RAW DATA DIGITIZING AND RECORDING SYSTEM FOR THE OMEGA-SONDE WIND FINDING GROUND STATION

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Abstract

This paper describes a low cost Omega-sonde data acquisition system consisting of a portable shipboard raw data recording package and a minicomputer interface used in the data reconstruction. The Omega phase is detected against a crystal controlled reference signal. The detected relative phase is recorded in digital form using timing signals controlled by the same crystal oscillator. The meteorological information is recorded in analog form. The data are stored on two-track audio tape cassettes which are processed via the interface and a minicomputer to yield IBM compatible computer tapes.

The interface converts both the phase and the meteorological data to parallel-bit format. The recorded meteorological data (frequency) is counted and digitized using a clock signal which is phase-locked to the recorded phase data timing signal. The effects of tape wow and flutter on the meteorological data are thus reduced considerably. Samples of recovered phase and meteorological data are included.

I. Introduction

Real time processing of Omega-sonde data requires a very sophisticated and costly ground station.[1,2] Such ground stations may be undesirable for field operation. If the real time requirement could be dropped, an alternate approach may be preferred. This approach will take the form of a low cost raw data recording system which, together with a 400 MHz telemetry receiver, comprise the field ground station. Processing will be done by a general purpose minicomputer equipped with the appropriate interface.

The instrumentation system described in this paper was used in the GARP Atlantic Tropical Experiment (GATE) to record and recover raw phase and meteorological data from Omega-sondes. The input to this system was derived from the output of the LO-CATE[3] 400 MHz telemetry receiver which was part of the existing shipboard Omega-sonde ground station; however, any 400 MHz telemetry quality receiver will do. The main purpose for the design of this recording system was to provide a nonvolatile record of the raw Omega-sonde data.

The system was designed to record the phase of the Omega signal in digital form and the meteorological data (a series of four, 200 msec duration, tone bursts, ranging from 50 to 2000 Hz) in analog form. Figure 1 shows a function block diagram of the recording system. The telemetry receiver output drives both the meteorological (MET) data filter and the Omega receiver. The MET filter has a low pass characteristic to remove extraneous navigation (NAVAID) data prior to recording the meteorological data on one track of a commercial stereo cassette tape recorder. The Omega receiver (bandpass limiter) raises the signal in the Omega frequency spectrum to logic levels. The phase of the output of the Omega receiver is first digitized and then modulated and recorded onto the second track of the cassette recorder. The digitizer timing is derived from a standard 10 MHz TCXO. Power for the system is obtained from the ship power grid and is conditioned by a commercial power supply. The complete system is packaged in a metal suitcase for RF shielding and ruggedness. A photograph of the Omega-sonde data recording system is shown in Fig. 2.

