The "Chirp" Digital Radiosonde[1]

VERNER E. SUOMI, KIRBY J. HANSON[2] AND ROBERT J. PARENT

University of Wisconsin, Madison

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ABSTRACT

This paper reports on a digital measurement ("chirp") system which has application for a wide range of meteorological and earth satellite measurements.

The system employs a simple concept in which a voltage pulse, proportional to a sensor voltage, is used to generate a burst of pulses from a voltage controlled oscillator (VCO). A count of the high frequency oscillations which make up the "chirp" provides the digital measurement. The system is adapted to multiple sensor use with a multiplexer.

The system has the advantage in that one has the option of selecting an ac amplifier for low level signals in conjunction with a variety of multiplexers and VCO for the desired measurement. One particular combination of multiplexer and VCO was used to demonstrate its use as a digital radiosonde.

A flight test of the digital radiosonde was obtained. Results clearly show fine structural detail in the temperature profile without any need for subjective interpretation by the operator. Numerous isothermal and inversion layers less than 100 m in thickness were observed.

The digital radiosonde used conventional (U. S. Weather Bureau) temperature and humidity sensors. Temperature resolution is about 0.1C and relative humidity is about 0.1 per cent. The system resolution is 0.1 per cent.

1. Introduction

A digital measurement ("chirp") system has been developed which has possible application for atmospheric studies from satellite, rocket or balloon carriers, or fixed station use in remote areas or on oceanic buoys. The system has been test flown as a digital radiosonde. This paper discusses the concept of the system and reports on its use for a digital radiosonde.

2. The system

The "chirp" system is based on the simple combination of two concepts. If a sensor voltage is used to develop a sequence of pulses of similar shapes, fixed duration, but variable height, the area under each pulse curve is proportional to sensor voltage. Furthermore, this relationship holds for many pulse shapes; for example, the shape one gets in a simple capacitor-resistor differentiating circuit. Second, if the pulse is applied to a voltage controlled oscillator (VCO), the area under the pulse curve can be measured simply by counting the total number of oscillations. Combining these two ideas, it is apparent that such a measurement would be proportional to sensor voltage. Small voltages can be used on the sensor because the pulse wave form is easily preserved with ac amplification; a more expensive dc amplifier is not required.

The system is "open loop" which requires a reference resistor in order to obtain absolute values. In this respect it is similar to the conventional radiosonde.

It should be emphasized that many other multiplexing schemes are possible, particularly when a larger number of sensors or low power consumption is desired. There are also many options available in selecting the VCO.

There is considerable flexibility in recording. Only a simple counter is required for measurement, and its output can be recorded by printing, punching, or on magnetic tape. These devices are available commercially. Direct computer input is also possible.

3. Digital radiosonde example

The particular multiplexer and VCO discussed in this paper were selected merely to demonstrate the "chirp" system as a digital radiosonde. The multiplexer (Fig. 1) is a modification of that developed by Kobussen and Weinman (1966) for use in radiosonde switching. The voltage controlled blocking oscillator is that developed by Unter (1965).

The sampling rate of the digital radiosonde is four measurements per second chosen to fit the Hewlett-Packard counter and printer. During a typical (90 min) balloon sounding, each sensor would provide about 5000 measurements. The system resolution is better than 0.1 per cent. The temperature resolution is about 0.1C and relative humidity is about 0.1 per cent.

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[2] National Environmental Satellite Center, ESSA, Madison, Wisc.

