SIMPLE TIMING DEVICE INCREASES RELIABILITY OF RECORDING TELEMETRIC ACTIVITY DATA

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Abstract: Many wildlife biologists still rely on strip-chart recorders for collecting telemetry information in the field, and modifications that improve the reliability of recording telemetric data and reduce the time required to analyze these data are needed. We observed that 2 identical recorders, which had been geared to run at the same chart speed (5.08 cm/hour), operated at different speeds (4.32 cm/hour and 5.49 cm/hour) and responded differently to declining battery voltage (12.8–12.3 V) over 5- to 15-day recording periods. We describe a simple timer circuit that can be added readily to existing chart recorder systems to designate time on the chart tape. The frequency and duration of timing marks are completely adjustable. A time-marking system enables the biologist to correct for changing chart speed quickly, know the time at which a remote unit may have failed or run out of paper, and greatly facilitates computerized analyses of the strip charts.

J. WILDL. MANAGE. 56(1):191–196

Recent advances in microcomputer technology and in the miniaturization of electrical circuits have led to a great increase in the applications of radio telemetry to wildlife research and management (White and Garrott 1990). These advances have influenced standard techniques for radio telemetry and have included the increasingly widespread use of satellites to monitor wildlife populations (e.g., Fancy et al. 1988, Garner et al. 1989). Satellite telemetry can provide limited information on animal activity (e.g., migration movements; Fancy et al. 1989), but it is not yet of much use to biologists who require detailed activity information from nonmigratory animal populations. For the most part, researchers studying animal activity patterns must still depend on more traditional telemetry techniques.

Some researchers have used microcomputers to record activity information directly from a telemetry receiving system (e.g., Cupal and Weeks 1989) or to interpret tape recordings of telemetry data (Nams 1989). The more successful applications of computer-based recording systems have involved either infrequent signals (e.g., Howey et al. 1989) or the recording of signals that are specific to individual activities (e.g., Bevins et al. 1988). Frequently, discerning specific activity patterns from telemetry information requires extended segments of data (Gillingham and Bunnell 1985, Beier and McCullough 1988); the associated volume creates extensive data processing problems. The cost and lack of portability of computer-based data recording systems, as well as the overall simplicity of strip-chart recorders in remote field recorders, favor the continued use of chart recorders for recording animal activity. Chart recorders also will continue to prove useful in radio-telemetric monitoring of physiological in-