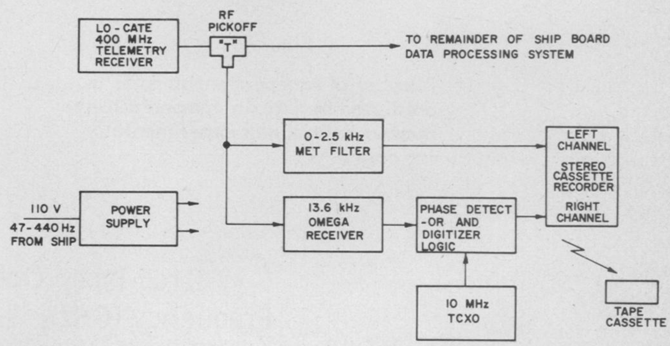

Fig. 1 Block diagram of overall system

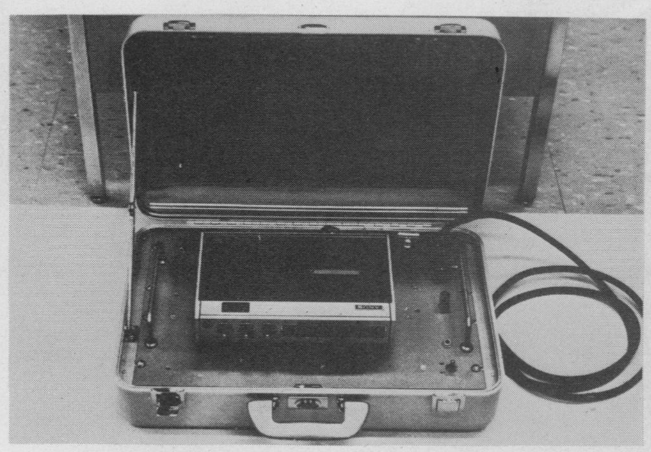

Fig. 2 Recording System

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II. Omega Receiver and MET Filter

The function of the Omega receiver is to extract and amplify the 13.6 KHz Omega signal from the output of the telemetry receiver. Considerations which are of prime importance in the design of the Omega receiver are that the receiver output be well filtered and that the phase and amplitude of the receiver output signal be constant over a wide range of input signal amplitude. The receiver specifications are given in Table 1.

Table 1. Receiver Specifications

Input Impedance	100 kΩ
Input Voltage Range	200 μV to 200 mV RMS
Dynamic Range	60 dB
Change in phase shift over dynamic range	$\leq 3°$
Net pre-limiter bandwidth	200 Hz at -3 dB 1000 Hz at -60 dB
Post-limiter bandwidth	100 Hz at -3 dB
Output	COS/MOS compatible, levels 0 and +12 V
Power requirements	± 12 VDC at 30 ma

The block diagram of the Omega receiver and the MET filter is shown in Fig. 3. Two types of filtering are used. Pre-limiting filtering is done in the pre-selector. The bandwidth of the pre-selector filter was chosen to eliminate adjacent signals and to minimize ringing response to large sferics. The input to the comparator (after amplification and limiting) is then filtered again to increase the Omega noise correlation time and eliminate wideband noise generated in the receiver.

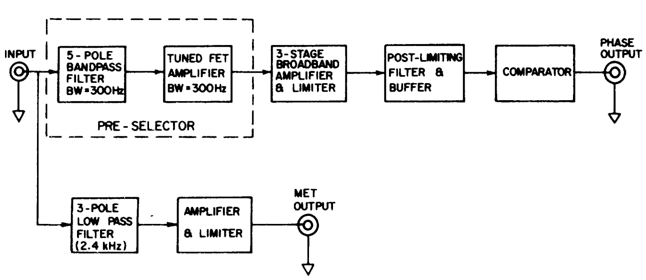

Fig. 3 Block diagram of the Omega receiver and MET filter

Overall receiver operation is as follows: The input signal is filtered and amplified by a 3-stage broadband amplifier, each stage having about 20 dB of gain. Each stage also incorporates limiting diodes to prevent overloading of the following stage (overloading would destroy the phase stability). The output of the amplifier is then filtered again and is applied to the comparator input. The output of the comparator is then buffered to make it compatible with COS/MOS logic levels.

The first stage of the receiver is a 5-pole, Butterworth design, passive bandpass filter having a 3 dB bandwidth of 300 Hz centered at 13.6 kHz. The characteristic impedence of the filter is 100 K Ohms. High stability is insured by the use of pot core inductors and silver mica capacitors.

There are two other tuned circuits in the receiver. One, in the preselector, is designed for a bandwidth of 300 Hz. The other, the comparator filter, has a 100 Hz bandwidth. Both filters use pot core inductors and high Q polystyrene capacitors.

The MET data filter extracts the meteorological information in the 0-2500 Hz portion of the Omega receiver input. The filter is a simple 3-pole Butterworth design active filter. The output of the filter is amplified and limited to make the signal suitable for recording.

