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Satellite Equipment for Determining the Overall Planetary Distribution of the Major Atmospheric Emissions — EMO-1

I. Purpose and Research Objectives, Measurement Technique, Optical Diagram and Mechanical Aspects

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Purpose and Research Objectives

The interest shown in the study of the atmospheric emissions is due to the fact that they can be used in obtaining information on:

A. Important aeronomic processes in the ionosphere in the altitudinal range of 60 to several thousand kilometers above the Earth's surface. Significant among these processes are the dissociative recombination of the molecular ions in the E and F ionospheric regions, a large spectrum of ion-exchange reactions, and the radiative recombination.

B. The precipitation of protons and electrons of different energy.

C. The heating of the high atmosphere under the effect of electromagnetic waves of various nature and genesis, and also the detecting of acoustic and inner gravitational waves.

D. The ionospheric-magnetospheric interactions.

E. The study of various aspects of the physics of solar-terrestrial relationships.

Measurements of the spectrum of the luminescent atmospheric layers are usually carried out from observation points fixed on the Earth's surface. This method offers certain advantages (possibility for continuous observations, continuity and homogeneity of the data, etc.), but it has a number of disadvantages as well. In the first place, we would like to refer to the spatial limitations of the data obtained. By way of example we would like to take the case of the magnetospheric-ionospheric interaction. The penetration of energy from the magnetosphere to the ionosphere is not the same at different points of the Earth's surface. This is due to the sectoral structure of the magnetosphere which is related not only to the shape of the terrestrial magnetic field but also to the diurnal rotation of the Earth, to the constant change in the direction to the Sun, for any given point. Consequently, it is not possible to obtain sufficiently complete information for this effect from such a fixed point. The network of observation stations is most unevenly distributed, and observations are often unavail-

