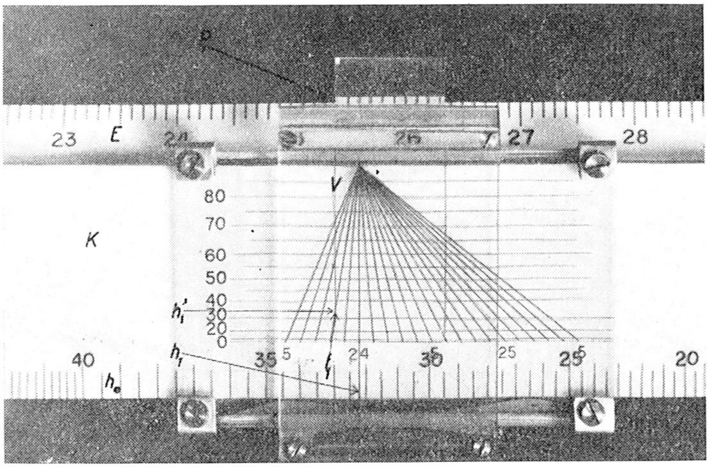

Fig. 2. The nomograph for computation of elevation angle.

ted scale. At other frequencies f_1, the distance $\sqrt{N_{x_1}^2 + N_{y_1}^2}$ is obtained by multiplying $\sqrt{N_{x_0}^2 + N_{y_0}^2}$ by the ratio of the frequencies. According to equation (2), *cos* h_0 is proportional to the distance $\sqrt{N_{x_0}^2 + N_{y_0}^2}$ and the right-hand member of equation (3) can therefore be represented by means of a straight line in a cordinate system with the values of f as abscissae and those of *cos* h as ordinate. In this manner a nomograph is obtained (Fig. 2), with reference to which the angle of elevation corresponding fo the frequency f_1 can be determined from the scale calculated for the trequency f_0. In order to accomplish this, both the rule K and the index line V are positioned to pass through the point P_1 (N_{x_1}, N_{y_1}). The nomograph, containing a cordinate system with the values of f as abscissae and those of *cos* h as ordinates, which is reproduced on a sliding rule moving along the rule K, is positioned so that V passes through the point h_1, f_1 of the nomograph. The value of h read at the intersection with the line passing through $f_0 = 24.0$ Mc/s will then be h_1. Since only the value of h_0 is available for the alignment of the nomograph with the line V, an error is made, which may attain an appreciable magnitude. It is therefore necessary, in practice, to use the value of h_1' of the preceding minute, or the value of the angle of elevation extrapolated from its preceding values.

The obtained point $P_1(N_{x_1}, N_{y_1})$ indicates as such the azimuth of the radiosonde, if the paired aerials are in the N—S and E—W directions.

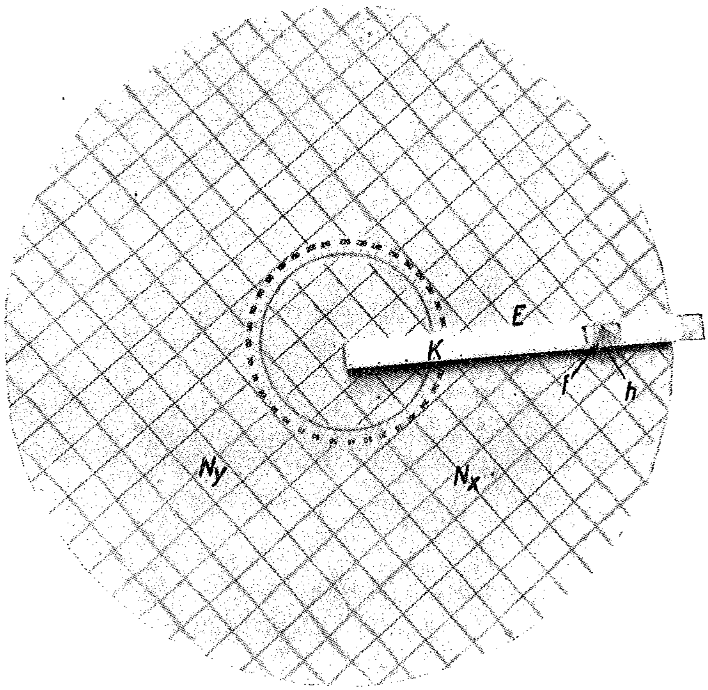

Fig. 3. The grid table with the rule *K* for graphical calculation of wind values.

In the practical application of this principle, the grid spacing corresponding to $N_x = N_y = 1$ has been chosen equal to 50 mm. The diameter of the grid table will then be 1 metre. In addition to the scale representing h_0, another scale is provided on the rule *K* (Fig. 3), giving the horizontal distance of the balloon from the point of departure. The path of the balloon is plotted on the table with the aid of this scale after its distance has been computed from the elevation angle h_1 and the heigt H by the formula

$$E = H \, ctg \, h_1$$

For this computation either the slide rule, or tables or a calculating machine can be used. The distance scale (E) has been chosen equal to that used in the calculations based on optical theodolite observations, in order that the same graduation may be used, regardless of which of the two types of theodolite the observations may have been made by. This has the advantage that an immediate comparison between the results obtained by optical and by radiotheodolite is made possible.

Sufficient accuracy is as a rule obtained with the procedure described in the foregoing. Its application does not require any great amount of special training. Moreover, its use allows the required speed of work, quite an important factor from a viewpoint of communication of the results.

REFERENCES

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2. VÄISÄLÄ, VILHO and YRJÖ WILSKA, 1956: A graphical method for computing wind values from the Finnish radiotheodolite record. *Geophysica* 6, 7—12.