III. Phase Digitizer

The phase digitizer consists of a phase detector and phase digitizing circuitry. The phase of a local TCXO is compared to that of the received 13.6 kHz Omega signal. The Omega phase is sampled at a 100 Hz rate so that there are an integral number of Omega cycles between each sample (see Fig. 4a). This insures that the sampling process starts at a fixed point relative to an Omega signal with constant phase. The sampling of the Omega phase is accomplished by counting a 2.5 MHz clock during the interval between the rising edge of the 100 Hz sample clock and the next positive zero crossing of the Omega signal (see Fig. 4b). For the 13.6 kHz Omega signal, neglecting noise, a maximum count of 184 is expected. Noise will cause a jitter in the signal edges making it possible for the maximum count to go beyond 184. An 8-bit counter (max count = 256) provides a more than ample margin for a noisy signal. For a chosen 10-bit word length (8 bits of data and 2 bits of word sync) and a 100 Hz sampling rate, the output data stream has a 1000 bit/s rate.

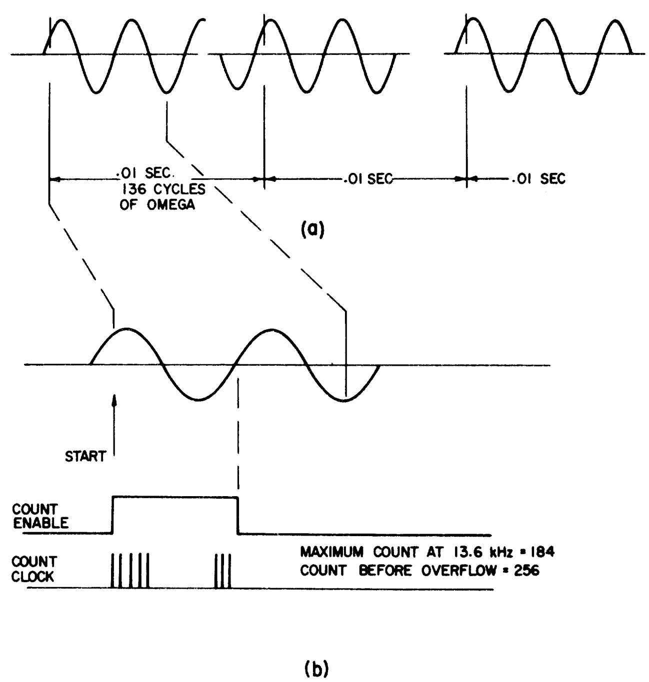

Fig. 4 Omega signal phase measuring scheme
4a) Sampling timing
4b) Phase measurement

Each Omega station transmits for 0.9 to 1.2 seconds once every 10 seconds. The phase digitizer produces a new phase data word every 10 ms which results in 90 to 120 phase samples per Omega station transmission. No additional information could be gained by increasing the number of phase samples above 100 per second, since, with an Omega receiver bandwidth of 100 Hz, higher sample density will produce correlated samples.

The block diagram of the phase digitizer is given in Fig. 5. With the exception of the 10 MHz TCXO, the first divide-by-four stage and the level shifter, the entire circuit is implemented with COS/MOS logic chosen for its high noise immunity, lenient power supply requirements and low power drain.