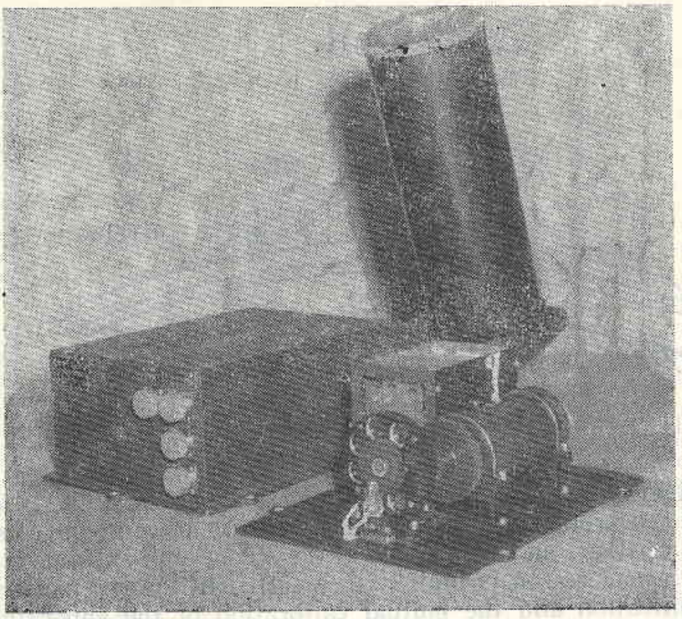

Fig. 1

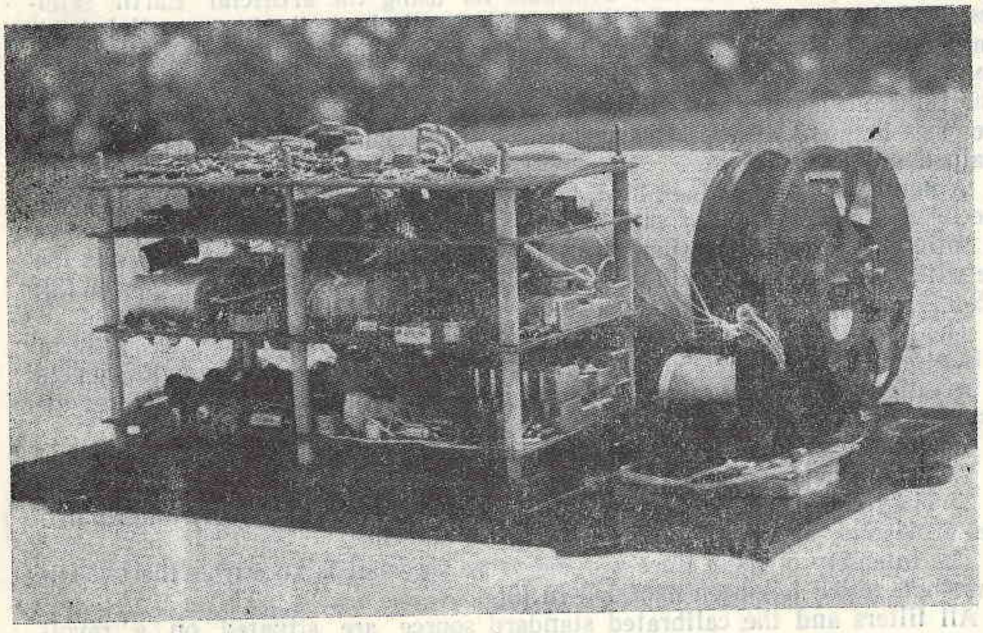

Fig. 2

able where they are most needed, e. g. in the region of the polar casp, in the mid-latitudinal trough, and in the crests of the geomagnetic equatorial anomaly. On the other hand, even if there was a sufficiently complete network of observation stations, their data would not have been sufficient to carry out magnetospheric investigations for the following two reasons: The first one is that in view of the need of synchronization, it becomes necessary to carry out observtions at periods of bad weather, in the presence of the Moon, etc., and this is not always possible. The second reason is that, with a sufficiently large network of observation the unification and the mutual calibration of the apparatuses used is practically impossible. This, of course, will lead to essential differences and to incompatibility of the data obtained.

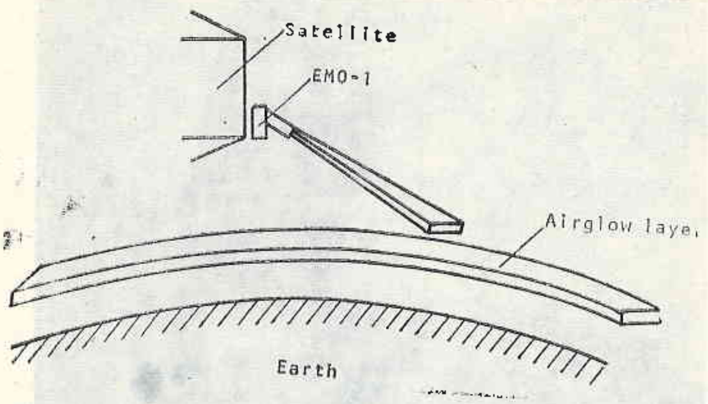

Fig. 3

With the possibilities now available for using the artificial Earth satellites (AES) for research purposes, it is possible to eliminate the two essential shortcomings of the terrestrial apparatuses. By the satellite electrophotometers it is possible to obtain overall planetary characteristics of the atmospheric emissions. And in view of the fact that these apparatuses fly in a complex set with other measurement devices, the scientific justification and the value of the data obtained are much greater.

A number of apparatuses have been developed in the course of the last decade for operation on board various satellites, whose aim is the investigation of the optic atmospheric emissions in a broad spectral and energy range, as is the case with the equipment on board the OGO-4 [1, 2], Atmospheric Explorer [3], ISIS-2 [4, 5] and many other satellites.

The present article describes the electrophotometric apparatuses designed at the Central Laboratory for Space Research of the Bulgarian Academy of Sciences for investigating the overall planetary distribution of the following major atmospheric emissions:

1. The red oxygen double OI $(^3P-^1D)\lambda$ 6300—6364 Å.
2. The green oxygen line OI $(^1D-^1S)\lambda$ 5577 Å.
3. The line λ 4278 Å from the first negative system of the singly-ionized nitrogen molecule.

The intensity of these lines was measured by what is known as the two-filter method which has been explaied in [6].

All filters and the calibrated standard source are situated on a revolving disk.

