A Low-Cost Sounding Balloon Experiment

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Watching the meteorological balloons customarily launched from our city, we wondered how we could develop an experiment to allow our students to effectively gather data about the low atmosphere and at the same time keep our limited financial budget. When you hear about atmospheric balloons, you usually think about balloons with large envelopes of nylon or mylar with payloads between 1 or 10 kg. They ascend to very high altitudes, have a data radio transmitter, and are not recoverable. This setup would be too expensive for us. In order to keep the cost low, the payload containing the data recorded had to be recovered, and therefore, the balloon must not go tens of kilometers away. We ruled out tethered balloons, which would not have recovery problems but can hardly go beyond 100 m high because of the weight of the tether and of lateral winds. Based on some estimates of ascension speed for small balloons and probable horizontal wind intensities, we decided that in order to easily recover the payload we had to limit its ascension to about 2 km high. At this altitude, the payload would have to be released from the balloon by means of a timer.

Balloon Setup and Payload Recovering

Our envelope (see Fig. 1) consists of four latex 1-m diameter balloons (the biggest we could get) of the kind used at children's parties. Altogether they had a net buoyancy capacity of 500 g. By net buoyancy, we mean the payload the balloon can handle after lifting
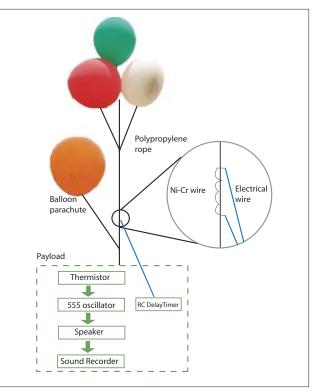

Fig. 1. Schematic diagram of the sounding balloon experiment.

its own weight. Many balloons obviously have a worse *weight/volume* ratio than one big balloon, but latex balloons are two orders of magnitude cheaper than mylar ones.

Apart from that, using more than one balloon allows us to forget about parachutes (which may fail to open). The payload goes up with four balloons, and after a predefined time a rope is cut, releasing three bal-
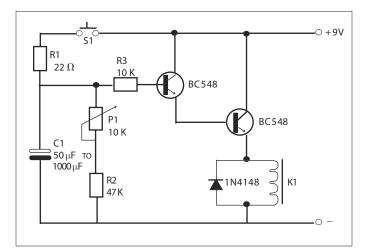
Fig. 2. Diagram of timer circuit used to liberate balloon parachute and its payload. The contacts (not shown) of relay K1 switch on power to Ni-Cr wire.

Fig. 3. The oscillator circuit. F **is the output sound frequency value.** R_b **is the NTC 10-kΩ thermistor. The values used for other components were:** R_a **= 2200 Ω, C = 20 nF.**

loons. The payload then falls down with just one balloon, which provides a drag force comparable with a parachute of approximately 40 cm of diameter. Using the balloon as a "parachute" has a twofold advantage to help us follow its fall visually. First, it is bigger than the parachute. Second, it stays aloft after the payload has hit the ground.

To cut the rope that liberates the balloon-parachute and its payload, we used an electronic RC delay timer circuit. We used the timer circuit shown in Fig. 2. Several other and more precise timing circuits can be found on the Internet (e.g. http://www.interq.or.jp/japan/se-inoue/e_ckt4.htm or http://users.pandora.be/educypedia/electronics/circuitsbysubject.htm). Five minutes after launching it activates a relay that connects a 9-V battery to a Ni-Cr wire (6 cm, 40 Ω, taken from a 1.5-kΩ wire resistor), which is wound around a polypropylene rope. The current from the battery heats the Ni-Cr wire, easily burning and severing the rope in a few seconds.

Data Recording and Analysis

We decided that an interesting parameter to measure in the atmosphere would be the temperature profile. Temperature decrease with altitude is something that most students have experienced when traveling to high-altitude places.

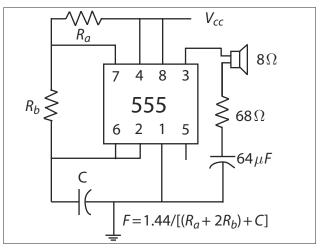The sensor used to accomplish this was a thermistor, whose resistance-versus-temperature curve was
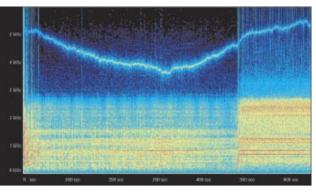

Fig. 4. The complete spectrogram produced by GRAM.

