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*A Telemeter System for Continuous Observations of Cosmic-Ray Intensity**

By SHIN-ICHI YASUE

Department of Physics, Faculty of Science,
Shinshu University
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Abstract

A simple telemeter system was constructed and has been in operation since March, 1972 for sending the cosmic-ray data from the underground observatory to our laboratory in the university. The system was simplified by considering both the distance (~3.5 km) and the amounts of data to be sent. The same punched paper tape as that at the underground is produced simultaneously at our laboratory, through which the remote apparatus in the tunnel can be monitored. A satisfactory data-sending has been obtained by utilizing the present system. Based on the experimental results, some improvements for the future performation are also mentioned.

Introduction

Continuous observations of the cosmic-ray intensity at 50 m. w. e. underground have been made in Matsumoto since April, 1971. The underground site as well as the experimental apparatus of the observation is described in detail by ICHINOSE *et al.* (1972) (hereafter, referred to as Paper I). It is expected that this observation may provide, together with other worldwide observations at the underground, important informations on the behavior of galactic cosmic-ray particles particularly with higher rigidities ($\gtrsim$100 GV).

It is generally acknowledged that in the continuous observations emphasis should be laid on obtaining reliable data without intermittence. Therefore, it is prerequisite to keep the observing apparatus in a stable condition, and to monitor the apparatus constantly for finding any accidents and disturbances. The daily routine check would be thus very important. Our underground observatory is, however, not close to our university, which will make the monitoring more

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laborious. To improve the situations, it will be preferred to send the observed cosmic-ray data from the tunnel to our laboratory and to monitor the remote apparatus in staying at the university.

In transmitting the data, some kinds of systems may be available. One is the system which uses the telephone circuit and the other utilizes radio. For example, the former is planned for sending the neutron monitor data from Mt. Norikura to Tokyo, and will be operated from this summer (WADA, 1973). In balloon observations, on the other hand, various kinds of and a great deal of data are usually sent by means of the telemeter system which uses superior modulation method such as FM-FM method (KODAMA *et al.*, 1969). In the present observation, however, the distance between the tunnel and the university is not so far (~3.5 km), and also they are in sight each other. And further, the amounts of data will be limited. Then, a simple and economical telemeter system may be available for the present purpose to send the cosmic-ray data automatically.

Multi-Directional Muon Telescope

Multi-directional muon telescope with 8 m^2 area has been operated in the underground observation as is described in Paper I. The telescope consists of 16 plastic scintillator detectors, each having 1 m^2 area. The detectors are placed in upper and lower layers of 2×4 m^2 area. A block diagram of the electronic circuits is shown in Fig. 1. Output pulses from each detector are amplified (~60 db) and then fed to two-fold coincidence circuit. Five directional intensities for Vertical, North, South, East, and West can be measured, and finally they are recorded on

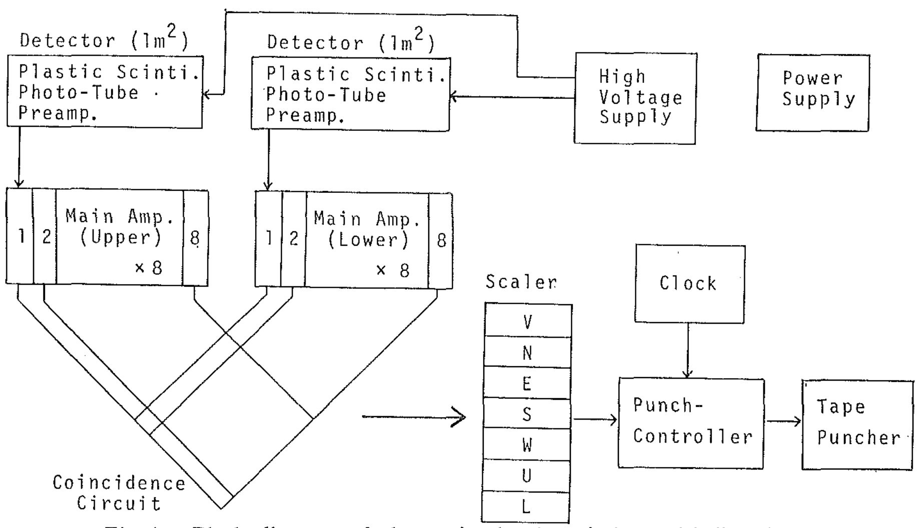

Fig. 1. Block diagram of electronic circuits of the multi-directional cosmic-ray telescope.

