6. Technology of production of a video map

In the process of preparing the map the following stages may be distinguished:

1) Collection and evaluation of the source materials.

2) Preparation of a compilation manuscript.

3) Transformation of geographical coordinates to rectangular plane coordinates (of those elements which are determined by means of geographical coordinates).

4) Elaboration of first copy of the map.

5) Elaboration of a fair copy of the map.

6) Production of the final form of the video map.

6.1. *Collection and evaluation of the source materials*

The collection and evaluation of source materials are the particularly important stage in the process of map elaboration. The essential value of the map depends on proper selection and evaluation of these materials. Underestimation of significance of these works or their unproper preparation may cause errors in the process of map editing and thus threaten to safety of flight in the air space.

Therefore, the existing source materials should be carefully completed and thoroughly analyzed from the standpoint of their topicality and accuracy requirements with respect to particular groups of elements of the map content.

The following data may be used as the source materials:

1) Geographical coordinates of the position of the radar head, of the points designating location of radionavigation equipment, of the points indicating boundaries of the unsafe zones, the limited and controlled zones, of the points indicating axes of airlines and air routes, of the points determining the location of air interferences.

2) Data referring to orientation of the map (geographical or magnetic).

3) Data relating to the generator time base.

4) Air maps and sketches, presenting the elements of the map content, mentioned in the item 3 as well as the other data as the FIR boundary, boundary of the State, coastline of the sea, directions of runways, sectors of vision of the precise radar, servo-navigation equipment on the elongations of the runways, etc.

5) The other data which should be included in the video map content, according to the opinion of the map user.

6.2. *Production of the compilation manuscript of the map*

The compilation manuscript is made on the transparent drawing film on the basis of completed and thoroughly analyzed source material.

The following rules should be considered during the selection of the scale of the compilation manuscript:

— the compilation manuscript ought to be prepared at the scale similar to the scale of the first copy,

— the scale of the compilation manuscript should be several times larger than the scale of the video map.

The most proper source material for producing the compilation manuscript is the aeronautical map at the scale 1:1 000 000 with geographical grid. The compilation manuscript is prepared in such a way that full content of the video map is introduced on the drawing film, overlapping the aeronautical map. It is performed on the basis of geographical coordinates and the other source materials. Correctness of introduction of the thematic content should be checked with the content presented on source maps and sketches.

In a case of lack of data, allowing for designing of the thematic content, all doubts should be explained and corrected, lacking source materials should be supplemented and necessary corrections should be introduced on the compilation manuscript. After verification the thematic content should be drawn by conventional signs, given in Table 1.

The compilation manuscript should be accepted by the user of the map.

6.3. *Transformation of geographical coordinates, determining the position of particular elements of the map content to rectangular plane coordinates*

In order to produce the first copy of the video map in the azimuthal, oblique, equidistant projection, it is indispensable to determine graticule intersections and the grid, and all points determining thematic elements of the map content in the rectangular plane coordinates system.

Since, however, the essential elements of the map content are usually determined by means of geographical coordinates φ and λ, it is necessary to transform them to rectangular plane coordinates x, y.

From the practical standpoint, the problem relies upon the definition of the relations between geographical coordinates φ and λ (the values of which are given) and azimulthal coordinates z and α of the point on the sphere.

Let BB_1 determine the rotating axis of the terrestrial globe, GG_1 — the diameter between the main points, P — an arbitrary point located

on the surface of the globe. Its location is determined by the φ, λ coordinates in the geographical coordinates system or the z, α coordinates in the azimuthal coordinates system (Fig. 4).

In order to determine the relations between φ, λ and z, α coordinates, the spherical triangle GBP will be discussed; its GP side is the arc of the vertical circle of the point P, corresponding to the z angle, GB side is the arc of the meridian passing through the point G, corresponding to the angle $90^\circ - \varphi_o$, BP side is the arc of the meridian passing through the point P, corresponding to the angle $90^\circ - \varphi_o$, the G vertex angle is equal to the azimuth of the GP line and the B vertex angle is equal to the difference of geographical longitudes of P and G points.

It is assumed that geographical coordinates of the point G are known. From the spherical triangle GRB, on the basis of rules of spherical triginometry it can be determined that:

$$\cos z = \cos (90^\circ - \varphi_o) \cos (90^\circ - \varphi) + \sin (90^\circ - \varphi_o) \sin (90^\circ - \varphi) \cos (\lambda - \lambda_o),$$

so

$$\cos z = \sin \varphi_o \sin \varphi + \cos \varphi_o \cos \varphi \cos ((\lambda - \lambda_o) \tag{5}$$

$$\sin z \cos z = \cos (90^\circ - \varphi) \sin (90^\circ - \varphi_o) - \sin (90^\circ - \varphi) \cos (90^\circ - \varphi_o) \cos (\lambda - \lambda_o)$$