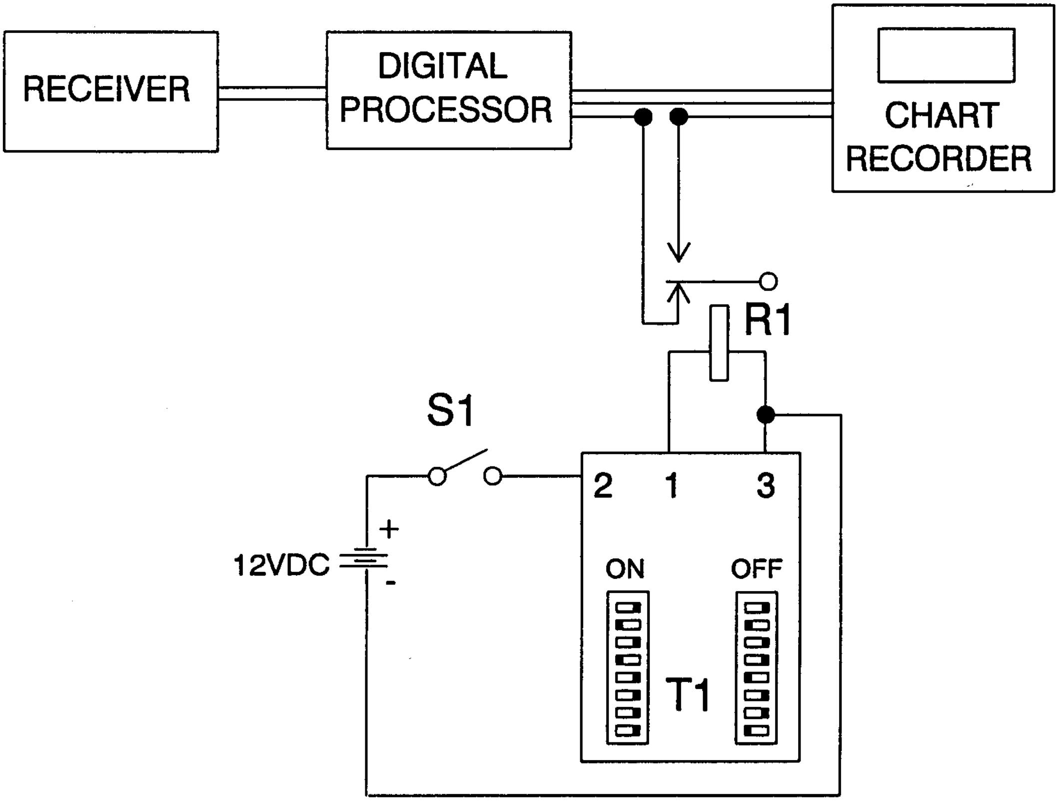

Fig. 1. Schematic representation of our data recording system including the timing circuit. The timer and relay circuit are connected to the amplitude wire between the digital processor and the chart recorder. R1 represents a 12-VDC relay, T1 the reset timer device, and S1 a single-throw switch. Closed circles represent connected wires; the numbers within T1 are the connection points on the reset timer device. The relay is connected to the timer so that the circuit from the processor to the chart recorder is normally closed.

dices such as body temperature and heart rate, weather stations, and the collection of stream discharge information.

The major disadvantage of non-computer-based recording systems is that time is not known accurately and must be assumed from a constant chart speed. Various timing devices have been described for ecological applications. For example, Jenness and Ward (1985) described a timer for recording elapsed time after an event, and Göransson (1980) reported on the use of timers to turn telemetry equipment on and off in the field. Attempts to combine time and strip-chart data in field applications have been limited (e.g., Gaardmand and Jeppesen 1984), and, for the most part, errors associated with fluctuating speeds of chart recorders in the field are undocumented. Herein, we describe the variation in speed within and between 2 identical chart recorder systems and describe an inexpensive timing circuit that can be added easily to existing telemetry systems to increase reliability of the data.

We were supported by the U.S. Forest Service, Pacific Northwest Forest and Range Experiment Station, Juneau, Alaska. T. A. Hanley was instrumental in providing the funding for the overall research project. We acknowledge technical assistance from G. A. Parker, and thank F. G. Lindzey, and S. H. Anderson for helpful comments on an earlier version of this manuscript.

METHODS

We obtained our data as part of an extensive study conducted on the bioenergetics of free-ranging black-tailed deer (*Odocoileus hemionus columbianus*) near Wrangell, Alaska (56°22′N, 132°10′W). We placed radio collars, containing a head-up and head-down tip-switch and an inactivity sensor (Model MOD-500; Telonics, Mesa, Ariz.), on 9 deer. All animals

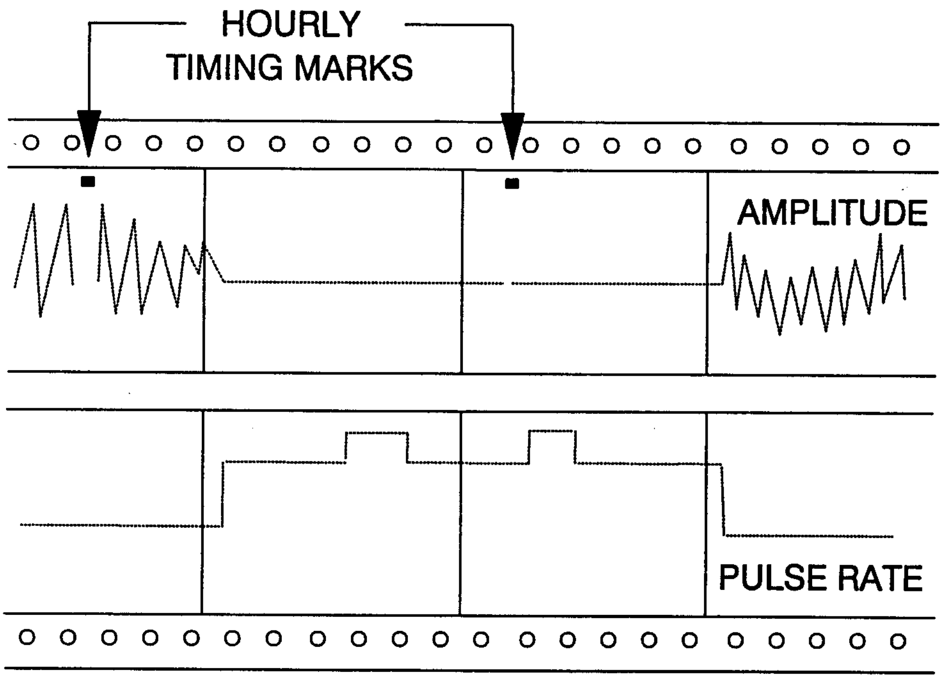

Fig. 2. Representation of a sample dual-strip chart tape showing traces of amplitude, pulse rate, and the position of the hourly timing marks on the chart paper.

roamed freely over an approximately 130-ha island. Telemetry information was recorded from a receiving station approximately 2 km by water from the island.