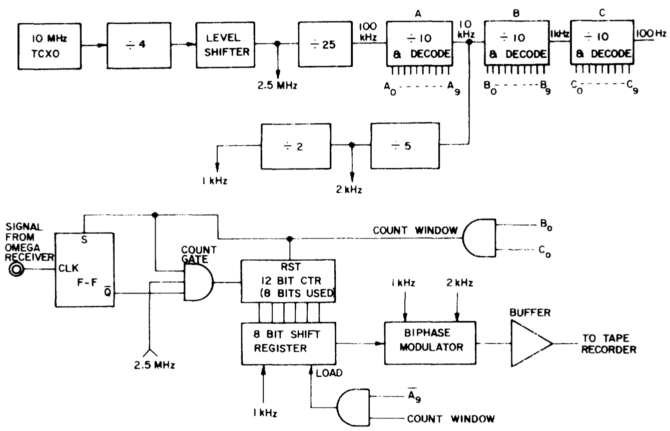

Fig. 5 Block diagram of phase digitizer

The stable (± 1 ppm from 0°C to 50°C) TCXO signal is divided down to form the timing and control signals. The count gate is opened at the start of the 100 Hz sampling signal, C_0. The gate is shut off on the first positive going zero crossing of the Omega signal. The interval between these two signals represents the phase of the Omega signal and is stored as a count in the 8-bit counter. The counter output is transferred to the 8-bit shift register which, in conjunction with the bi-phase modulator, converts the stored phase count to bi-phase NRZ data. This bi-phase data is buffered and then recorded on the remaining track of the tape cassette. The form of the data words is 8-bits of bi-phase data (MSB first) followed by 2 bits of constant level word sync.

Normally, audio cassette recorders are considered unsuitable for digital data recording because many digital data applications cannot tolerate any bit dropping.[4] In our application, such a recorder is usable because an occasional loss of a data sample is tolerable.

IV. Phase and MET Data Demodulators and Computer Interface

The raw Omega-sonde data, once stored on the tape cassettes is, in itself, of little value unless the data can be put into a format which can be readily accessed by the data processing program in a computer. A data demodulation system was designed to convert the raw data on the cassettes to an IBM compatible 9-track computer tape. Since the formats of the phase data (digital) and the MET (analog) data are quite incompatible, the two schemes will be discussed separately.

The block diagram of the phase data demodulator is given in Fig. 6. The bi-phase data from the tape recorder is passed through a differentiator and a Schmitt trigger to remove distortion caused by the narrow band response of the recorder and to raise the signal to logic levels. The signal is then passed through an edger which produces an output pulse for each waveform edge. The pulses are fed to a bi-phase demodulator circuit which reconstructs the original NRZ data and extracts a bit clock and a word sync strobe. The serial demodulated data is converted to parallel bit form and is then held in an 8-bit latch for input to a minicomputer.

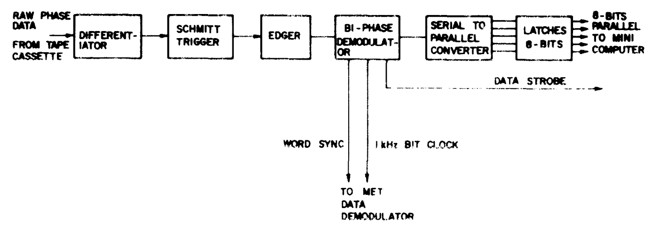

Fig. 6 Phase data demodulator and minicomputer interface

The MET data demodulator and computer interface is given in block diagram form in Fig. 7. The raw MET data is first amplified and passed through a differentiator to emphasize signal transitions. The transitions are then identified using a Schmitt trigger. Next the signal is hard-limited to define cycle boundaries and to raise the signal to logic levels. The signal is then digitized in a counter by gating a 1 MHz clock which is phase-locked to the 1 kHz phase data bit rate. Phase-locking of the clock reduces errors due to speed variations in the tape recorder playback.