A general view of the photometer is shown on Fig. 1. Figure 2 shows individual units of the equipment. Figure 3 presents the measurement diagram, realized by means of a satellite with a minimum altitude of 500 km, which is oriented and stabilized with respect to the Earth's surface. The electrophotometer EMO-1 is fitted to the board side and is oriented at a given angle to the Earth's surface ($\gamma=79°$). An analogous diagram is to be found, by way of example, in OGO-6 [7].

The angle γ is selected in accordance with the following considerations. At a minimum altitude of the satellite of 500 km, the optic axis of the photometer must be tangential to the Earth's surface. At the passage to the perigee altitude, and at the perigee, the photometer measures emissions from different atmospheric layers at a certain altitide above the Earth.

Optical Diagram

The selection of the optical diagram is determined by the orbital parameters, by the altitudinal dimensions and the distribution of the emitting layers, and by a certain destabilization of the carrier. In accordance with the above considerations, a rectangular field of vision has been selected with vertical dimension 1° and horizontal dimension 3.5°. The photo receiver was FEU-79 whose spectral curve embraces the range examined with very high sensitivity.

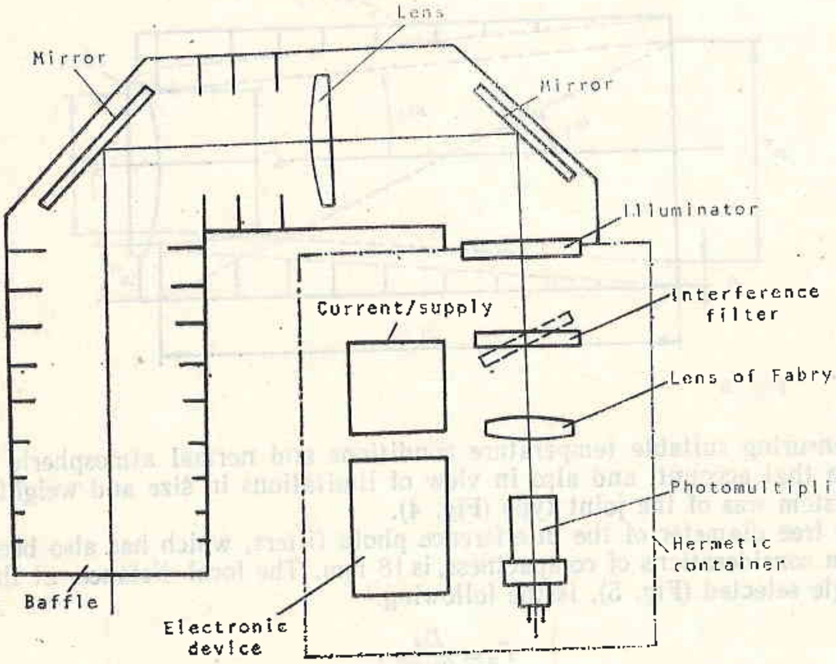

Fig. 4

The principal function of the optical diagram in this case is to improve the signal-to-noise ratio and also to locate the emitting layers. In selecting this system it is sometimes necessary to take account of incompatible and contradictory requirements related to the weight of the device, its size, and its structural and technological requirements. A two-component Keplerian telescopic system has been selected in this case. In order to reduce the weight and to minimize the losses of absorption, two simple lenses were selected for objective and ocular (Fabri's lens).

To ensure the correct operation of the interferential photo filters, the photoelectric multiplier, together with the electron blocks, is placed in a sealed container ensuring suitable temperature conditions and normal atmospheric pressure. On that account, and also in view of limitations in size and weight, the optic system was of the joint type (Fig. 4).

