BULGARIAN ACADEMY OF SCIENCES
SPACE RESEARCH IN BULGARIA, 3
Sofia · 1980

Development of Information Possibilities of Scientific Satellite Experiments

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A determinant factor in the contemporary stage of space research is the rapid increase of the information flux necessary to be transmitted to ground-based receiving stations. That is why special attention is paid to the information capacity increase in complex experiments, preserving the information capacities of the service satellite systems. This refers mainly to experiments involving studies of the structural parameters such as space plasma, solar wind and planetary atmosphere.

The problem of increasing the information possibilities in satellite experiments could be considered in two aspects, namely:

— The necessity to compress the information taken by the satellite, aiming at the decrease in the number of telemetric channels used. In this manner the possibility is created of performing new experiments and of using classical equipment for new additional measurements.

— The necessity, when a definite type of telemetric system is available (with limited information capacity), to establish conditions for recording data in special time intervals. This is the so-called intermediate information storage.

In the case of information compression the data are transformed so that, with quality preserved, the energy or the frequency band during emission is decreased, or the memory volume in data storage is reduced. The "shrink" effect cannot be determined simply as it depends exclusively on the methods of primary data presentation. Usually, with a given source whose limits are known in advance, this effect is evaluated by the degree of approximation to a minimum admissible volume to secure the informative capacity of its data.

There are three methods of information compression which are used more frequently. The first one is based on statistical coding and is subject to the theory of information. In this case the discrete data obtained through the phenomenon recorded are presented with the help of a definite number of symbols. During the statistical processing the volume of data stored is decreased, as the quantities which do not contain information for a given parameter are reduced.

The second method of compression is known as the interpolation and extrapolation method. Its effectivity does not differ from the first one, but it is easier to perform and can be applied successfully in cases when the parameters of the source are not fully known. This method usually involves partial approximation of the initial characteristics to a known simpler function. Afterwards, instead of the entire characteristics, only the parameters specifying each sector of the approximating curve are transmitted [1].

The third method is applied usually in statistical measurements. In this case the experimenter is interested not in the momentum quantities of the parameter observed but in its mean value, dispersion, derivatives, etc. The replacement of the initial parametric totality by some of its characteristics is designated as parametric separation. This results in rapid volume reduction of transmitted or stored data. Typical of this method is the performance of inconvertible initial data transformations. So there are some doubts as to whether it can be taken as a compression method. It is clear that the final result makes it possible to relate this method to the one described above, notwithstanding the fact of the qualitative transition to a new data totality [2, 3, 4]. This method might require verification of the agreement between the data obtained during the experiment and the mathematical model of the phenomenon. It is a problem solved basically by statistical methods in the ground-based receiving stations.

In addition to the above methods there are others which, through one designation or another, could be related to the types already listed but which possess their own specificities.

By way of example we shall consider the information compression in probe methods of plasma diagnostics. These methods are used in studying the voltage-current dependence of conductor (probe) immersed into the space plasma. Usually a linearly changing voltage is applied to the electrode immersed in the plasma, and measurements are taken of the probe current of the input of a DC amplifier connected with the electrode (collector). The sawtooth sweep and the current signal amplified and transformed into voltage are recorded simultaneously. It is obvious that in order to transmit the volt-ampere characteristic thus obtained we need telemetry with sufficiently big capacity. This restricts the experiments performed on the same carrier and is not admissible, taking into account the fact that the probe measurements are usually accessory. In this case, the use of the equipment described in [3] to determine the probe characteristic derivatives reduces many times the volume of the information transmitted. The method described in [3] and the equipment initially used onboard the Ariel-1 satellite are interesting from the point of view of the possibilities provided for fully utilizing the Langmuir probe specificities. Measurements might be taken in this case of the thermal ion densities and temperatures (ion trap) or of the electron densities and temperatures (electron probe) in the ionosphere.

In the equipment considered use is made of the fact that the information necessary for the volt-ampere characteristics occurs in a more suitable and reasonable form if one deals with the curve derivatives.

