An Intelligent Telemetry System for Show Caves

An intelligent telemetry system has been installed in the Covadura system of caves to monitor the effect of visitors on the cave environment. ***JA Gázquez, JM Calaforra, N Novas, A Fernández-Cortés and J Verger*** *describe the hardware and present some results. Partially translated by* ***John Rabson.***

The article (Gázquez et al, 2003) is a reprint of an article which was first published in the IEE Electronics Systems and Software Journal. Here we provide additional information (specifically technical details of the hardware and some results) which didn't appear in the original article. This article is adapted from a poster presentation by the authors – Ed.

Power System

The regulator chosen for the photovoltaic panel is based on a positive DC/DC converter, with a PWM control and bootstrap configuration with half-bridge of MOSFETs (*Figure 1*), in order to obtain a higher efficiency (□ 85%) (*Figure 2*). This configuration captures more solar energy than the classical hysteresis on/off solar regulator. This type of regulator limits the maximum voltage of the battery, without allowing it to supply energy, and in situations of high levels of solar radiation may supply more current at the output than that of the input of the panel. This is an inherent property of DC/DC transformers.

The overall system also includes a control and supervisory system (*Figure 3*) consisting of an ADC to measure the battery voltage and to determine its charge level, and a microcontroller that controls the electrical energy system of the installation using a 3-relay output. The system supply can be automatically limited, either totally or partially, when the battery charge level is below a threshold. Every 30 seconds the values of the battery voltage and charge state are transmitted using the radio modem based telemetry system to the central station located at the University of Almería. From the central station it is possible to analyse the state of the energy system and to connect or disconnect energy-consuming sectors in the cave (environmental sensors).

The Control Card

To include a presence detector, which is necessary to determine a suitable interval between measurements, a system was developed based on a microcontroller

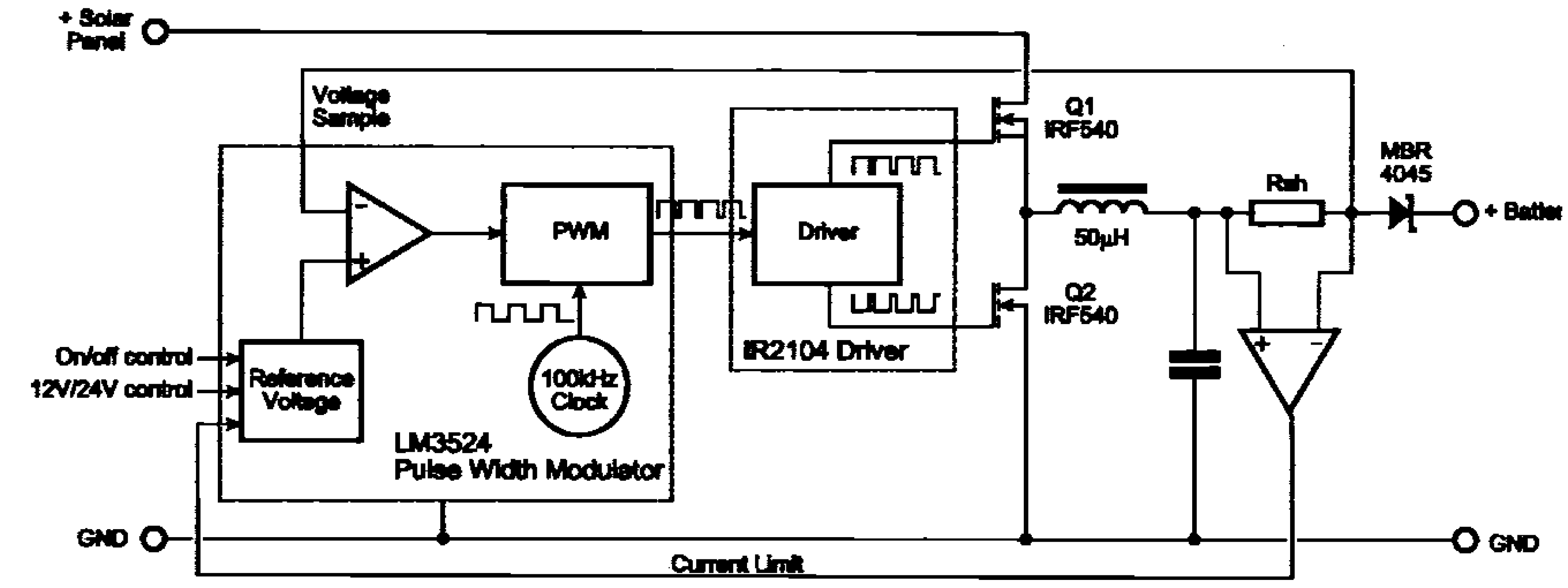

Figure 1 – Block Diagram of the Regulator which was used with the Photovoltaic Panel