$$\sin z \cos z = \sin \varphi \cos \varphi_o - \cos \varphi \sin \varphi_o \cos (\lambda - \lambda_o) \tag{6}$$

and

$$\frac{\sin z}{\sin (\lambda - \lambda_o)} = \frac{\sin (90^\circ - \varphi)}{\sin \alpha}$$

thus

$$\sin z \sin \alpha = \cos \varphi \sin (\lambda - \lambda_o) \tag{7}$$

dividing (6) by (7) it is obtained:

$$\operatorname{ctg} \alpha = \frac{\operatorname{tg} \varphi \cos \varphi_o - \sin \varphi_o \cos (\lambda - \lambda_o)}{\sin (\lambda - \lambda_o)} \tag{8}$$

By means of the equations (5) and (8) the azimuthal coordinates z and α of the point P may be calculated, if its geographical coordinates are known.

If geographical coordinates of certain points correspond to determined z and α coordinates, rectangular coordinates may be calculated by means of the following formulae:

$$\begin{aligned} x &= \varrho \cos \alpha \\ y &= \varrho \sin \alpha \end{aligned} \tag{9}$$

The radius ϱ of the almucantar parallel of the point P (of the zenithal longitude z, fig. 5) is calculated on the basis of the equation:

$$\varrho = \pi R \frac{z}{180^\circ} = R \operatorname{arc} z \tag{10}$$

Equations for calculating rectangular coordinates of the point of intersection of the vertical circle α and the almucantar parallel z have the final form:

$$\begin{aligned} x &= R \operatorname{arc} z \cos \alpha \\ y &= R \operatorname{arc} z \sin \alpha \end{aligned} \qquad (11)$$

Making use of the above-mentioned formulae, geographical coordinates should be transformed to rectangular plane coordinates for all the points, the localization of which has been determined by means of geographical coordinates, as well as for such points, for which it is possible to calculate these coordinates.

The following sequence of operations is advised for the calculations:

— determination of geographical coordinates φ_o and λ_o of the central point (of the radar head);

— determination of geographical coordinates φ and λ of point elements of the map content;

— determination of the accuracy of calculations;

— calculation of azimuthal coordinates z and α of point elements of the map content;

— calculation of the radius of almucantar parallels (of altitude);

— calculation of rectangular plane coordinates x and y of point elements of the map content.

Independently on the transformation of coordinates of point elements of the map content it is also necessary to calculate rectangular plane coordinates of graticule intersections and the grid of squares, what enables to map in the elements of content, which are determined by geographical coordinates.

The calculated in such a way rectangular plane coordinates may have positive as well as negative values, since they are referenced to the system, the center of which is located at the point of the site of the radar head. In order to simplify further work it is necessary to shift the system of coordinates, so that all the coordinates would have positive values. The final list of coordinates ought to comprise numbers of points and values of coordinates fitted to the scale of elaboration of the first copy of the radar map.

The transformation of coordinates ought to be performed independently by two persons. The results of the two independent calculations should be checked and compared in order to detect possible errors and to introduce corrections.

6.4. *Elaboration of the first copy of the map*

During the elaboration of the first copy of the video map it is important to determine the scale of its elaboration. The choice of the scale is conditioned by technical aspects, by technical parameters of the radar

equipment as well as by cartographic reasons connected with the readability of the map and with the photomechanical process of reducing the map in the final stage of its elaboration. Technical parameters of the radar equipment, such as the basis of time of the generator, the frequency of repeating the pulses, and the number of rotations of the radar antenna per minute, very exactly determine the dimensions of the video map.

Since the assumed basis of time of the generator of the AVIA-BM radar equipment equals to 300 km, and the video map must be included in the circle of the diameter of 50,8 mm, thus it is easy to calculate that the scale of the video map will be equal 1:5 905 512.

Considering the requirements related to the accuracy of preparation of the video map, it is necessary to elaborate the first copy of this map.

The practice in this field proves that the most appropriate scale for preparation of the first copy is 1:1 000 000. It follows from the fact that the aeronautical map constituting the kind of the background source material and the compilation manuscript of the map was prepared at this scale. It facilitates both drawing up of the map content on the first copy as well as the control of its correctness, by comparison with the compilation manuscript.

Comparing the scale of the video map (1:5 905 512) with the scale of the first copy — 1:1 000 000 — may be observed that the scale of the first copy will be 5,9 times larger. Conventional signs, being applied to preparation of the first copy have to be also 5,9 times enlarged (see Table 1).

For maintaining the required reliability, the first copy should be prepared on the cartographic sheet with the aluminium plate or on the stable polyester cartographic film.