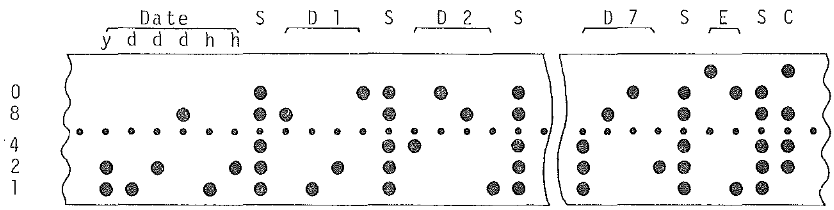

Fig. 2. One of examples of punched paper tape. Date is the punched time which is composed of six figures; year, days and hours. D1～D7 represent the counting-rates for Vertical-, North-, East-, South-, West-, Upper- and Lower-components. S, C and E stand for a 'space' mark, a 'carriage-return' mark and an 'end' mark, respectively.

the paper tape once an hour, together with total counts of each single layer (Upper and Lower). The punching format on the paper tape is shown in Fig. 2. Table 1 also gives the characteristics of the present muon telescope.

The merits of the multi-directional cosmic-ray telescope have been shown successfully by NAGASHIMA and his colleagues (1972), by using data from multi-directional large area cosmic-ray telescope at Mt. Norikura. The producing instructions for the present telescope are much owed to cosmic-ray group of Nagoya University.

Table 1. Characteristics of the multi-directional cosmic-ray telescope at 50 m.w.e. undeground in Matsumoto.

Component	Center Direction of View (Zenith)	Observed Counting Rate ($\times 10^4$/hr)	Standard Error (%/hr)	Barometric Coefficient (%/mb)	Number of Sub-Telescope	Depth (m.w.e.)
Upper Single	—	30	0.18	—	8	—
Lower Single	—	30	0.18	—	8	—
Vertical	0°	6.0	0.41	−0.05	8	50
North	40°	3.4	0.54	−0.04	6	42
South	40°	0.85	1.08	−0.01	6	92
East	40°	1.1	0.95	−0.01	4	65
West	40°	1.55	0.80	−0.03	4	53

Design of the Telemeter System

As is mentioned above, observed cosmic-ray counts are finally punched on the paper tape every one hour, according to the punching program shown in Fig. 2. The tape puncher is driven by the punch signals, which are generated in the punch-controller circuit in Fig. 1. We attempt to send the punch signals by radio and to get the same punched tape simultaneously both in the tunnel and in the university. Through the punched data at the university, we will be able to monitor the remote underground apparatus. In the above method, the amounts of data to be sent are limited within 48 figures and characters as shown in Fig. 2. And also the time interval between data-sendings is long enough (one hour). Thus, the signals can be sent rather moderately, in contrast to other cases such as balloon observations in which various kinds of and a great deal of informations are usually sent with multi-channel ways, utilizing FM-FM method. By considering the facts that the amounts of data are limited and also the distance between the two places is not so far and in sight each other, the following simplification of the telemeter system may be possible in our case.

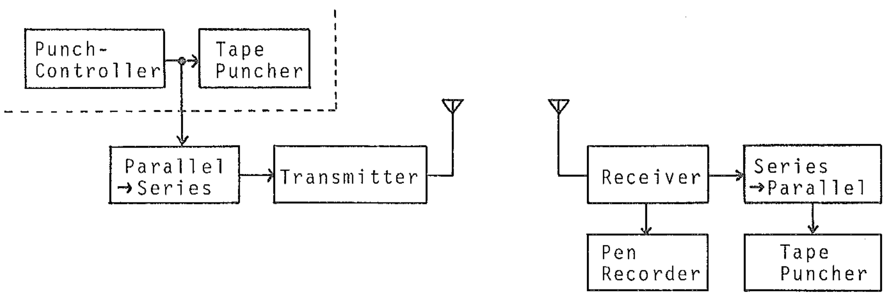

Fig. 3. Block diagram of the present telemeter system.