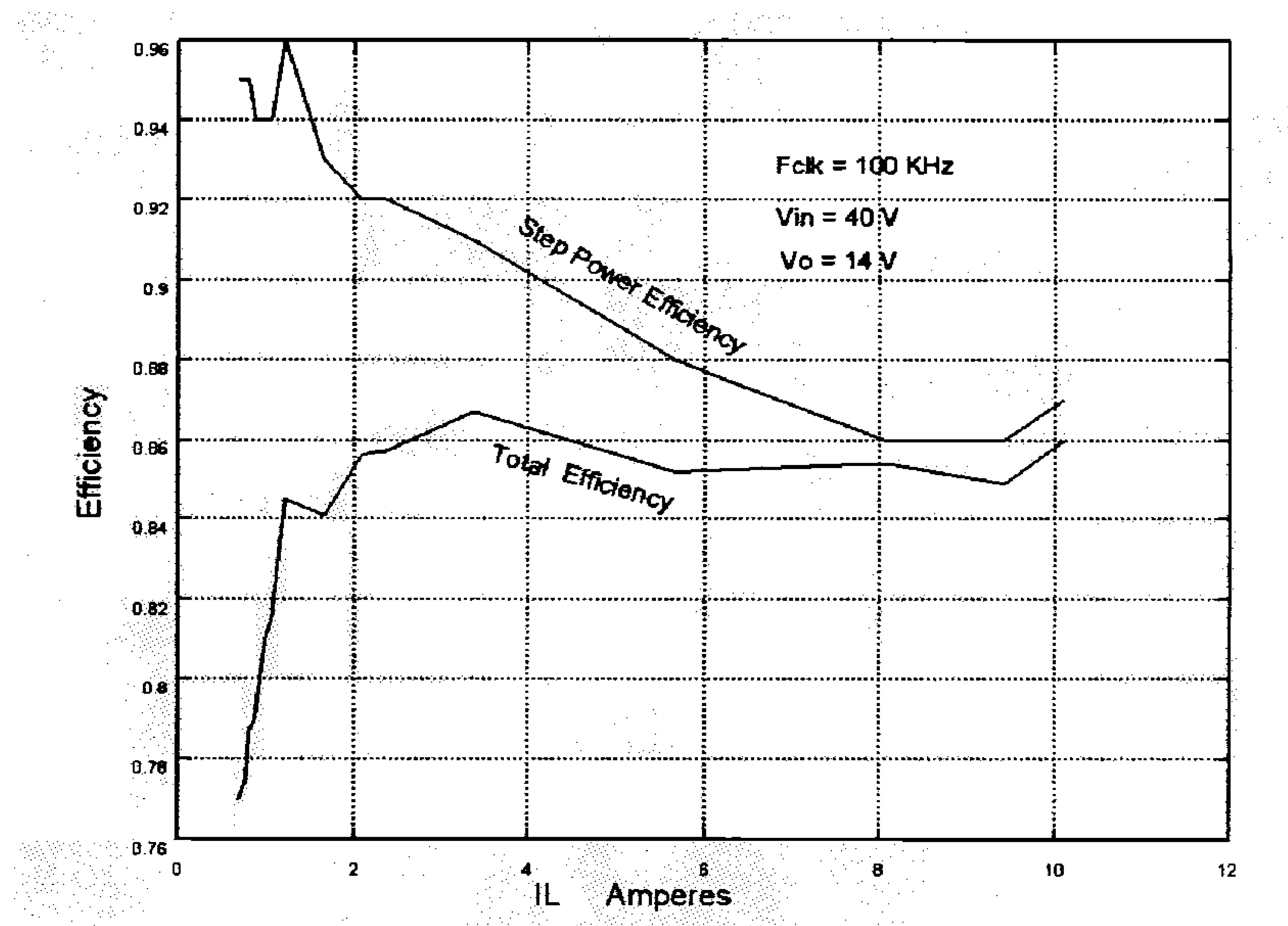

Figure 2 – Experimental Efficiency of the Regulator

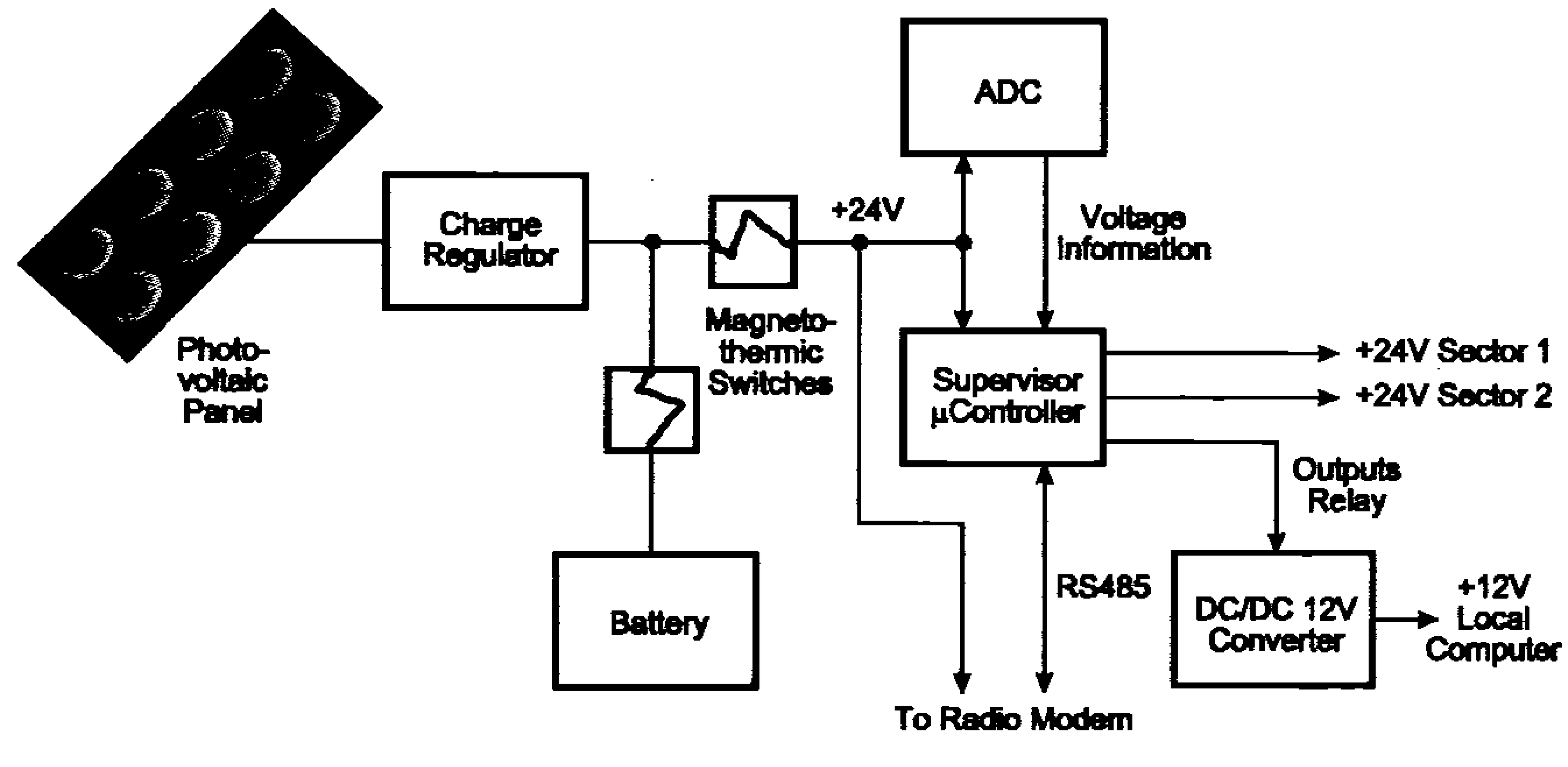

Figure 3 – Block Diagram of the Control and Supervisory System

specifically intended for this application, with an RS485 interface (*Figure 4*).

Figure 5 shows a Remote Station with the presence detector attached.

