LOW COST DETERMINATION OF SNOW ACCUMULATION[1]

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An inexpensive commercial instrument has been developed for measuring snow depths. The Belfort 900 uses acoustic ranging techniques to sense the surface of the snow and reports out the height of this surface above a reference level, such as the ground. Operation of the instrument and results of testing in the first year in the field are described. Some problems inherent in the use of this technique are discussed.

INTRODUCTION

The ever growing desire for "real time" meteorological and climatological data has prompted the development of a new breed of automatic data gathering equipment. Among the various parameters of interest to hydrologists, agriculturists and others, such as operators of ski resorts, is the depth of snow on the ground.

Manual observation of snow depth is so labor intensive, and sometimes impossible, due to inaccessibility of measuring sites, that the need for an inexpensive automatic snow depth sensor is obvious.

This sensor must be fully automatic in operation, be highly reliable, and have an output compatible with currently available data logging and transmitting equipment.

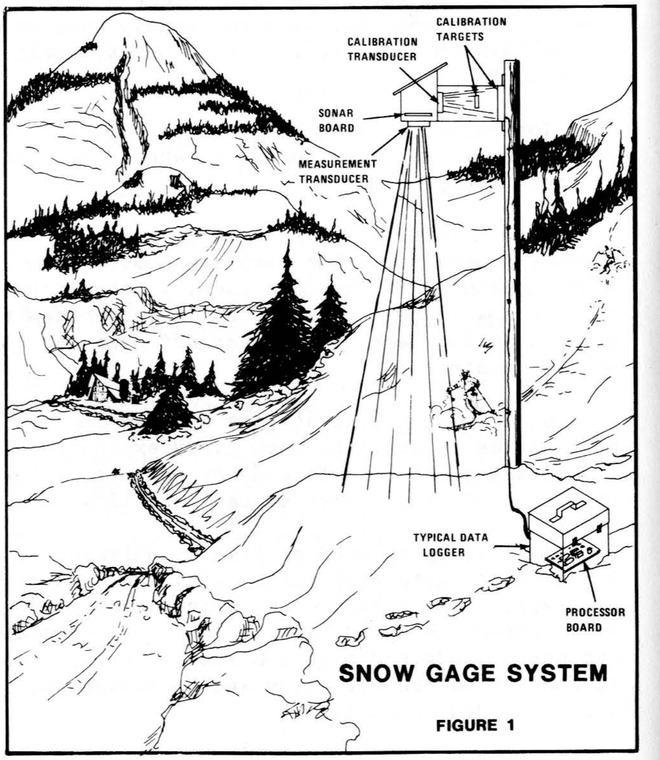
With these requirements in mind, a stand alone Acoustic Depth Gage has been developed that uses very little power and produces output signals of both an analog and digital nature.

SYSTEM DESCRIPTION

The Belfort 900 Acoustic Depth Gage determines the distance between a fixed sonic transducer and the snow surface by timing the flight of an acoustic pulse from the transducer to the target and back again. Knowing the speed of sound, the distance can then easily be calculated, and if we know the whereabouts of ground level, we can compute the height of the accumulated snow.

Developments in Canada (Goodison et al, 1985 and Edey et al, 1985) have offered proof of the feasibility of the concept. In prototype systems put together by Belfort in 1984 and 1985, a package suitable for commercial manufacture was designed and hardware and software developed for processing the sonic signals and converting the information into user compatible data.

Figure 1 shows the make up of the Acoustic Depth Gage. The sensor assembly consists of a pair of identical sonic transducers, a Ranging Module and Sonar printed circuit board, housed in a vented enclosure. The enclosure is mounted on a support arm of such length as to properly position the measuring transducer with respect to the ground when the unit is mounted at up to its maximum height (20 ft. from the ground).



SNOW GAGE SYSTEM

FIGURE 1

[1]Paper presented at the International Snow Science Workshop, Lake Tahoe, California, October, 22 - 25, 1986.

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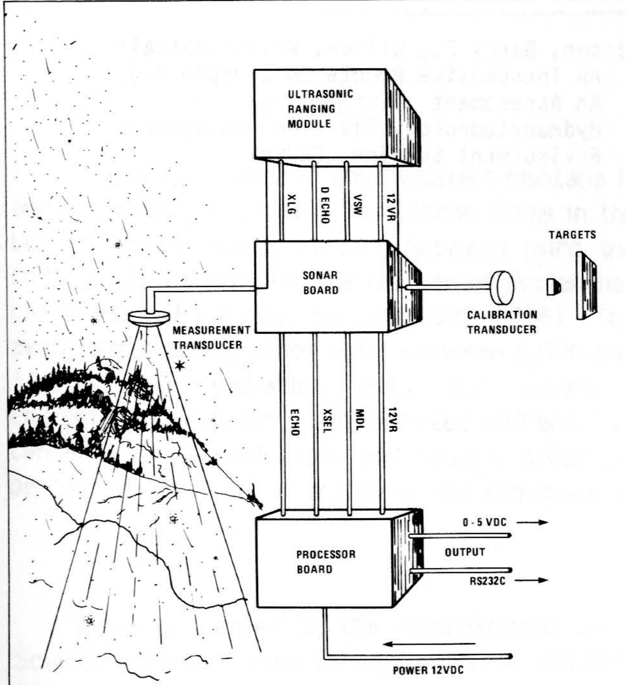
A second transducer, used for compensating for changes in the speed of sound due to temperature, pressure and humidity changes, beams an ultrasonic signal down the support arm. This signal is reflected by a pair of targets mounted in the support arm which defines a reference path of fixed length.