Mapping particular elements of the map content, determined by the rectangular plane coordinates, should be performed by means of a high precision plotter. Accuracy of plotting is controlled by overlying of the compilation manuscript upon the first copy and comparison of the respective elements of the content. After checking and possible correcting the errors, the points mapped by the plotter will constitute grounds for construction of the remaining map content.

The drawing of the first copy is traced with a pencil in agreement with conventional signs given in Section 4 of the paper.

Besides the content comprised inside the circle, it is necessary to plot, on the meridian crossing the central point, 397,5 mm North and South of the central point, two adjusting (standard) symbols in the form of black squares with white crosses indicating the centres of these symbols. These symbols, of strictly qualified dimensions 73,8 × 73,8 mm, are indispensable for proper placing the video map in the adjustable carriage of the AVIA-BM radar equipment.

After elaboration of the first copy, it is obligatory to check the accuracy of overlying the content by comparison with the compilation manuscript. The verified first copy ought to be submitted to the acceptance of the map user. After approval, this first copy becomes the basis for elaboration of the fair draught of the map.

6.5. *Preparation of the fair draught of the map*

Pencil-drawn, verified and accepted by the user, first copy is traced very carefully with black drawing ink according to the conventional symbols given in Section 4.

In the course of drawing linear elements of the map content one should pay attention to the necessity of tangential thickening of radial lines and almost-radial ones. It results from the functioning of the radar device, and particularly from the frequency of repeating the pulses and the number of the antenna rotations per minute. If the radial or quasi-radial line was 0,27 mm thick both on the map margin as well as near the central point, then such a line 5,9 times reduced on the final video map would diappear with moving from the central point. In order to prevent to this phenomenon all the radial lines and almost-radial lines, i.e. those being situated inside the central angle 15° of the vertex in the central point, have to be thickened tangentially. It was computed on the basis of appropriate formulae that the minimum thickness of line on the video map may be of 0,046 mm, whereas at the scale 1:1 000 000 of the first copy of the original manuscript — 0,27 mm.

Tangential thickening of radial and almost-radial lines should be started at the distance 10,8 mm from the central point.

Thickness of these lines on the margin of the first copy should not be smaller than 0,84 mm.

The centring ring, located at the central point, is a very important element of the map content. The reliability of the whole map depends on the reliability of this ring. In view of small dimensions of the ring (two concentric rings of the diameter 0,75 and 1,50 mm), it is difficult to be plotted exactly even on the fair draught of the map. Therefore, its separate plotting with the drawing ink at the large scale is advised, and then it should be photomechanically reduced to the required dimensions and inserted in the central point of the fair draught. The centring ring serves for the proper placing of the video map in the adjusting carriage of the radar equipment.

The fair draught of the map plotted in this way should be carefully checked in respect of its correctness of plotting of all content elements. Particular attention should be paid to the deep and uniform black colour of the drawing plotted with the drawing ink.

The checked fair draught is the basis for preparation of the final form of the video map, as is the glass plate in the form of the negative.

6.6. *Preparation of the final form of the video map*

The final form of the video map, conditioned by technical reasons of the AVIA-BM equipment, should have the form of the negative glass plate of strictly determined dimensions and qualitative parameters.

Considering the above-mentioned requirements, the fair draught of the map has to be very accurately 5-times reduced to the demanded dimensions. The reducing of size is carried out on the photoreproductive apparatus.

The most proper photographic material is the glass plate — Kodak Kodalith Ortho Plate, type 3, dimensions 12 × 16,5 cm.

On account of the possibility of cracking the video map, preparing 2 — 4 extra copies of this map is advised.

Conclusion

On the basis of the above described technology, a series of video map have been elaborated, which have been succesfully applied in practice in the AVIA-BM radar system for controlling and steering the air traffic for the determined areas on the whole terrain of Poland.

Translation: Regina Majewska

ЯН ЦЕСЕЛЬСКИ

ВИДЕОКАРТА ДЛЯ РАДИОЛОКАЦИОННОЙ СИСТЕМЫ УПРАВЛЕНИЯ И КОНТРОЛИРОВАНИЯ ДВИЖЕНИЯ САМОЛЕТОВ В ВОЗДУШНОМ ПРОСТРАНСТВЕ AVIA-BM

Резюме

В статье изложены принципы разработки специальной видеокарты для радиолокационного устройства AVIA-BM, предназначенного для управления и контролирования движения самолетов в воздушном пространстве.

Эти принципы охватывают: подбор соответствующей картографической проекции, определение оптимального объема содержания карты и её графической формы, установление критериев точности видеокарты и технологии её составления. Технологическое описание охватывает следующие действия: сбор исходных материалов, подготовку авторского макета карты, способ пересчёта географических координат в прямоугольные плоские координаты, разработку составительского и издательского оригинала карты, а также подготовку окончательной формы видеокарты, приспособленной для радиолокационного устройства AVIA-BM.

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