A block diagram of the system designed for the present purpose is shown in Fig. 3 and Fig. 4. As is shown in Fig. 3, the punch signals at parallel channels are firstly converted into series pulses by the parallel-to-series converter. Series signals are then used as the modulation signal of the transmitter, where one of simpler modulation methods, A1 type (by usual terminology), was adopted in the present system. By the receiver, series signals sent by radio are detected, and punch signals are reconstructed with them in the series-to-parallel converter, with which the tape puncher at the university can be driven. Any additional memmory circuits are not required in the present method. In this way, cosmic-ray data can be recorded simultaneously on both paper tapes in the tunnel and in the laboratory. The whole time for data-sending is about 15 seconds. During the rest time (59 min. and 45 sec.), only the carrier without modulation of A0 type (also by usual terminology) is transmitted, which will serve for monitoring the electric failure. The output voltage of the receiver is plotted with the pen recorder.

In Fig. 4, a block diagram of the transmitter and the receiver is displayed.

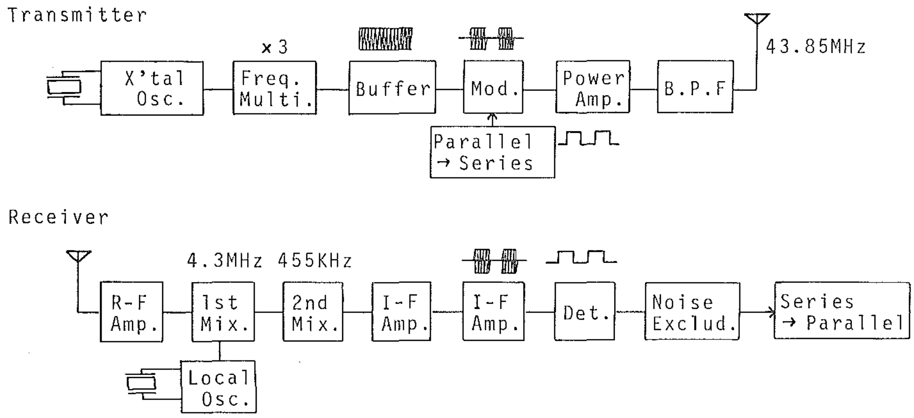

Fig. 4. Block diagram of the transmitter (upper) and the receiver (bottom).

Both circuits are simple and common, thus are supplied at low cost. The wave frequency of the carrier is 43.85 MHz and the output power 0.5 Watt. During the time for data-sending, the signal pulses make the carrier intermittent in the present modulation method (A1 type), likely to the usual radiotelegraph. It is noted that the output pulses of the detection circuit are introduced to the noise excluder circuit, with which the present telemeter system will make sure a good signal-to-noise ratio (S/N ratio). A great part of noises which demonstrates either narrow width or slow rise time is excluded here, while signal pulses with both fast rise time and wide pulse width (10 msec.) can pass through the circuit. Some characteristics of the transmitter and the receiver are listed in Table 2.

Table 2. Some characteristics of the transmitter and the receiver.