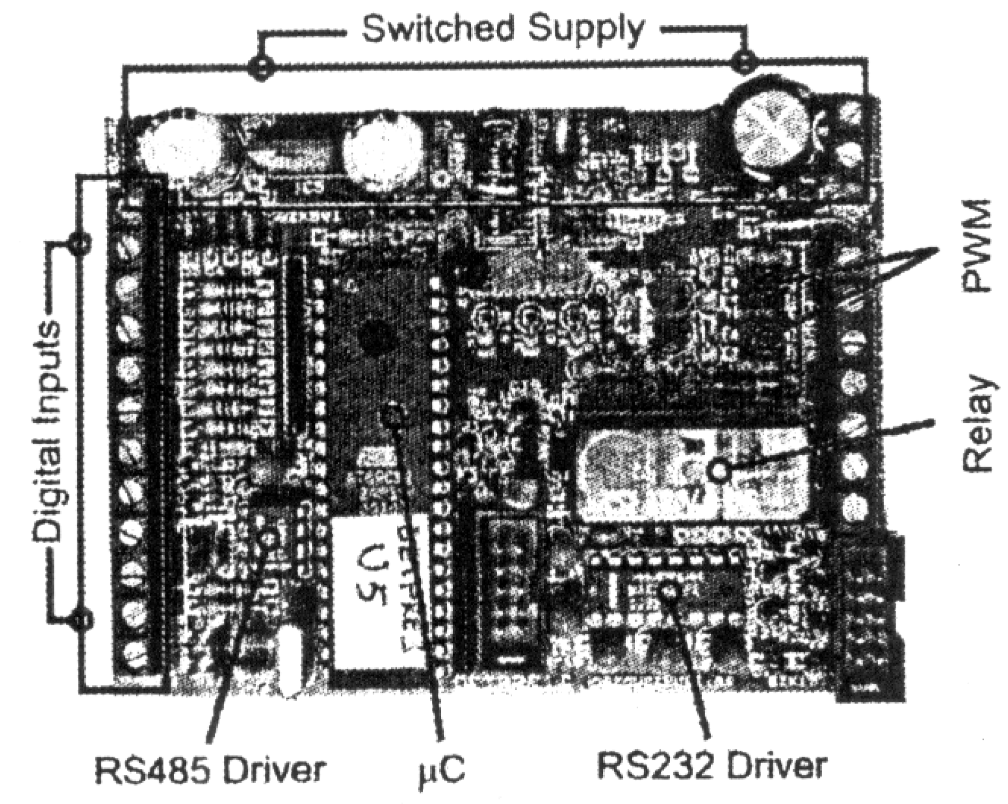

Figure 4 – The Control Board

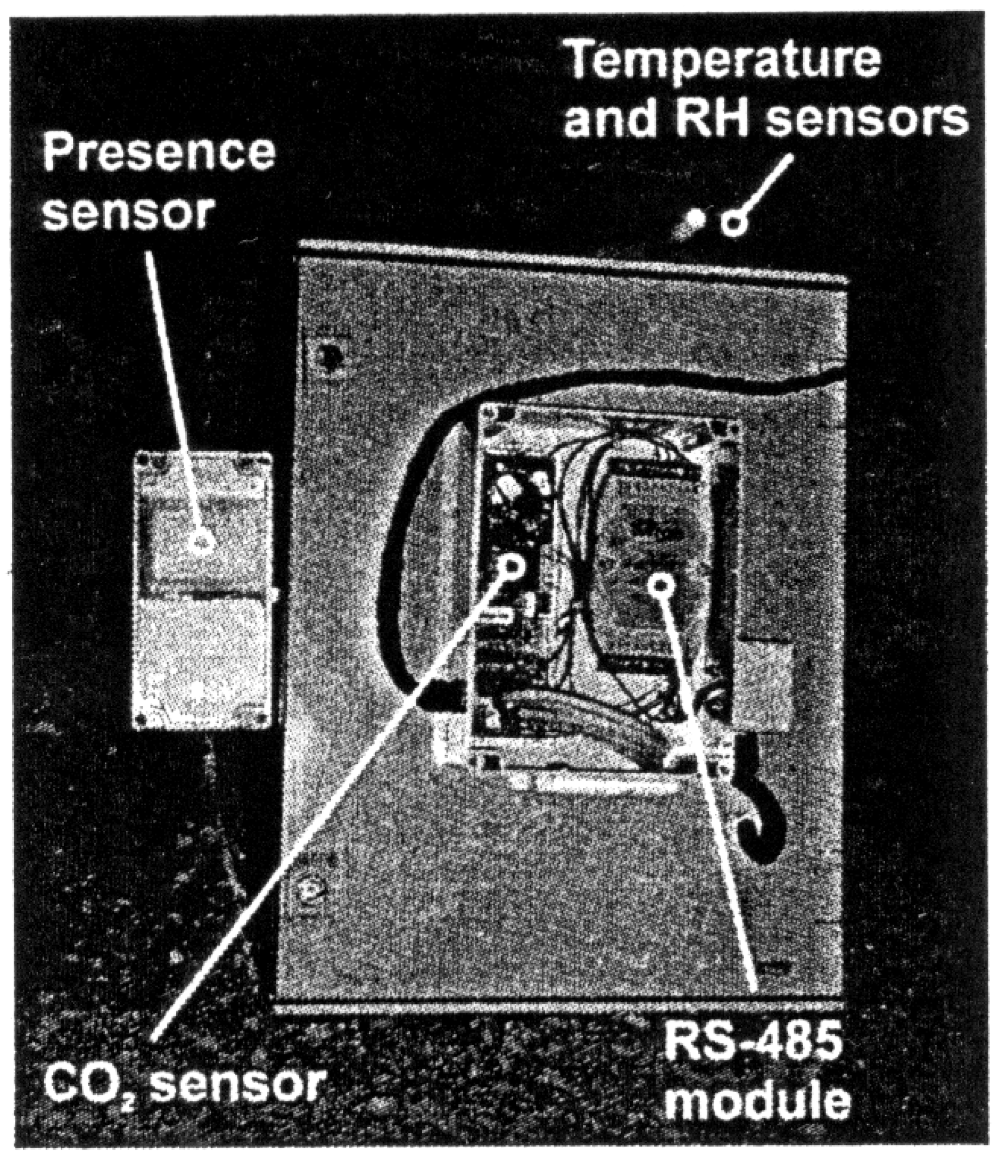

Figure 5 – Remote Station with the Presence Detector Attached

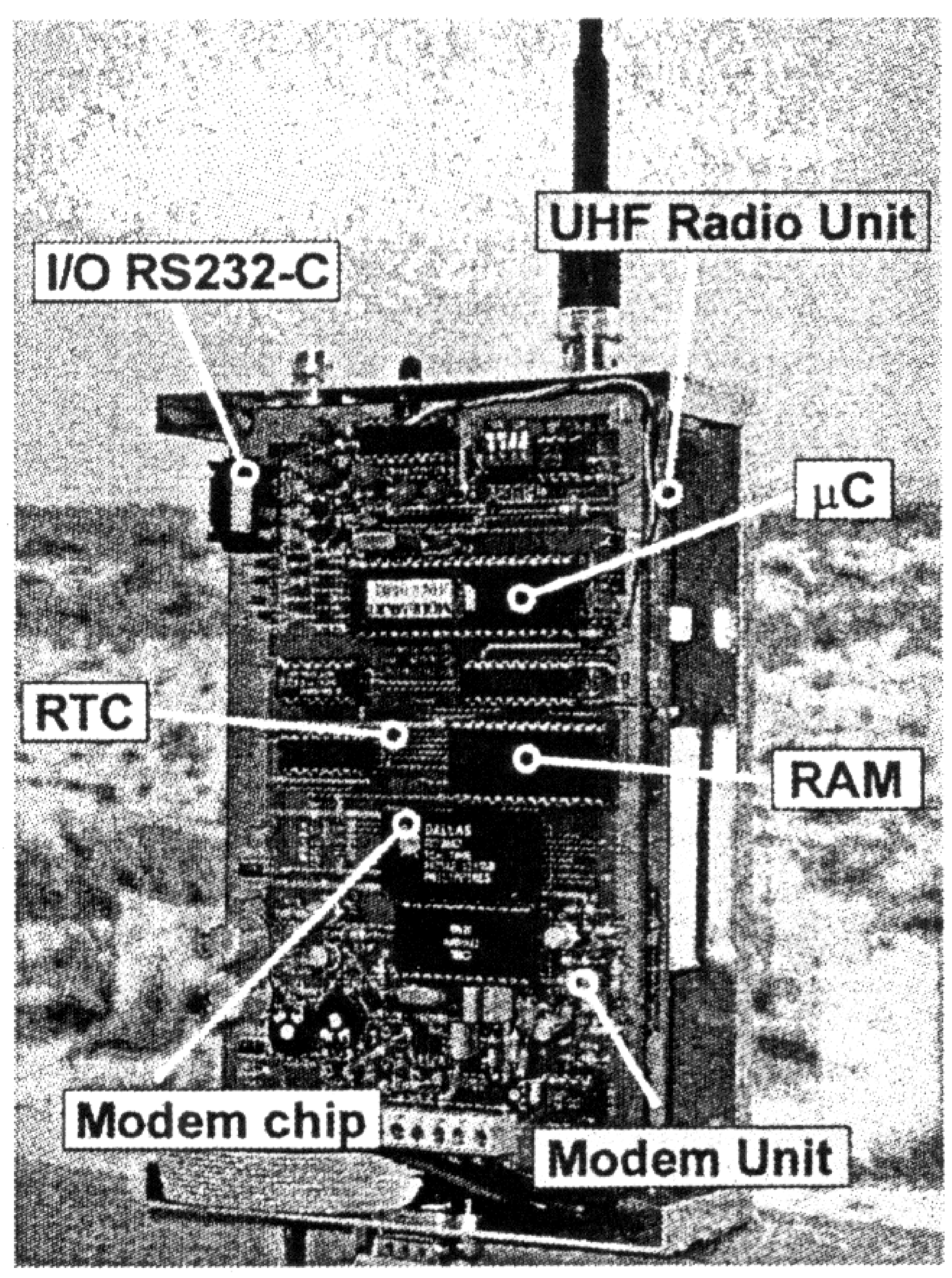

Figure 6 – The Radio Modem

The Radio Modem

A radio modem, developed in the University of Almeria for solar energy applications, was found to be suitable for our purposes (*Figure 6*). It is controlled by a microcomputer, and the internal software could be adapted for our application – an option which is not available with closed commercial systems.