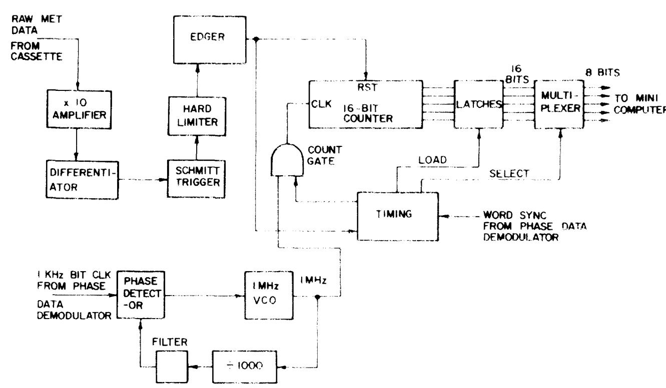

Fig. 7 MET data demodulator and minicomputer interface

The 1 MHz clock is counted for two complete cycles of the input frequency, starting with the first zero crossing which follows every fifth Omega word sync. Since the Omega word appears every 10 ms, this counting procedure is carried out four times during a 200 ms transmission. Software polling of the four consecutive samples allow the bad data due to frequency boundary errors to be discarded. The concept is summarized in Fig. 8. At the lowest frequency, 50 Hz, each counting period occupies 40 ms out of the 50 ms allocated. A two cycle time interval produces a count of 40,000. At the highest frequency, 2000 Hz, each counting period occupies only 1 ms every 50 ms, and results in a count of 1000. From the above we see that a 16 bit counter is required to count the full range of MET frequencies.

The output of the counter is stored in a 16 bit latch. The 16 bits of parallel data are input into the mini-computer, 8 bits at a time, using an 8-bit multiplexer.

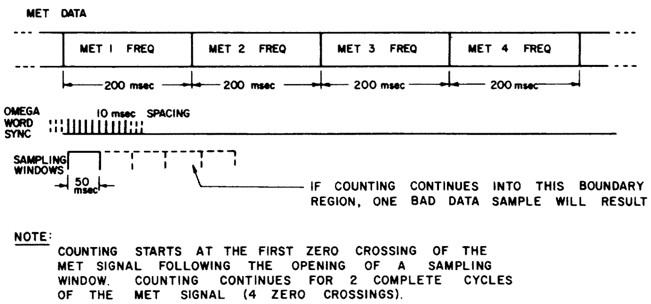

Fig. 8 MET data demodulation timing

Samples of recovered data are given in Figs. 9 and 14. Fig 9 shows the record of a 10 second portion (one complete Omega station transmission sequence) of phase data from flight #179 launched in the mid-Atlantic from the ship "Oceanographer" on June 18, 1974. An Omega transmission time format is included for reference. The strong station which starts the record is North Dakota. The strong station transmitting in the 4-5 second portion (the Australia slot) is believed to be an experimental transmission from Forestport, New York. Norway and Trinidad are evidenced by the concentration of data in the 6-7 and 8 second portions of the record, respectively.

The phase location of even the weak Norway and Trinidad transmissions becomes clear if the raw data for each station is plotted in its own time interval as a phase distribution. The strong transmissions, North Dakota and Forrestport, New York, exhibit a sharp phase distribution as seen in Figs. 10 and 11, respectively. The phase distribution for the weaker transmissions, Norway and Trinidad, in Figs. 12 and 13, respectively, are much more diffuse. There is, however, no difficulty in selecting the probable phases of these transmissions. It should be emphasized that Figs. 9 through 13 are of raw data with no processing performed to enhance the signal.