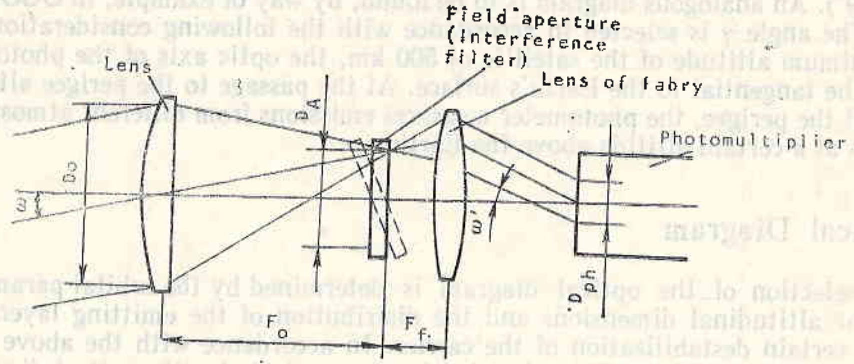

Fig. 5

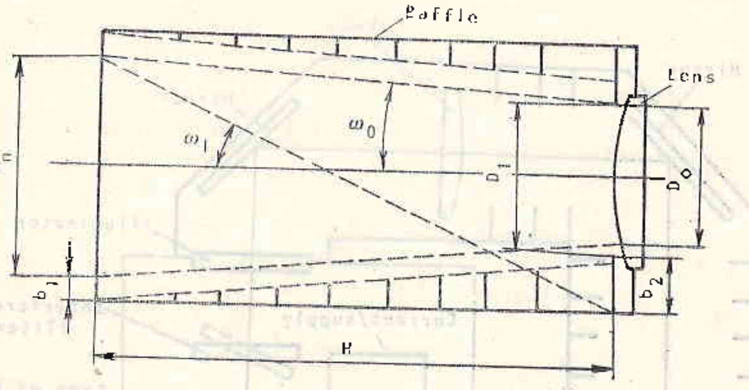

Fig. 6

The free diameter of the interference photo filters, which has also been selected on considerations of compactness, is 18 mm. The focal distance, at the visual angle selected (Fig. 5), is the following:

(1) $$F_0 = \frac{D_d}{2\operatorname{tg} W_0},$$

where F_0 is the focal distance of the objective, D_d is the size of the blind of the visual field, and W_0 is one-half the angle of the visual field. In this case, at a visual angle of 3.5°, the focal distance of the objective is 284.2 mm.

The basic ratio for the telescopic systems is

(2) $$\gamma_0 = \frac{F_0}{F_{jf}} = \frac{D_0}{D_0'},$$

where F_{II} is the focal distance of the ocular (Fabri's lens), D_0 is the diameter of the input aperture (coinciding with the diameter of the objective), and D_0' is the diameter of the output aperture.

With a view to the optimum utilization of the optic system as a transmitter of photoenergy, it is necessary for the photocathode of FEU to be in the plane of the output aperture. Besides that, the output aperture must be equal to or smaller than the diameter of the photocathode. Then it follows from (2) that at a 60 mm diameter of the objective we shall have

$$\gamma_0 = 10 \text{ and } F_{\text{II}} = 24.42 \text{ mm}. \tag{3}$$

The operation of the apparatus is accompanied by the influence of strong sources of light situated close (at an angle) to the regions subject to measurement. These sources usually have radiation energy (their own or reflected) exceeding the energy measured. The tube with protective diaphragms (Fig. 6) is used to eliminate the influence of these sources. The principal dimensions of this system are determined from the following formulae

$$D_1 = \frac{D_0}{\operatorname{tg} W_1 - \operatorname{tg} W_0}, \tag{4}$$

where D_0 is the free diameter of the objective, W_1 is the angle of the protection, and W_0 is one-half the angle of the visual field.

$$H_{\min} = \frac{(D_1 + B_2) \cos (W_1 + \Delta W_1) \cos W_0}{\sin [(W_1 + W_1) - W_0]}, \tag{5}$$

where B_2 is the depth of the blind and ΔW_1 is the angle of deflection of the axis of the apparatus from its nominal position as a result of the incomplete stabilization of the object.

$$D_p = D_0 \frac{\operatorname{tg} W_1 + \operatorname{tg} W_0}{\operatorname{tg} W_1 - \operatorname{tg} W_0}. \tag{6}$$

In this formula D_0 is the diameter of the last diaphragm.

All diaphragms have sharp edges and curvature radius not exceeding several microns. In order to reduce the background noise from the edges, only the first and the last diaphragm are situated outside, parallel to it at a distance B_1.

The position of the diaphragms along the axis has been determined graphically. In order to reduce the amount of the dispersed light, the inside of the tube is furrowed and light-absorbing coatings are laid on the polished diaphragms.

To reduce the dispersed light in the optical glass, the latter has been selected with minimum bubbles and non-uniformities in its structure.