The expression for the curve sector related to electron retarding can be presented as follows:

$$i_e = i_{e0} \exp\left(\frac{eU}{kT_e}\right) - i_+ - i_p ,$$

where U is the probe potential (negative) with respect to the space potential; and i_+ and i_p are the positive ion current and the photocurrent, respectively. As U is negative, the i_+ and i_p currents change with the change of U much less than the current i_e. Then we obtain after differentiation by U

$$i'_e = \frac{e}{kT_e} i_e - \frac{ai_+}{aU} - \frac{ai_p}{aU} \approx \frac{e}{kT} i_e ,$$

as well as

$$i''_e \approx \left(\frac{e}{kT_e} \right)^2 i_e ,$$

therefore

$$\frac{i'_e}{i''_e} = \frac{kT_e}{e} .$$

For the linear part of the semilogarithmic characteristic this ratio is constant and its transmission by the telemetric system requires much smaller dynamic range than is the case when the curve itself is transmitted. Besides the electron temperature we can obtain the electron density, as this value corresponds to the refraction point of the characteristic.

The circuit used to obtain the derivatives is shown on Fig. 1. In order to determine the slope and the curvature of the characteristic, two voltages with small amplitudes are amplified and mixed. If the AC voltages are presented in the form of $U_1 \cos(\omega_1 t + \varepsilon_1)$ and $C_2 \cos(\omega_2 t + \varepsilon_2)$, where $\omega_1 \ll \omega_2$, then the expression for the current i could be written in the form of a row

$$i = i_e + i'_e [U_1 \cos(\omega_1 t + \varepsilon_1) + U_2 \cos(\omega_2 t + \varepsilon_2)] + i''_e [U_1 \cos(\omega_1 t + \varepsilon_1) + U_2 \cos(\omega_2 t + \varepsilon_2)]^2 + \cdots ,$$

where the currents and their derivatives relate to values corresponding to the DC voltage value along the sweep at the moment t.

In this way the amplitude of the component with angular frequency $\omega_2 (U_2 i'_e)$ yields the value of i'_e. In the circuit an automatic adjustment of gain is employed to keep constant the output signal of the first amplifier. The value i'_e which changes within broad limits is determined by the voltage of the automatic adjustment circuit. The quadratic term in the expression contains the component

$$2 U_1 U_2 \cos(\omega_1 t + \varepsilon_1) \cos(\omega_2 t + \varepsilon_2) \, i''_e .$$

Therefore, the second output signal gives the modulation relative depth which is proportional to $2 U_1 i''_e$.

The circuit shown in Fig. 1 differs from the one used in Ariel-1.

The reasons for making the given circuit complicated lie in the inconvenience of the suggested method. Actually, the above reasoning assumes that any deviation of the current carriers from the Maxwellian distribution would occur in instability of the ratio i'_e / i''_e and could be identified. In the general case, this is not observed even at net electron measurements where a sharp carrier potential change (in transition from light to nonlight orbital sector and the reverse, when other items of probe equipment are operating on the same carrier-satellite) could result in operation out of the linear-logarithmic region of the volt-ampere characteristic.

On the other hand, any occurrence of a new type of positive ions is reflected in a new slope of the volt-ampere characteristic for the ion measurements. This makes it still more difficult to decode the type of the characteristic derivatives. In general, the unavailability of the authentic volt-ampere characteristic is an essential defect which constitutes a specific feature of the third type of methods for information compression.

To a certain extent the reliability of the method [4, 5] could be increased by telemetry through given sufficiently long time intervals and the authentic volt-ampere characteristic. Furthermore, as shown on Fig. 1, it is possible to use the same number of telemetric channels. The full equipment description for Fig. 1 is given in [6].

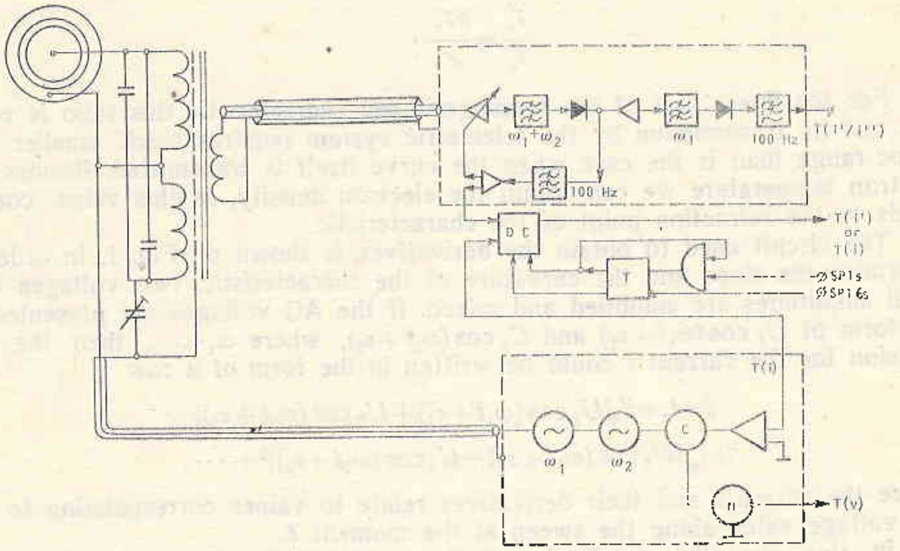

Fig. 1. Circuit diagram: DC — diode commutator, T — trigger, SP 1s and SP 16s — synchropulses, C — converter

Everything said until now refers to the first aspect of the problem of information possibility increase in satellite experiments.