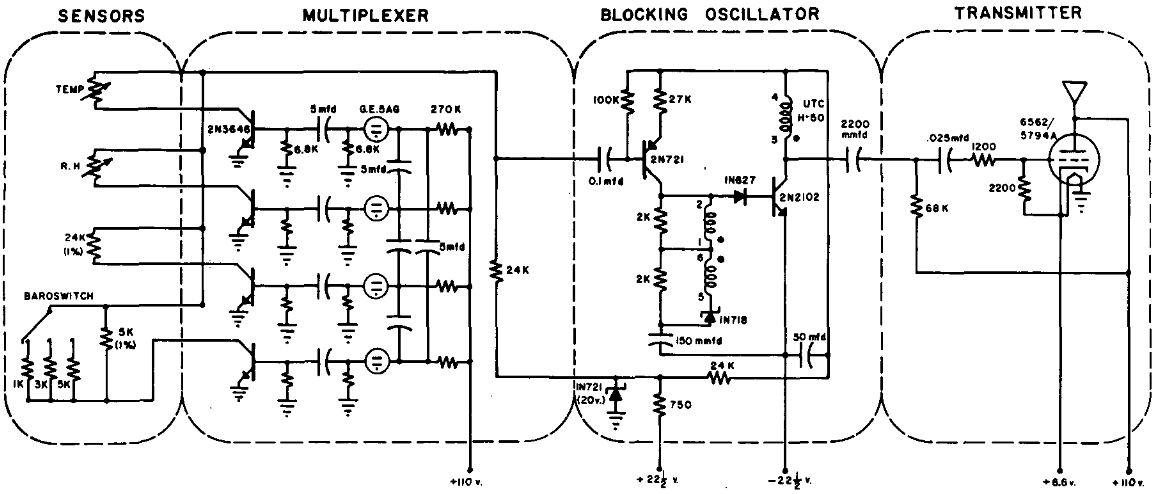

FIG. 1. Circuit for the "chirp" digital radiosonde that was flight tested at Madison, Wisc., on 8 November 1965.

Because the pulse sampling time is short, it is possible to apply high voltages to sensors without overheating. For example 20 V was applied to the thermistor and only 50 μW of power was dissipated in the sensor.

4. Test flight and results

A flight test of the digital radiosonde was made (1500 CST 8 November 1965) using a balloon sounding from Madison, Wisc. The results are illustrated in Figs. 2 and 3 together with a sounding made at Green Bay, Wisc., three hours later. The Green Bay sounding is that obtained by the U. S. Weather Bureau using a standard (or conventional) radiosonde. The similarity of the temperatures at heights above 675 mb (Fig. 2) is quite apparent. The departure of the two soundings below 675 mb can be expected considering space and time differences and the weather situation at that time.

A great deal of structural detail can be seen in the inversion layer, shown in Fig. 3. The main meteorological interest is the fact that the *steep slope* of the

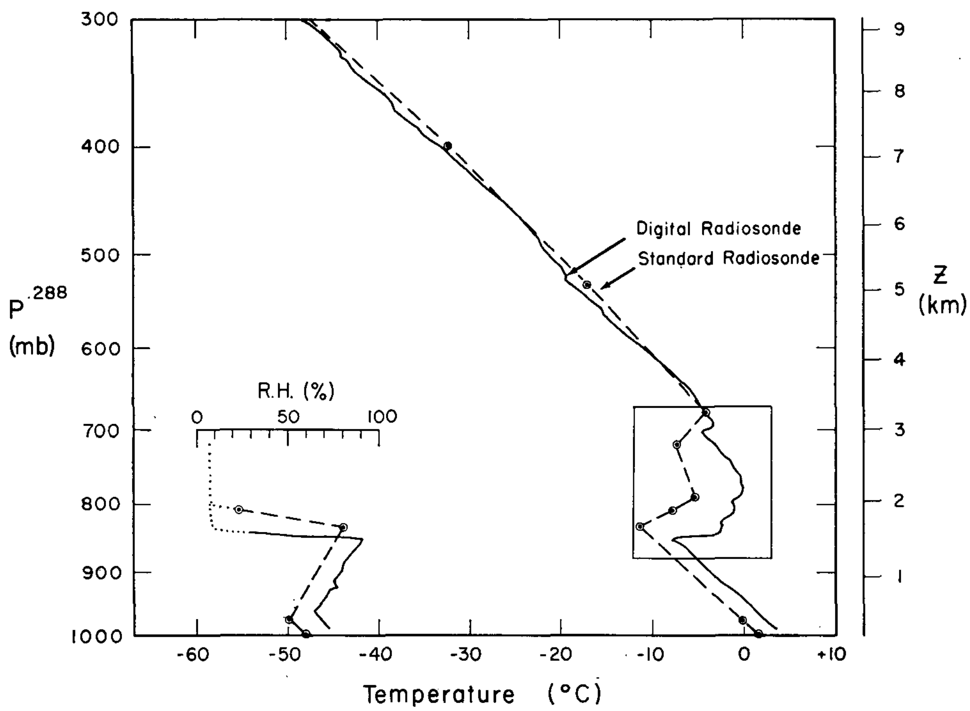

FIG. 2. Radiosonde observations of 8 November 1965, from the "chirp" digital radiosonde at Madison, Wisc., 1500 CST and a standard radiosonde at Green Bay, Wisc., 1800 CST.