Transmitter	
Frequency	43.85 MHz
Freq. Stability	$\pm 10\times 10^{-6}$
Output Power	0.5 Watt
Mod. Method	A1, A0
Antenna	Yagi, Three Elements
	Horizontally Polarized
	Gain= 5 db
Receiver	
Receiv. Method	Double Super Heterodyne
Intern. Freq.	1st =4.3 MHz
	2nd =455 KHz

The method of conversion of parallel signals into series is shown with a logic diagram in Fig. 5. And also its time chart is given in Fig. 6. When the clutch signal, one of the punch signals is introduced, both the input pulse and clock signals of the shift register are generated as is shown in Fig. 5 and Fig. 6. The input pulse is then shifted from '1' to '6' in that order by clock signals. The output of

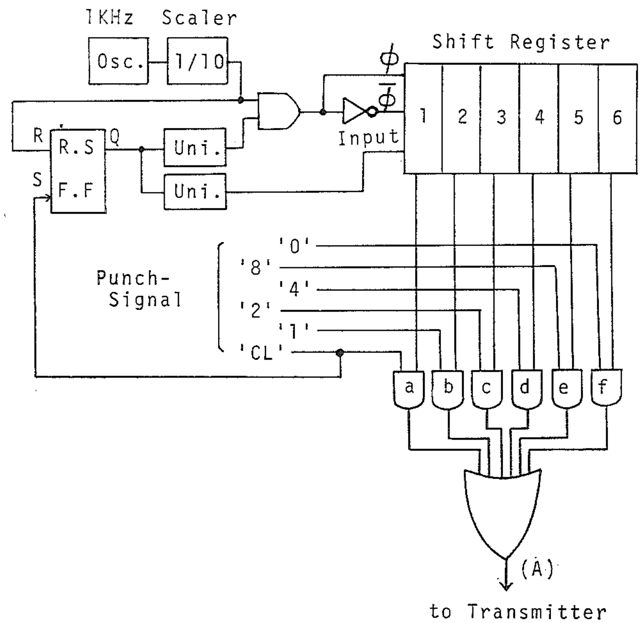

Fig. 5. Logical circuits of the parallel-to-series converter. 'CL' represents 'clutch signal'.

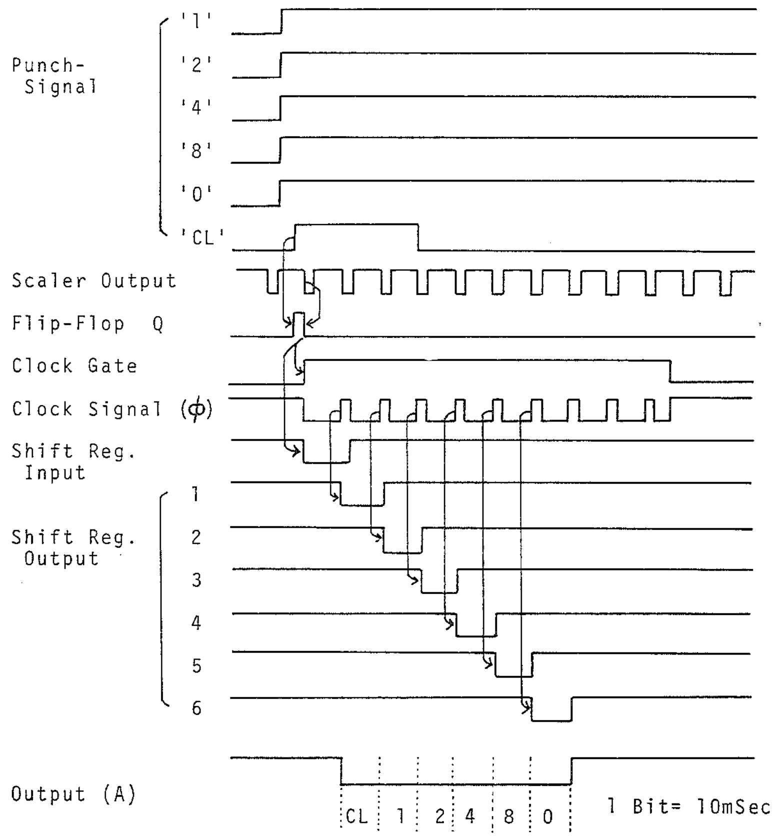

Fig. 6. Time chart of the parallel-to-series converter.

each bit of the shift register makes the gate open, from 'a' to 'f' in turn. Thus, the ouput voltage at six terminals, named 'CL', '1', '2', '4', '8' and '0' in Fig. 5, will appear at (A) in that order. In this way, parallel signals are converted into series pulses. Descriptions of the series-to-parallel converter are not given here, for the function may be understood by tracing back the above process. Designing and assembling of the electronic circuits of the system were made by Sanko Electric Industry.