If we continue developing the case presented in Fig. 1, we shall notice that all observations relate to direct data transmission regime, when the telemetric system information possibilities are sufficiently large. When we pass to data memory regime, basic for most of the satellite experiments, the number of points transmitted per time unit from the characteristics of interest decreases rapidly.

In probe experiments the interpretation is impossible in the case of a small number of points (e. g. under 12). That is why experimenters reach a compromise solution — decrease of the number of characteristics used at the expense of an increase of the number of points transmitted from a separate characteristic. This is the second aspect of the problem of information possibility increase, as mentioned in the initial part of this paper, namely, the establishment of record conditions in determined time intervals of interpretable data. The other denomination of this method is intemediate information storage.

The method consists of the following [7]: Over a certain period of time discrete measurements are performed with relatively large frequency of discretization, after which values obtained in the discrete measurements are transmitted over a period of time several times longer than the measurement period. Thus we obtain a picture of the measured volt-ampere characteristic, stretched in time for establishing, under the above conditions, in order to increase the number of points transmitted at the expense of the number of characteristics taken down.

The block circuitry of such a memory device designed on the basis of the intermediate memory method is shown on Fig. 2. For considerations of convenience the operation is described based on a concrete circuit version. The master oscillator (MO) with square angle oscillation frequency of 65,563 kHz feeds the electron switch (S) through the divider (DV-256) with square voltage frequency of 256 Hz. The switch S is maintained by a synchronizer-convertor (S-C) [3] at the input of which a synchronizing voltage "meander" type U_M enters with a 2 s period of repetition (Fig. 3a). At the output of the S-C we obtain voltage U_{S-C} as shown on Fig. 3b. Therefore the record time T_{write} (1 sec in this case) of the controlling input of the switch S has a logical "0" and the reading time T_{read} (8 s in this case) has a logical "1". In the time interval "record" 256 strobes are fed V_{S1} (Fig. 3d) through the astable multivibrator AMV 1 to the A-D converter (ADC), i. e. at the rate of 256 measurements per second. At the same time, through the binary counter, up to 256 (BC-256) RAM memory addresses with organization 256×8 (Fig. 3c) are involved. As in the concrete case use is made of RAM type 1101a with access time of about 1 s, there immediately follows a transformation time requirement of ADC 1 s. As seen from Fig. 2, the A-D converter is of 8 bits with parallel output which feeds the memory. The control voltage from S-C feeds the bus READ/WRITE (R/W) as during the record there is a logical "1" at the input R/W and a logical "0" during reading.