We know that under conditions of radiation the optic glasses reduce their transparency coefficient and become stained. This leads to errors in measurement. Special types of glass have been selected in order to avoid this shortcoming, and their properties are not affected by the radiation.

Mechanical Equipment

The body of the EMO-1 device consists of the following principal units (Fig.7): base (1), cover (3) and tube with protective diaphragms (2). Fitted to the base are the unit with FEU, the electronic block, the disk with the filters, and the step-by-step generator.

This design provides for easy assembly and adjustment of the device, since free access is obtained to the basic unit by the removal of the cover. The base has six apertures by means of which the device is attached to the carrier, thereby providing for efficient heat exchange. The cover (3) ends in a flange whose groove contains vacuum rubber 4 mm thick. The casing of the optic system is fitted to the front part of the cover. The latter ends with a socket in which the tubes with the optic elements are secured. Further fitted to the cover are an illumination admitting the photo flux to the sealed part of the device, four sealed connectors and a pipe connection for filling the device with inert gas.

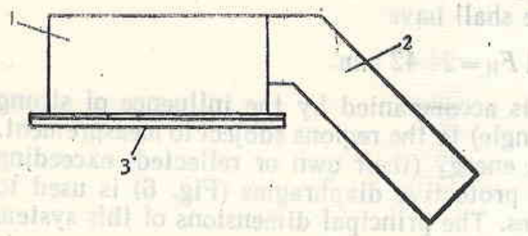

Fig. 7

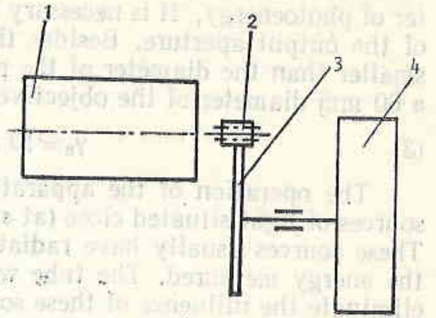

Fig. 8

Kinematic Diagram

In selecting the kinematic diagram the aim is to perform the cyclic rotation of the disk with the interference photofilters by a minimum number of elements. Out of the possible solutions — ratchet gear, Geneva wheel, driving with single-revolution clutch, and step-by-step motor, the choice fell on the last one. Fig. 8 shows the kinematic diagram of the drive. The step-by-step motor with bipolar control has the following characteristics: supply voltage 15 V, power 1.5 W, and weight 0.7 N. The control of the motor is shown on the block diagram shown on Fig. 9, in which PG is a generator of tact pulses, CR is a resolution circuit, PM is a prohibiting monovibrator, ID is a pulse distribution, PA is a power amplifier, and M is a step-by-step motor.

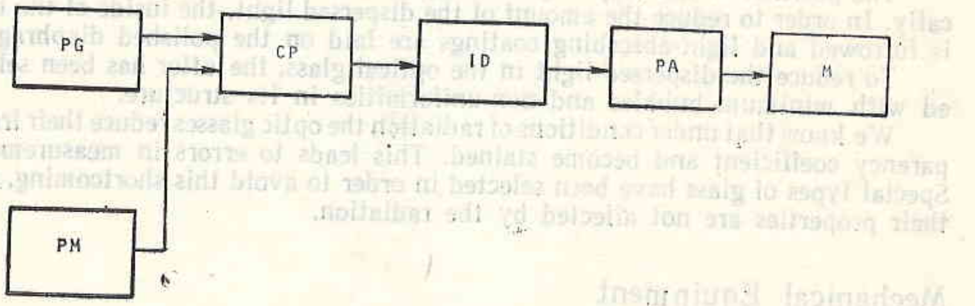

Fig. 9

The pulse generator provides rectangular pulses with a period $T=200$ ms. These pulses are sent to the pulse distributor while there is no ban from PM. The prohibiting pulse from PM has a duration of 1.2 sec. The pulse distributor ID converts the pulses received into a two-phase system (Fig. 10), phases A and B.

These rectangular pulses from the power amplifier are fed to the step-by-step motor M. Integrated logic circuits have been used in the design of PG, PM, ID and CP.

The power amplifier PA is of the non-reversive type and is fed by a d. c. supply. PA consists of two identical channels amplifying the ID pulses obtained.

