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An Electronic Radiosonde of continuous telemetering type

H. MITRA

Meteorological Office, New Delhi

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1. Introduction

The India Meteorological Department uses two types of radiosondes for upper air sounding. One of these is known as the F-type and the other as C-type radiosonde as the driving mechanism is either a fan or a clock. As mechanical systems have their limitations, it was decided to develop a radiosonde in which mechanical parts are eliminated as far as possible. These are the major causes of their failure under extreme conditions and also introduce unknown errors due to thermal stresses set up in the frame structure. These considerations favoured a completely electrical recording and telemetering system.

2. Principle of the Electronic Radiosonde

It was considered that a variable audio frequency type offered the best opportunities to explore and that an inductive probe operated by an aneroid capsule for measurement of pressure, a bead or rod type thermistor for measurement of temperature and another inductive probe operated by stretched Gold beater's skin for measuring humidity would offer a suitable system to experiment upon. The aneroid changes the inductance of a low frequency coil (as is done in the British radiosonde) which consequently changes the frequency of an audio oscillator. This frequency f_1 along with other two frequencies f_2 and f_3 from a thermistor and a humidity oscillator, is mixed and the complex waveform is made to frequency-modulate the 400 mc rawin transmitter. For the thermistor oscillator, RC circuit has been employed with suitable modification to cover the desired frequency range. For the humidity oscillator a similar inductive probe varies the frequency f_3 of an oscillator. The block diagram of the balloon-borne part of the equipment is shown in Fig. 1.

The pressure operated inductive probe oscillator has been assigned 9 to 11 kc band and a total change of 1500 cycles for a pressure range of 1000 mb so that each millibar corresponds approximately one cycle. The thermistor temperature oscillator operates over the frequency range of 5 to 7 kc/s with 2 kc separation from the pressure oscillator. Here also the total change in frequency is about 1500 cycles for covering the temperature range of $+50°C$ to $-80°C$, a total of 130°C, so that each cycle means a change of $0 \cdot 1°C$, this being the desired accuracy. The humidity oscillator operates over the range 3 to $3 \cdot 5$ kc with total change of about 200 cycles for 20 to 90 per cent relative humidity with a separation of $1 \cdot 5$ kc/s from the temperature oscillator.

The outputs from these three oscillators are simultaneously added in a resistive network and the complex waveform is fed into a 1 mc oscillator. This oscillator frequency modulates the standard 400 mc rawin transmitter with a maximum deviation of ± 75 kc.

The receiver consists of conventional rawin receiver with suitable modifications in the circuit after the discriminator stage to take into account the wide audio frequency range of 3 to 11 kc/s.

3. Balloon-borne equipment

The aneroid element consists of $6 \cdot 5$ cm diameter Ni-Span C alloy capsule suitably heat-treated to eliminate temperature errors.

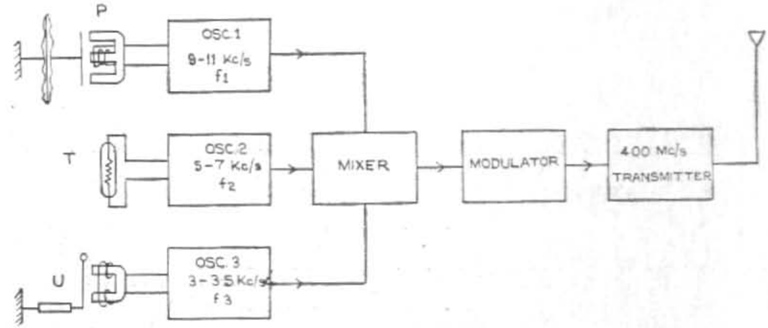

Fig. 1. Block diagram of balloon equipment

The inductive probe is made of E-type silicon steel core material with a coil in the central limb. A mumetal armature is attached to the aneroid and is placed in front of the core. In Fig. 2 may be seen the mo nted aneroid fixture together with the probe element. Q-corrections are applied to aneroid readings as is done in the Kew Radiosonde but attempts are being made to compensate for these errors.

Fig. 3 shows the circuit of the balloon-borne equipment along with the pressure oscillator. It employes a conventional Hartley circuit with subminiature tube type DL67. With 90 V on plate, it provides a peak amplitude of 3 volts. Drift due to change in H.T. and filament voltages is negligible for the operative range of 1·5 to 0·8 volts for low tension and for 90 to 70 volts for plate supply. Drift due to cooling of components has been compensated by using two parallel condensers in the tank circuit, one having negligible temperature coefficient and another having positive temperature coefficient with cerium oxide base developed by the National Physical Laboratory, New Delhi. Due to cooling of components the frequency usually increases. The waveform is sinusoidal over the operating frequency range.