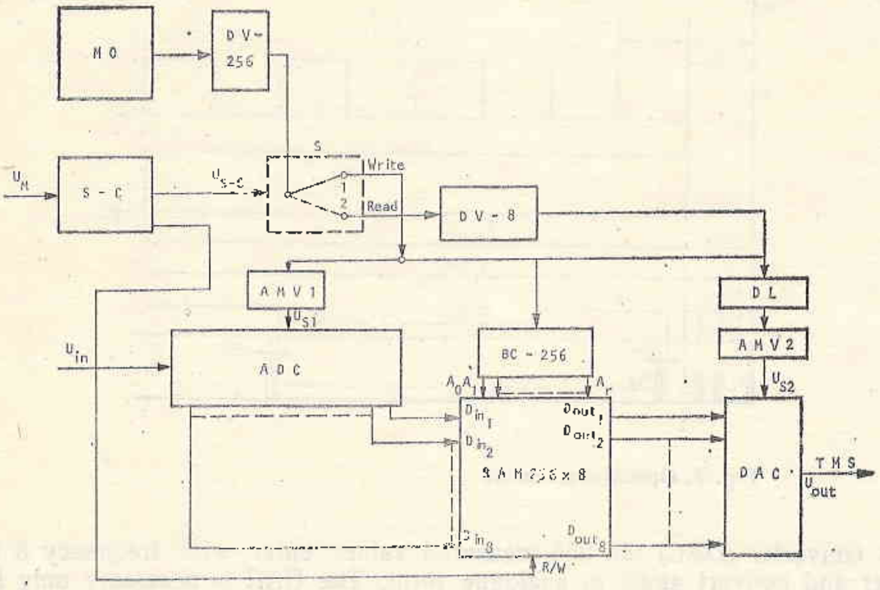

Fig. 2. Block-diagram of the memory unit: MO — master oscillator, S — electron switch, S-C — synchronizer-converter, ADC — A-D converter, BC-256 — binary counter, DV-8 and DV-256 — dividers, AMV 1,2 — multivibrators, DAC — D-A converter, RAM — real access memory

The recorded information is transmitted after the measurement (T_{read}). The switch S is in position 2. The frequency divider DV-8 reduces 8 times the frequency of the memory addresses involvement. The delay line DL is necessary to shift the strobes U_{S2} (Fig. 3d) from the astable multivibrator AMV_2 to 2 s with respect to the pulses controlling the addressing counter BC-256 (3c). This necessity arises from the time of memory access. So at the input of the D-A converter (DAC) the 256 measured values enter with frequency 8 times lower and convert again in analogue form. The DAC is necessary only if the telemetric channels by which the information is transmitted are in an analogue form. In case they are digitals the DAC drops out of the circuit.

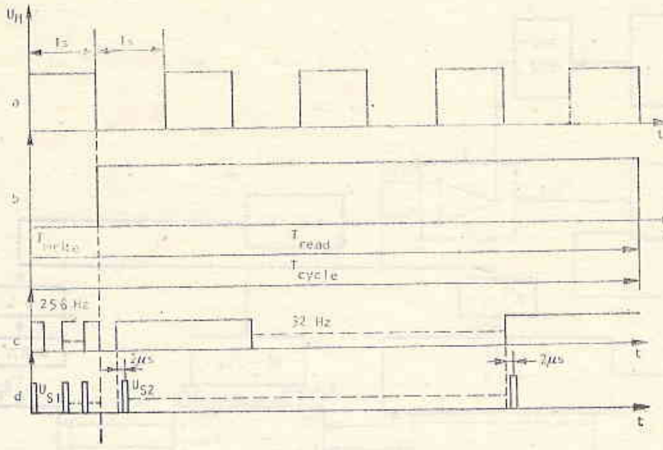

Fig. 3. Operations scheme

As the suggested intermediate memory device is used in different probe experiments with different types of volt-ampere characteristics, it is very difficult to determine simply according to Kotelnikov's theorem the necessary number of discrete measurements. That is why, on the basis of the structure shown in Fig. 2, it is possible to use storages of different capacities, as the frequency of the master oscillator and the capacity of the addressing counter would be subject to change.

Besides that, in the availability of digital telemetric channels, it is possible to use several telemetric channels simultaneously, especially in data transmission, with a certain complication of this structure. When we dispose of a microprocessor with an appropriately given programme (e. g. by first or second derivative change) the possibility arises of processing the volt-ampere characteristic recorded in the memory and of transmitting information only for special points from it.

Conclusion

The devices discussed above have been developed at the Central Laboratory for Space Research of the Bulgarian Academy of Sciences. Notwithstanding the fact that they are intended for probe measurements, the principles involved in their design could be employed in any type of space research where the final result is an analogue signal (volt-ampere characteristic). The reasonable employment of the possibilities of increasing the effectivity of space experiments would lead to the full use of the experimental technique and equipment and of the satellite system. This could open up an entirely new stage in this field, particularly in routine space morphological measurements.

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Повышение информационных возможностей научных спутниковых экспериментов

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(Резюме)

На современном этапе исследования космоса изучаются связи между явлениями, установленными прежними измерениями, и закономерностями в околоземном космическом пространстве. Это требует осуществления комплексных научных экспериментов. Резко возрастает поток научной информации, которая передается на наземные приемные станции. На этом этапе приходится решать вопросы, связанные с уплотнением информационных каналов; с сжатием передаваемого информационного потока, когда это возможно и целесообразно, иными словами — с повышением информационных возможностей научных спутниковых экспериментов. Коротко рассмотрены некоторые методы сжатия информации. Анализируется эффективность предварительной обработки информации. В качестве примера рассмотрен частный случай — космический зондовый научный эксперимент. Рассматриваются некоторые зондовые системы с предварительной обработкой сигнала и их информационные возможности.