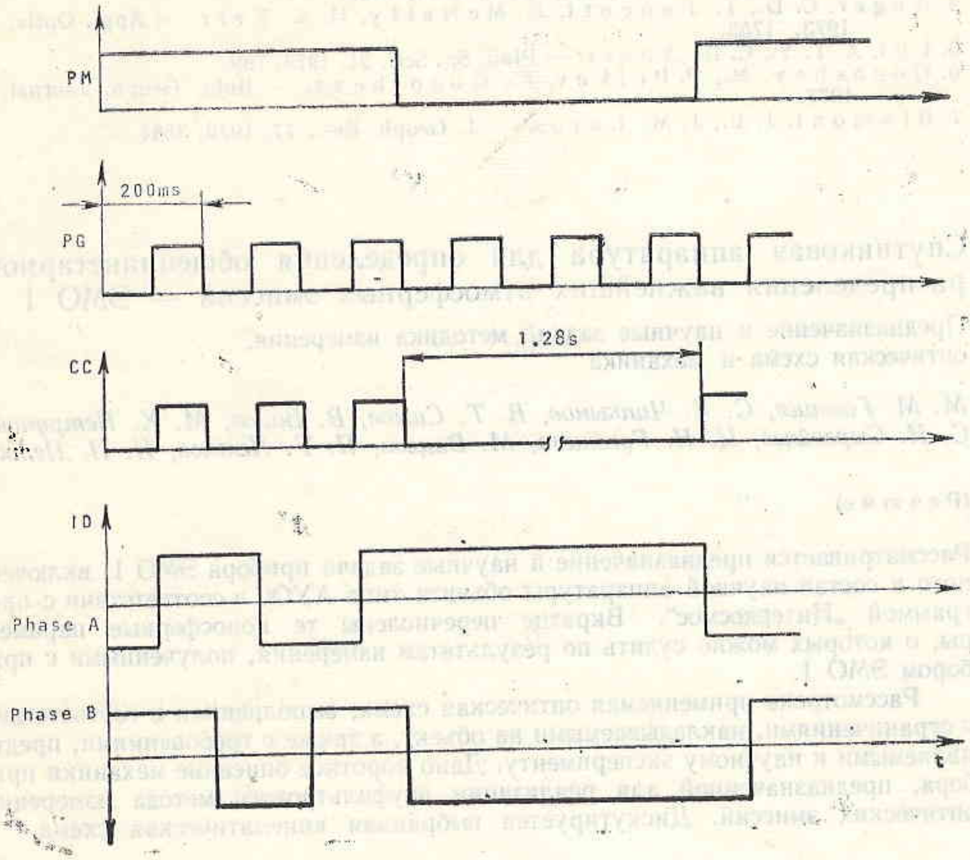

Fig. 10

The PA amplifier is designed with silicon transistors operating on a key pattern.

The step-by-step motor, according to the block diagram on Fig. 10, will move until it receives a prohibiting impulse from PM. Upon reaching a particular position, the motor and the disk with filters connected to its axle stop for a certain time, during which a measurement is taken. After that the motor is reset. The eight positions of the disk are covered successively in this manner.

When two of the authors (M. G.and Ts. G.) first suggested the idea of using these apparatuses, it obtained full support and its realization became possible thanks to the active assistance of Professor K. Serafimov, Corresponding Member of the Bulgarian Academy of Sciences and Director of the Central Laboratory for Space Research in Sofia. The authors would like to express their warmest gratitude to him.

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Спутниковая аппаратура для определения общепланетарного распределения важнейших атмосферных эмиссий — ЭМО 1

Предназначение и научные задачи, методика измерения, оптическая схема и механика

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(Резюме)

Рассматривается предназначение и научные задачи прибора ЭМО 1, включенного в состав научной аппаратуры объекта типа АУОС в соответствии с программой „Интеркосмос". Вкратце перечислены те ионосферные параметры, о которых можно судить по результатам измерения, полученными с прибором ЭМО 1.

Рассмотрена применяемая оптическая схема, выполненная в соответствии с ограничениями, накладываемыми на объект, а также с требованиями, предъявляемыми к научному эксперименту. Дано короткое описание механики прибора, предназначенной для реализации двуфильтрового метода измерения оптических эмиссий. Дискутируется выбранная кинематическая схема.