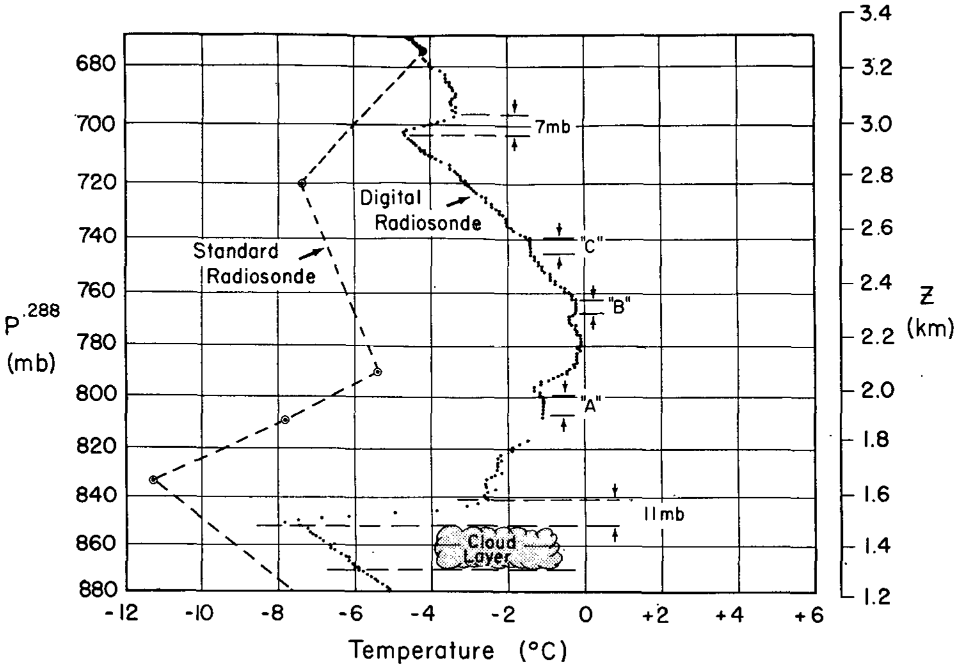

FIG. 3. Expanded scale illustration of the inversion layer shown in Fig. 2.

temperature inversion is limited to a shallow (11 mb) layer just above the cloud top. A second shallow inversion layer, 7 mb thick, is found near 700 mb. Both of these layers are only about 100 m in thickness.

The three layers marked "A," "B" and "C" are shallow isothermal layers; through each of these layers, the count value from the temperature sensor did not vary. Such repeatability inflight provides an indication of the low noise level and high reproducibility that can be obtained with this system.

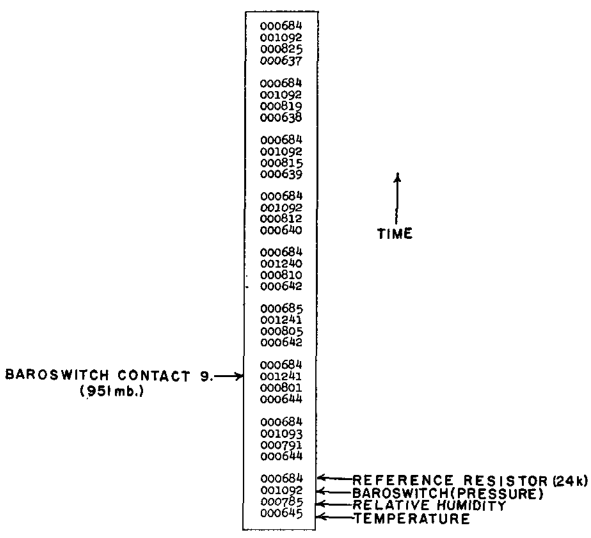

FIG. 4. Sample of paper tape record of the "chirp" digital radiosonde during the test flight on 8 November 1965.