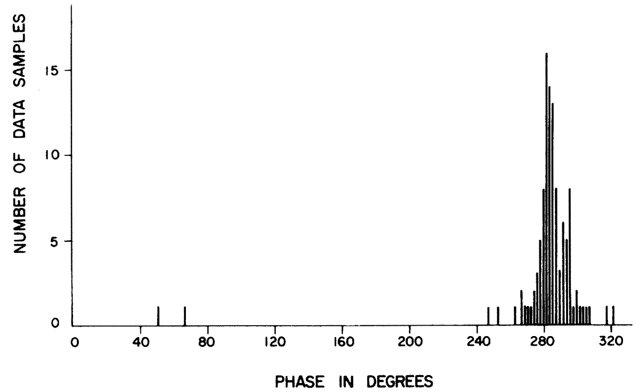

Fig. 10 Phase distribution of data in the North Dakota time interval

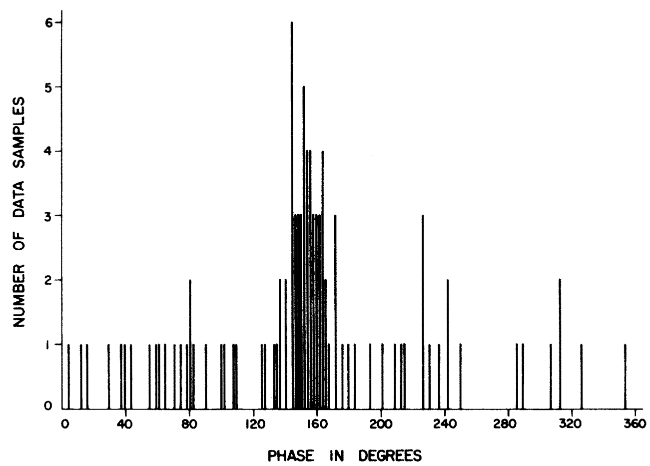

Fig. 11 Phase distribution of data in the Australia (Forestport, New York) time interval

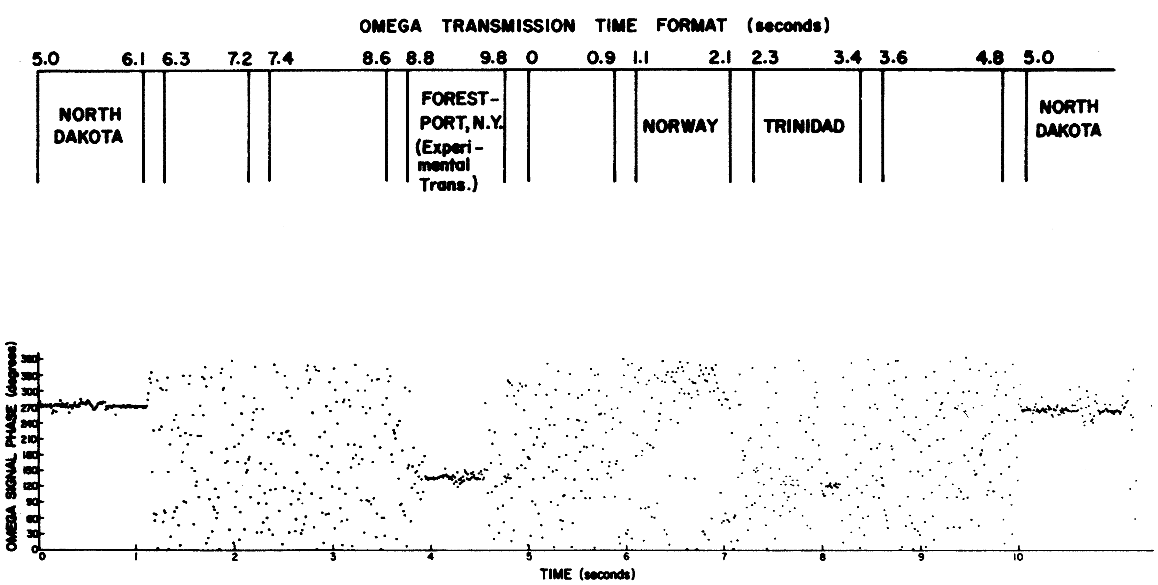

Fig. 9 A 10-second record of phase data (flight #179, 18 June 1974)