Experimental Results and Discussions

The telemeter system was completed in March, 1972 and the licence for the radio station was given in May. By using this system, the same punched tape as that in the tunnel was obtained in our laboratory.

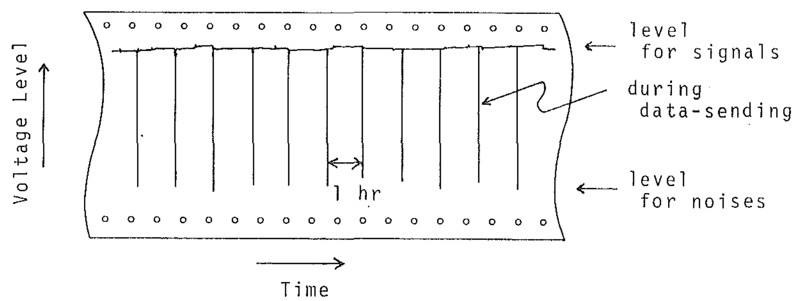

Fig. 7. One of examples of the recording chart on the pen recorder.

In Fig. 7, the plotted chart of output voltage of the receiver is displayed. As is demonstrated in the figure, the output voltage keeps a constant level of about 0.8 V except the time period for data-sending. During data-sending, the carrier is suppressed repeatedly in a short time intervals, when the output level goes back and forth between two levels for signals and for background noises. The former is about several times greater than the latter, indicating sufficient S/N ratio. The electric failure in the tunnel can also be monitored through this chart, when the level moves down to that for noises (see Fig. 7).

The character of miss-sendings in the present system was examined. It is found that there are two types in occurrence of errors. In one type, its occurrence is concentrated in a short time period, and in the other type errors take place rather discretely and scarcely. A greater part of errors belongs to the latter type, and whose freqeuncy was roughly estimated from the data in 60 days running. The ratio R of the number of these errors to the total number of figures was obtained as

$$R = (\text{several}) \times 10^{-4},$$

indicating one error in several days. This error-rate would be permissible for the present purpose of monitoring. For reducing the above ratio much smaller, 'parity check function' may be effective, by which the position of an error bit on the paper tape (see Fig. 2) will be easily found in the following ways. Firstly, the parity signals along the vertical direction and those along the horizontal direction are sent together with the punch signals, and then the received parities along the above two directions are checked. If there exists an error bit in the received data, its position on the paper tape will be indicated by a pair of punched holes on both the vertical and the horizontal lines. A double sending of the identical data might also be effective for reducing the above ratio.

Another type of miss-sending is especially accompanied with thunders, when the received data is considerably confused. In order to defend the system from such disturbances, an alternation of the present modulation method to the other superior one might be recommended. A frequency modulation (FM) method may assure much better S/N ratio than the present one which is a kind of amplitude modulation (AM) method. This type of disturbance, however, scarcely occurs and hardly continues for a long time, thus is not so serious for the present case.

Concluding Remarks

A simple telemeter system was constructed for sending the observed cosmic-ray data from the underground observatory to our laboratory in the university. The system was simplified by considering both the distance and the amounts of data to be sent. By using the message, the same data was obtained simultaneously at the university as that recorded at the underground, through which we can easily monitor the remote apparatus in the tunnel. The system would be satisfactory for the present purpose. It is also suggested that reliability of the system will be much increased by adding the function of parity check and by changing the modulation method to the other superior one such as FM method.

Another cosmic-ray telescope with larger area of 16 m^2 is now under construction in a new tunnel at Misato village, which is about 15 km west from the university (MORI *et al.*, 1973). Also new telemeter system will be utilized in the future observation, by adding some improvements with functions of parity check and of double sending.

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