Each of 2 receiving systems consisted of an omnidirectional antenna (Model RA-6B; Telonics, Mesa, Ariz.), a TR-2 receiver and TPD-2 digital processor (Telonics, Mesa, Ariz.), and a Rustrak® dual-channel strip-chart recorder (Series 300; Gulton Industries, Manchester, N.H.) geared to run at 5.08 cm/hour. We used WAA strip-chart paper (Telonics, Mesa, Ariz.). After noting substantial differences in the speeds of the supposedly identical chart recorders (Gillingham, Univ. of Wyo., unpubl. data), we added a timing circuit to the system (Fig. 1). This circuit was connected to the amplitude wire between the digital processor and the chart recorder. In our application, the amplitude information passed undisturbed to the chart recorder for 59 minutes out of every hour. Every sixtieth minute, however, the timing circuit opened the connection between the processor and chart recorder. The result was a 1-minute timing mark on the amplitude side of the strip chart (Fig. 2) every 60 minutes.

The main component of the timing circuit (Fig. 1) was an adjustable reset timer (Model RS1A22; SSAC Inc., Box 1000, Baldwinsville, N.Y.) in which dip-switches could be altered so that the timer was on from 0.1–102.3 minutes and off from 0.1–102.3 seconds. We used a simple 12-VDC (volts direct current) relay (Coil: 320 Ω, 37.5 mA; Model #275-241; Radio Shack, Fort Worth, Tex.) to reverse the effect of the timer on the amplitude circuit. Consequently, when the timer was on, the relay opened and the amplitude channel of the chart recorder received no voltage, resulting in a dot (hereafter a timing mark) on the strip chart; as long as the timer was off the amplitude information was passed directly to the chart recorder. Thus, by setting the timing circuit to be on for only 1 minute/hour, we did not lose amplitude information if the timer failed, as might happen if we did not incorporate the relay into the circuit.

We used a simple toggle switch (S1 in Fig. 1) to synchronize the timing marks on the strip-chart recorder with actual clock time. When we opened and closed the switch the timer was reset. Generally, we reset the timer once every 24 hours ending an individual trial. Over the course of the continuous 2½-year monitoring period, however, we let the system run on the same animal for 11–15 days on 4 occasions.

We determined the actual duration of the on

Table 1. Measured chart speeds for 2 Rustrak® recorders (A and B) geared to advance at 5.08 cm/hour.

Chart recorder	No. batteries[b]	Chart speed (cm/hr)[a]		
		n[c]	$\bar{x}$	SD
A	1	1,240	4.44[d]	0.28
A	2	7,767	4.31[e]	0.23
B	1	1,195	5.63[f]	0.77
B	2	8,112	5.48[g]	0.63

[a] Individual chart speeds measured by digitizing procedure described in text.
[b] Both telemetry systems ran on 1 12-VDC deep-cycle marine battery for 67 days. Each system was powered by a separate battery for the final 380 days.
[c] n = number of timing marks (1-hour periods) measured for each chart recorder and battery combination.
[defg] All means differed ($P < 0.05$); 2-way ANOVA and Tukey's test.

and off sequences of each timer by counting the number of timing marks per known period each time we reset the systems. We analyzed all tapes using our own BASIC software and a 48-inch Digitizing tablet (Model 9148; Calcomp Inc., Anaheim, Calif.) equipped with a 16-button cursor for data input. First, after inputting the average time between timing marks (in seconds), we entered the location of the start of each hourly timing mark on the strip chart with the 16-button cursor. These locations (±0.025 mm) were saved to an output file for the analyses presented in this paper. Second, we touched the 16-button cursor to each change in activity on the strip chart; we used a distinct button for each activity level (i.e., active, inactive, unknown). The program then wrote a separate output file for each individual recording of an animal including each behavior, duration of the behavior, and the starting time of that behavior.

During the recording period, we used 2 different battery configurations to power the telemetry systems. For the first 67 days of the data presented in this paper, both telemetry systems were powered by 1 12-VDC marine battery. On 6 September 1989 we separated the systems and used 1 battery/telemetry system (380 days of data). We used 2-way ANOVA (SAS : GLM 1987) to compare differences in chart speed between Rustrak® recorders and to determine how the use of 1 versus 2 batteries influenced the recorders' performances. We used Tukey's Studentized range test (SAS : GLM 1987) to locate differences in mean values.