A sample of the paper tape record obtained during a portion of the test flight of the digital radiosonde is shown in Fig. 4. Data was received sequentially from the sensors beginning with temperature. Time proceeds upward on the record. Temperature, humidity, and reference resistors were sampled on each sequence of four measurements (i.e., once each second). The baroswitch was also sampled on each sequence and had one of four *fixed* resistance values, depending on the position of the baroswitch arm (see Fig. 1). In this way, a *change* between the fixed resistance values indicated a *change* in the baroswitch position, which in turn provides the pressure measurement. A similar method is

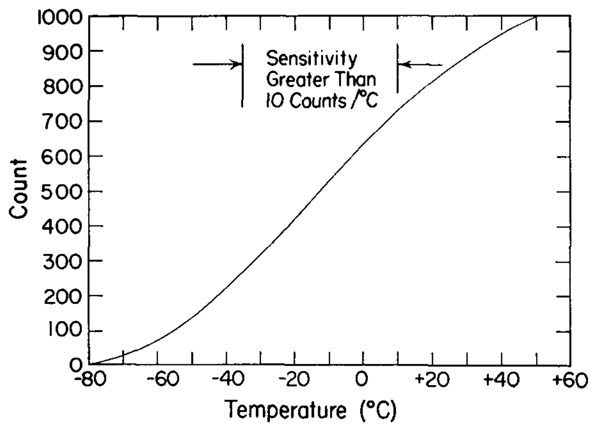

FIG. 5. Temperature measurement sensitivity of the "chirp" digital radiosonde.

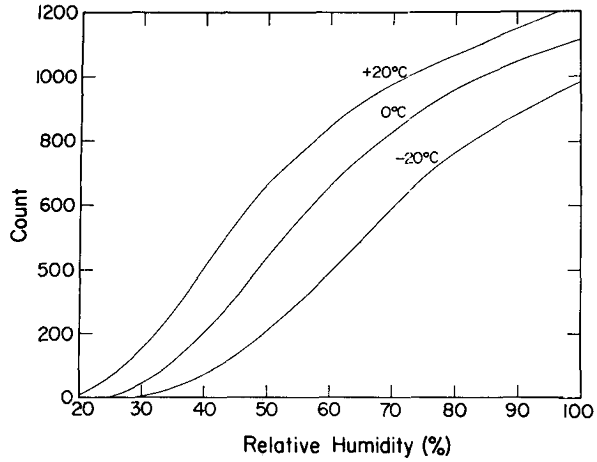

FIG. 6. Relative humidity sensitivity of the "chirp" digital radiosonde.

used in the conventional radiosonde. For routine use, a continuously varying pressure sensor would improve resolution a great deal.

A direct comparison between the soundings cannot be made because of space and time differences. The standard radiosonde has analog output and provides much more detail than is illustrated in Figs. 2 and 3. However, much of this fine structural detail is lost in the routine scaling of "significant" levels from the analog records. All of the "significant" levels have been included in Figs. 2 and 3, however. The same types of sensors were used for both soundings.

5. Digital radiosonde characteristics

A standard U. S. Weather Bureau rod-type thermistor was used for temperature measurement with the digital radiosonde. The *count* as a function of temperature for that particular sensor is shown in Fig. 5. The count-temperature relationship is nearly linear over a large portion of the temperature range. The sensitivity is greater than 10 counts $(°C)^{-1}$ from +10 to −35C. Above and below this range the sensitivity is less.

For humidity measurement, a lithium chloride strip-type sensor was used. The count as a function of relative humidity (for three constant temperatures) is shown in Fig. 6. These curves show that the maximum sensitivity is about 20 counts per unit percentage change; however, the sensitivity is greater than 10 counts per unit percentage change over nearly the entire humidity range.

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