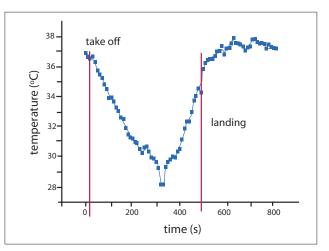**Fig. 5. The temperature profile obtained from frequency readings.**

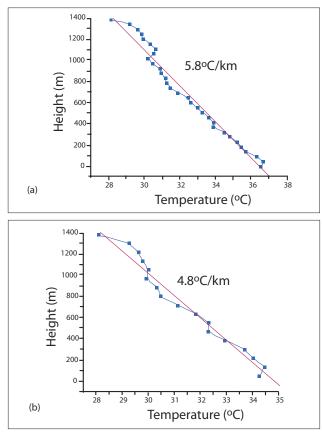Fig. 6. Temperature profiles during (a) ascension and (b) the fall.

Fig. 7. A picture taken before launching.

obtained in our lab. The thermistor, an NTC 10 kΩ, was used as a variable resistor in a 555 astable multivibrator oscillator circuit (Fig. 3), which generates a sound that was recorded by a portable sound recorder. The sound frequency is thus related to the resistance of the thermistor. After recovery, we used shareware spectrum analyzer software to read the frequency value over time (Fig. 4).[1]

We videotaped the balloon taking off, placing a camera some hundreds of meters away in order to measure its ascension speed. The calculated speed was 4.6 m/s (it reaches constant speed almost immediately); therefore, supposing that this speed remains constant over all the flight, our 5-min interval allowed it to reach a height of around 1400 m. Data from meteorological sounding balloons show that the assumption of a constant ascension speed of around 5 m/s is very reasonable.

To calculate the falling speed, we need to know how long the balloon took to fall. We could see the payload releasing and the balloon hitting the ground

(it landed 1 km away), but even if we had not recorded this time or seen these events, we could easily have recorded the time interval between the instant the lowest temperature was recorded on the tape and the time at which the impact sound with the ground was heard. A typical descent took about 2 min 40 s, which gives a descending speed of 7.5 m/s. We could hear ourselves screaming "launching" when the system took off, which allowed us to check the ascension time.

Figure 5 shows the temperature readings during the flight, highlighting taking off and landing. The minimum temperature recorded, which corresponds to the highest point, was 28°C.

Supposing constant speed, Fig. 6 shows the temperature profiles both (a) during ascension and (b) during the fall. The meteorological literature tells us to expect a variation from 5 to 6°C/km of altitude, which is close to our results. Notice how the two plots show the same artifacts at higher altitudes. At low altitudes they differ by some degrees. The reason may be that the system was launched over a sandy terrain and

landed over dense vegetation.

Note also that just after landing, the temperature jumps almost 2°C and then continues rising to 38°C. The sensor fell over some trees where it may have touched warmer material heated by sunlight. Once inside this forest the temperature increased even more, perhaps due to a sort of greenhouse effect.

Comments

We launched a sounding balloon through the first kilometers of the atmosphere, measuring high-resolution temperature data with fair accuracy, while keeping the budget comfortably under $100.

In order to minimize the risk of losing the balloon and payload, we chose a large open area (see Fig. 7), waited for a calm wind, and set the timer for a run of a few minutes. This enabled us to visually follow the whole flight and recover the balloon soon after.

Another option (to be tested in the next flight) would be to use a walkie-talkie to transmit the sound signal to the ground. Additionally, other sensors (pressure, humidity) could be added using other astable circuits, which can be set to a different frequency range.

Pictures and movies can be downloaded from the Quark website at: http://www.clubequark.org.br.

References
1. GRAM software, by R.S. Horne, available at http://www.visualizationsoftware.com/gram.html. Links to other commercial and freeware programs for audio spectrum analysis are at http://www.visualization software.com/gram/links.html.

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