The principal characteristics of this equipment are:

- Frequency: 430-450MHz,
- Power: up to 250mW,
- Modulation: direct 4-level FSK at 4800, 9600 and 19200 bits/s,
- Bandwidth: 12.5KHz for 9600 bits/s and 25KHz for 19200 bits/s,
- Internal buffer of 32Kbytes,
- Forward Error Correction, -105dBm sensitivity @BER<10^{-6} for 9600 bits/s.

Results

The system has been in operation for about a year and in this time a large amount of information has been collected and processed. *Figure 7* was taken directly from **karst-yeso.ual.es** (n.b. no **www**).

In this figure the effect of two consecutive visits can be seen, and how in between them the CO_2 concentration returns to its previous level.

The most interesting graphs are those which show the effect of the conducted visits on the variables (CO_2, Relative Humidity and temperature), and suggest increasing the frequency of measurement for a better study. In the graph of *Figure 8* we can see the

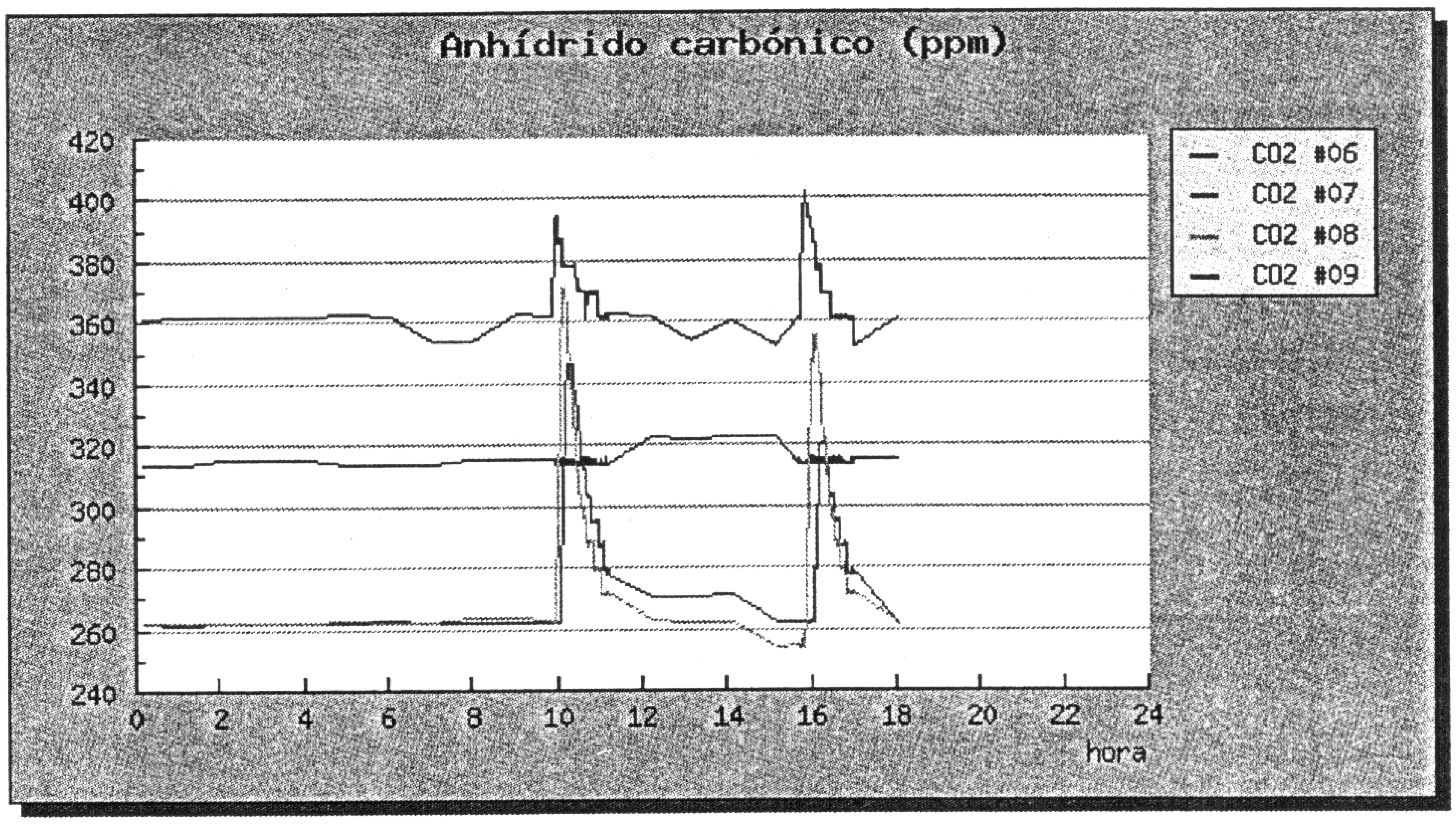

Figure 7 – Carbon Dioxide Levels a Various Recording Stations in the Cave. The Effect of two Visits can be Seen