A cable connects the Sonar board with the Processor board which may be mounted in an enclosure with the users data logger if desired. A power supply within the range 11 to 14VDC is required.

OPERATION OF THE SYSTEM

The operation of the Acoustic Depth Gage is based on the use of the Polaroid ultrasonic ranging system developed for use in the Polaroid Auto Focus Camera. The elements of this system include an improved ultrasonic transducer and the Ultrasonic Ranging Module. They are shown in Figure 2. In addition to the Polaroid components, a Sonar board and the Processor board make up the system.

System operation is initiated in the Processor board. First the +12VR line to the Sonar board and the Ultrasonic Ranging Module (URM) is energized. The processor then sends a transducer select signal (XSEL) to the transducer relay which switches in the calibration transducer. A gating signal (MDL) from the processor then causes the Sonar board to initiate a series of ultrasonic pulses to be generated in the URM and passed



SNOW DEPTH GAGE BLOCK DIAGRAM

FIGURE 2

through the relay to the calibration transducer. Echos from the fixed calibration targets are received by the calibration transducer, which functions both as a sound generator and as a microphone, and passed back to the URM. The echo pulses are amplified in the URM to a degree depending on the distance of the target from the transducer. Since the transmitted power decreases as the reciprocal of the square of the distance to the target and the returned echo does likewise, the detected signal strength from maximum range (20 ft.) is actually almost 60 db below that detected at minimum range, 12 inches from the transducer. To compensate this, a cascaded amplifier circuit which changes gain as a function of time is employed. The processed echo (PECHO) is then sent to the Sonar board where it is combined with a sample transmitted pulse and passed on to the Processor board as ECHO. The calibration echos are processed to determine the speed of sound under the present environmental conditions, and this value is stored for use in later computation of the distance to the snow surface.

After a series of calibration transmissions have occurred, the measurement transducer is switched in the circuit and the procedure repeated.

This measurement is then converted to a DC voltage (scaled in accordance with instructions entered on the key pad). and an ASCII coded message is generated and output at the RS232 level.

On the Processor board, a keypad and LED display enable the user to put into operation various programs that are stored in permanent internal memory. The instrument has already been calibrated at the factory and critical values representing the characteristics of that particular instrument have been stored in Non-Volatile Random Access Memory so that calibration data will not be lost when power is turned off. The user has only to establish a base for his measurements (ground level, for example, if measuring snow depth) and select (with the keypad) from options available, such things as the desired time interval between measurements, English or metric units, selectable baud rate, etc. In order to conserve power, the system "goes to sleep" between measurements, but can be awakened at any time by pressing a key.

PRELIMINARY TEST RESULTS

A number of production units were shipped from the factory for the 85/86 season. Unfortunately, a few design gliches surfaced in some of these instruments and they had to be recalled for modification. Others were not installed for various other reasons. We do have a report that the output of a snow gage installed at Copper Mountain is being logged along with other weather data in a Campbell CR21, the data being sent to the complex of hotels, booking offices and travel agencies around the ski resort where it is displayed. The results are so good that early morning ski conditions briefings by the ski patrol have been eliminated.

Planned factory testing of a number of units installed in Baltimore for the 85/86 winter was almost completely a failure, since we had, at the very most, a total of four inches of snow the entire season.

PROBLEMS USING THE TECHNIQUE

Preliminary testing has disclosed several problems inherent in the sonar technique that can have an effect on the accuracy of the measurements.

One problem involves the character of the snow surface itself. While the depth gage will perform for weeks in the laboratory with maybe only a tenth of an inch variation, the reflection of the sonic pulse off the surface of a soft, low density powdery snow is quite different from that echoing off a tile floor. Although we have no quantitive measurements, it appears that penetration of the acoustic signal into the soft snow will result in undermeasuring the total depth of the snow - possibly by as much as several centimeters.

Another, and possibly more serious problem, is the performance of the gage during a snowfall or under conditions of blowing snow. Since the acoustic signal will be reflected from anything placed in its path, falling or blowing snow will introduce reflections of varying strengths into the return echo with results that may mask the primary echo from the snow surface.

Finally, it is not certain that the method of compensating for variations in temperature of the atmosphere is adequate. Depending on environmental conditions, sunlight, air movement, etc., a considerable temperature gradient may exist in the measurement path. We are assuming that the atmosphere in the calibration path is truly representative of that in the measuring path which of course it is not. Preliminary measurements under simulated environmental conditions have shown that we might expect up to 0.3 inches of error due to this effect.

To address these problems, Belfort has initiated a test program to be conducted this season in Buffalo, New York, where we have been guaranteed a sufficient snowfall to give us a multitude of data. We also propose to cooperate with others who plan installations this season.

CONCLUSIONS

In spite of the existence of the problems discussed above, the Acoustic Depth Gage appears to offer a completely suitable method for measuring snow depth at a point. Its low cost make it economically feasible to deploy a number of gages over a large area. Reliability has been part of its design and further refinements are expected to increase its usefulness.

LITERATURE CITED

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