To assess how the chart speed varied within a trial, we examined all trials when the recorder was left on 1 animal for more than 5 days (longest 15 days; $n = 28$ trials). We then used Pearson correlation analysis (SAS : CORR 1987) to examine relationships between the speed of the tape per timing-mark interval and the timing-mark number in a given trial. We used a separate analysis for each Rustrak® recorder. For this analysis we only used data when the systems were powered by separate batteries.

RESULTS

Two identically geared chart recorders differed (Machine 1: 4.32 ± 0.25 cm/hour [$\bar{x}$ ± SD], n = 9,007; Machine 2: 5.49 ± 0.65 cm/hour, n = 9,307; F = 26,072.81; $P < 0.001$) in the distance the paper moved per hour; average chart speeds also differed (F = 163.75; $P < 0.001$) when they were powered by separate batteries compared to when they shared a common power source (Table 1). There was no statistical interaction (F = 1.10; P = 0.294) between the chart recorder speed and the number of batteries powering the system, nor did we see any difference in the time between timing marks (Timer A: 3,641.93 ± 25.64 sec [$\bar{x}$ ± SD], n = 255; Timer B: 3,641.24 ± 25.65 sec, n = 265; P = 0.629). The time between timing marks on each machine, however, was affected (F = 762.68; $P < 0.001$) by the number of batteries powering the system.

The use of the timing marks enabled us to determine that the chart speed of each recorder changed within runs of 5–15 days and that the 2 machines behaved differently under these conditions. For Machine A, we observed a negative correlation between the speed of the machine and the number of timing marks in the trial ($r = -0.238$; $P < 0.001$; n = 2,326), meaning that the recorder tended to slow down with time. In contrast, the greater the number of sequential days in a trial, the faster Machine B tended to run ($r = +0.167$; $P < 0.001$; n = 2,098).

Besides increasing accuracy, our combined use of timing marks and digitizing of data greatly reduced the amount of time needed to analyze strip charts. We could process an entire tape in 2–3 hours. Because the data were written to computer files, any further data entry steps also were eliminated. This timing system costs approximately $50.00, and the on and off timing sequence can be modified easily in the field without changing any of the circuit's components.

DISCUSSION

Without the addition of the described timing circuit to our activity-recording system, we would have incorrectly assumed a constant chart speed and consequently introduced errors into our interpretation of the activity data. Assuming a constant chart speed before we installed the timers, we used linear interpolation between known times to estimate the times of activities. Often, no end time was known when a chart recorder was not working properly. We then were forced to assume that the chart recorder was advancing at the factory-specified rate. Our data show that this would have been an incorrect assumption for these machines.

We observed that the 2 chart recorders changed speed in response to declining voltage (i.e., longer trials) and that they responded differently to changes in voltages ranging from 12.8 VDC down to 12.3 VDC. Machine A, which ran at the slower chart speed (Table 1), slowed during longer unattended periods; the second chart recorder (Machine B) increased speed. We believe the latter may have resulted from the machine being less sensitive to voltage, and as the amount of paper on the supply roll decreased, the gears advanced the decreasing amount of paper at a faster speed.

We also observed large amounts of variation (up to 30%) in the distances between consecutive timing marks on a chart tape; recorders did not advance at a constant speed. Temperature, voltage, and the amount of remaining paper may have contributed to this variation. To our knowledge, variation in chart speed only has been reported as a problem in recording activity information by Gaardmand and Jeppesen (1984), despite the extremely wide use of similar recording systems in research and management.

The timing system we describe was precise and only about 40 seconds over the timing interval we specified with the dip-switches. We believe that both the precision and the accuracy of the system could be increased by substituting a "time-of-day" timer instead of the elapse timer that we used. For most applications, however, the accuracy of the described timing system should be adequate.

RESEARCH IMPLICATIONS

Biologists using chart recorders to collect activity information from remote telemetry stations must assume that the chart speed is constant when interpreting their data. Our results show that for the 2 machines that we used, this was not true. Neither of our machines performed at the speed specified with the gearing system. The addition of a simple timing circuit that marks time on the amplitude portion of the strip chart would improve the reliability of interpreting time and activity from chart records. Additionally, the time at which a chart recorder fails or runs out of paper can be determined using this system. Finally, our use of a digitization procedure based on timing marks enabled us to decrease significantly the time necessary to encode data from the strip charts.

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Received 9 July 1991.
Accepted 3 September 1991.
Associate Editor: Fagerstone.