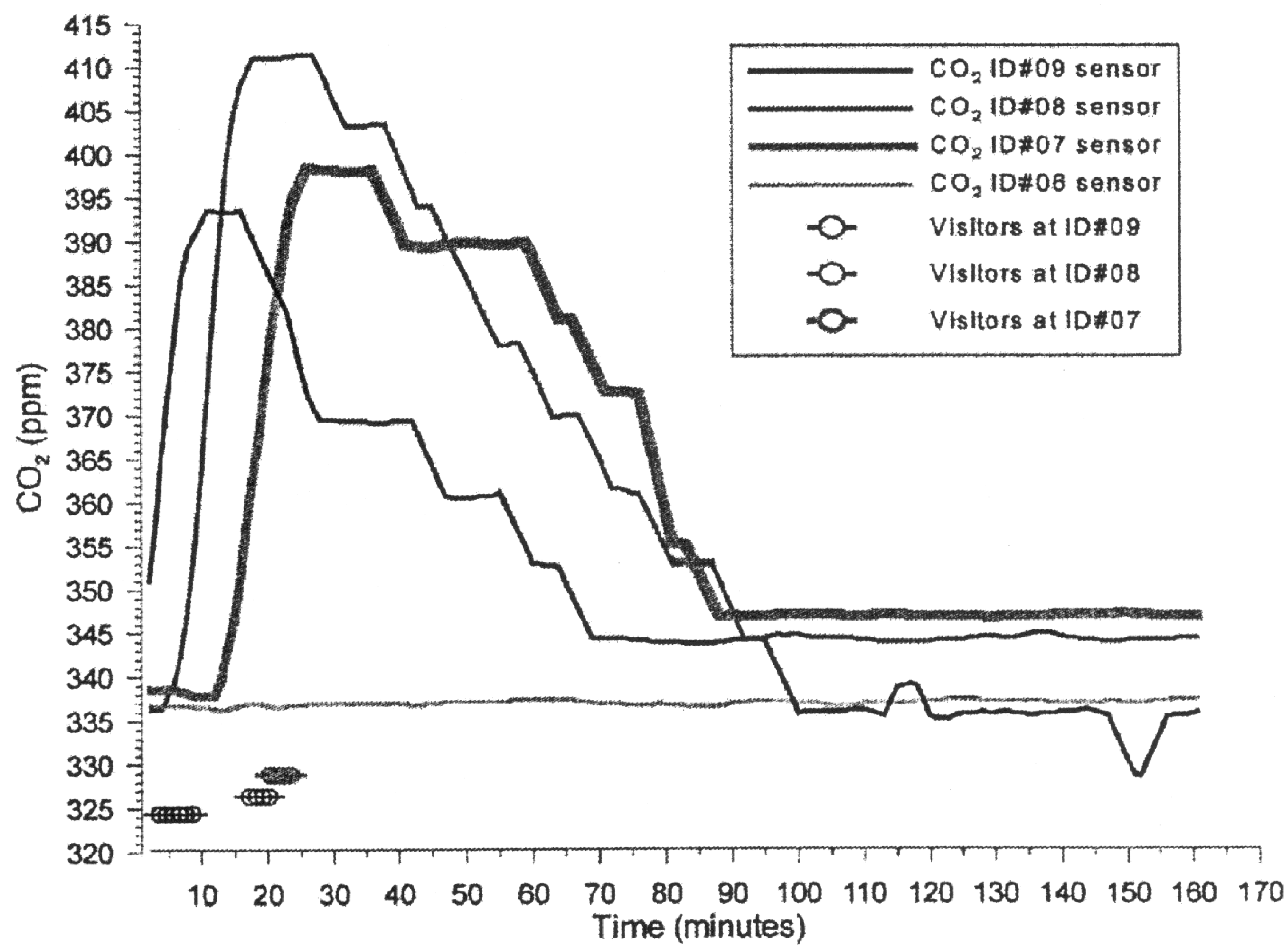

Figure 8 –Detail of CO_2 Variation with Visitor Numbers

increase of the CO_2 concentration due to the entrance of visitors to the cave, and how it subsequently diminishes.

These data are of great interest to the companies who organise the visits, as from their offices they can receive real time data and decide when the next visit should start so as not to affect adversely the ecosystem of the cave.

Conclusions

The development of systems for specific applications requires considerable effort compared with the installation of closed commercial systems. However, it allows projects to be undertaken which, because of their novelty, cannot be pursued satisfactorily with commercial systems. In the case of this project it has been possible to undertake the export of information in real time, from sensors inside a cave located in a remote place without telephone line or electrical light, to the Internet. This is thanks to the development of specific systems.

The system can be considered, in addition, as a tool for managing tourist use of the cave. Decisions about the composition of groups of visitors (number of people and frequency) can be made in real time, varying these parameters according to the intensity of the environmental effect produced.