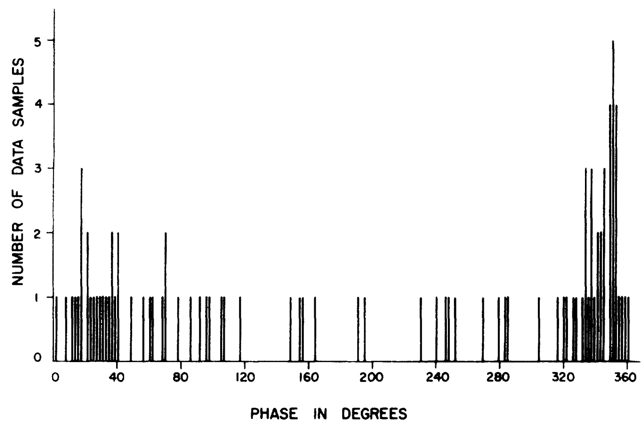

Fig. 12 Phase distribution of data in the Norway time interval

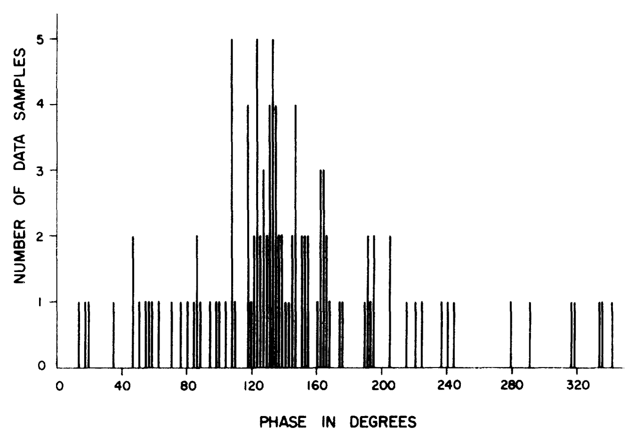

Fig. 13 Phase distribution of data in the Trinidad time interval

Fig. 14 shows the MET data corresponding to the 10 second record of phase data. The bad data points due to frequency boundary errors are obvious and can readily be eliminated

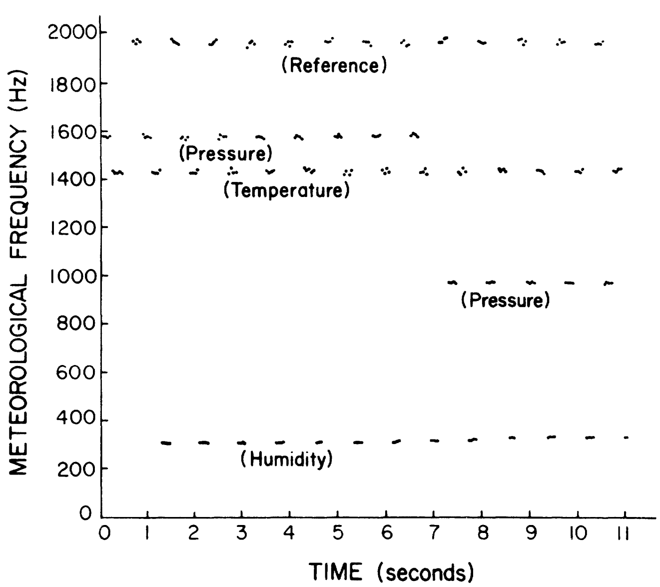

Fig. 14 A 10-second record of MET data corresponding to the phase record of Fig. 9.

V. Suggestions for System Improvement

The raw phase and MET data recording system described above is probably the simplest possible scheme. This scheme suffers from two limitations, namely, (a) the MET data is degraded by playback speed variations, and, (b) the playback has to be done at the same tape speed as the recording, consuming much minicomputer time.

The first limitation could be overcome if the MET data digitizer used in the computer interface circuitry were incorporated into the ground station. The resultant digitized phase and MET data could then be recorded (still on an analog recorder) on separate channels or could be time multiplexed onto a single channel.

Once both the MET data and the phase data are digitized before recording, the second limitation could be overcome by utilizing an incremental digital cassette recorder. While more expensive, the digital cassette recorder allows play-back at many times the recording speed, reducing the cost of demodulation.

Acknowledgement

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References

[1] J.M. Beukers: "Integrated Upper Air Meteorological Sounding System" Preprints of 2nd Symp. on Meteorological Observations and Instrumentation, San Diego, March 27-30, 1972, pp. 116-123.

[2] Vaisala Oi: "CORA--Windfinding and Radiosonde System, General Description and Specifications" 1974.

[3] Trademark of Beuker's Laboratories, Inc.

[4] L.G. Sebestyen: "Digital Magnetic Tape Recording for Computer Applications" London: Chapman and Hall, 1973, Sec. 7.6.