Acknowledgements

We wish to acknowledge, first of all, project funding from FEDER – Characterisation of the Environmental Conditions for Tourist Visits to the Karst in Yeso de Sorbas ref CICYT 1FD97-1577. This project has provided economic support and manpower for the execution of this development.

The following have taken part as associate and collaborating organisations in the project:

- the Councils of Tourism, Sport and Environment of the Regional Government of Andalusia,
- the City Council of Yeso de Sorbas,
- the company Iberyeso MED, S.A. and
- the CICYT project DPI2001-2380-CO2-02 for development of the instrumentation

C.I.E.M.A.T., under a contract with the University of Almería, subsidised the manufacture of the special-purpose radio modem used in this project.

Reference

Gázquez et al (2003), *Intelligent Telemetry Watches Cave Visitors*, CREGJ **53**, Sep 2003, pp4-5

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Electronic Detection of Carbon Dioxide

*Concerns have been expressed about the high levels of carbon dioxide found in some caves. Further research is needed, and this would be an ideal application for a cave data logger. But, as **David Gibson** explains, it is not easy to detect CO_2 with an electronic sensor.*

SpeleoScene **52** (Sept-Dec 2002) reports that elevated levels of CO_2 have been detected recently in caves in Mendip, Forest of Dean and Derbyshire regions. The article suggests that the increase may be linked to changes in farming practices (e.g. the washing out of cowsheds and the spraying of the resulting nitrogen-rich slurry on fields). CO_2 levels have been observed to change with the weather and the seasons, so there is clearly an interest in trying to correlate CO_2 levels with meteorological conditions and surface agricultural activity.

A sub-surface data-logger that monitored CO_2 levels at frequent intervals could probably provide some interesting data. However, this equipment is likely to be prohibitively expensive, even if largely home-built. CO_2 is not an easy gas to detect and the sensors are correspondingly expensive. When you consider that several data-loggers might be required to cover one cave, the cost soon mounts up.

The problem is that CO_2 is not a very reactive gas and it cannot be further oxidised. For example, the fuel gases (e.g. CO, H_2, CH_4) can easily be detected by oxidising them on a hot electrode and detecting the change in resistance. Sensors that do this are available at low cost. And carbon monoxide (CO) can be detected at concentrations as low as 1 ppm using a cheap sensor based on an electrolytic cell. But these methods cannot be used to detect CO_2. So how might we detect CO_2 and can we built a cheap home-made sensor to avoid having to buy commercial equipment?

From A-level chemistry, we know that bubbling CO_2 into lime water makes it turn milky, due to a suspension of $CaCO_3$. Could we devise a machine to pump the gas through water and then measure the cloudiness using a simple photocell? Probably not. As those of you who studied chemistry at A-level will recall, the milky solution disappears if you continue to bubble in CO_2 because the precipitate re-dissolves in the weakly acidic solution – not to mention the problems of accurately calibrating such a system.

On the basis that many scientific instruments use technology that is years out of date, we could investigate some more esoteric methods. Could we build a device based on nuclear magnetic resonance (NMR)? NMR in liquid water can be demonstrated with simple electronic equipment but, unfortunately, this is not so for a gas (it is too rarefied) and, in any case, not for CO_2 because it is only the rare ^{13}C isotope that we could get to resonate.

One possible solution would be to measure O_2 depletion rather than CO_2 build-up. But oxygen sensors are expensive too, and for research into CO_2 this technique would not be experimentally sound, as some sources of CO_2 do not result in depleted oxygen levels.

It seems that any home-built CO_2 detector would have to be based on infrared absorption – just like commercial sensors. CO_2 absorbs strongly at 4.3μm. Obtaining an infrared emitter at this frequency is straightforward (anything 'hot' will do). An optical filter tuned to 4.3μm would have to be specially manufactured but the cost, spread over a number of units would not be too great. We might need a similar filter tuned to a nearby frequency to allow us to make a ratiometric reading. The infrared detector is a slight problem because cheap passive-infrared detectors (as used in burglar alarms) usually use an 'unfavourable' arrangement of sensors. But there are a number of possible solutions to this problem.

But, all things considered, the design work would be time-consuming. Perhaps the best option would be to keep an eye on the new solid-state gas sensors being developed by Ion Optics (**www.ion-optics.com**). These MEMS-based infrared gas sensors (MEMS = micro-electrical-mechanical systems) feature an emitter, filter and detector all on a single chip and promise an attractive low-cost solution to CO_2 sensing – if they eventually hit the market place.

These notes by David Gibson form part of an article by Garry Smith in *Speleology* 3 – Smith, Gary K (2003), *Carbon Dioxide in Limestone Caves and its Effect on Cavers*. Speleology 3, pp10-12, Sep 2003

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