The temperature measurement is done by rod type thermistor which forms one element of a RC oscillator. The resistance of this thermistor is about 18 K-ohms at 25°C. Lag is of the order of 3-5 sec and reproducibility better than 0·2°C over the operative temperature range. No radiation shield is used on account of the small mass of the rod; it is also coated with a reflecting material with high albedo. The element together with its mount may be seen in Fig. 2.

The temperature oscillator consists of a RC feed back circuit with four networks each causing a phase shift of about 45°. The loading caused by successive networks has been reduced by increasing the reactance by a factor k, which is 1, 2, 4 and 8 while keeping the CR value approximately same. The total attenuation of the network is about one-third, requiring a very small gain for maintaining oscillations. The thermistor forms the resistive element in the second section in parallel with another resistance to make the characteristic more linear and for restricting the range of the desired frequency change. There is no noticeable change in frequency due to variation of filament supply from 1·5 to 0·9 volts. There is no change in frequency when the plate supply changes from 90 to 60 V for the two extreme values of resistances of thermistors. The drift due to cooling of components has been eliminated by using negative temperature coefficient condensers in one of the sections. The waveform is sinusoidal with peak to peak amplitude of about 3 volts.

The humidity element consists of Gold beater's skin in the form of a strip which actuates another inductive probe. Its treatment follows the well-known standard practices and its errors and accuracies are the

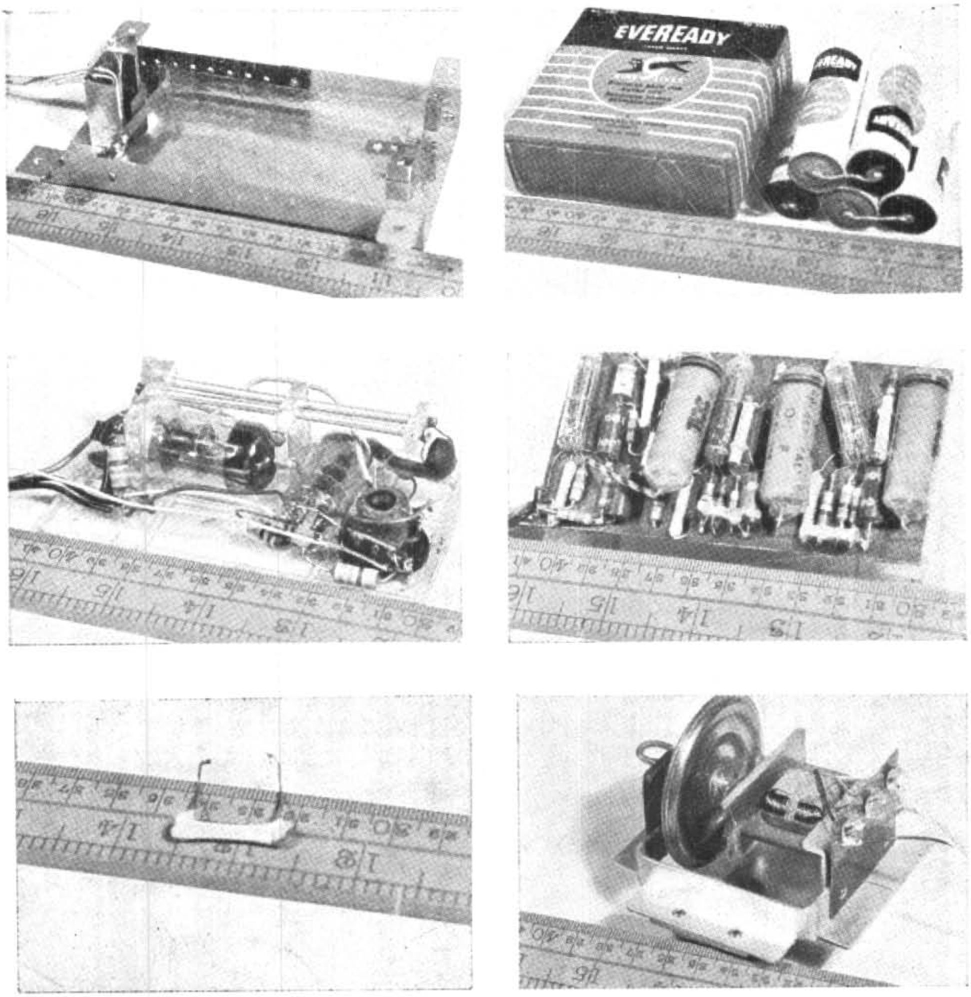

Fig. 2. Components of New Radiosonde

Top row : Humidity Probe and high and low tension batteries

Middle row : Left —400 mc oscillator and modulator
Right—P, T and U oscillators

Bottom row : Left —Rod type thermistor
Right—Pressure measuring element

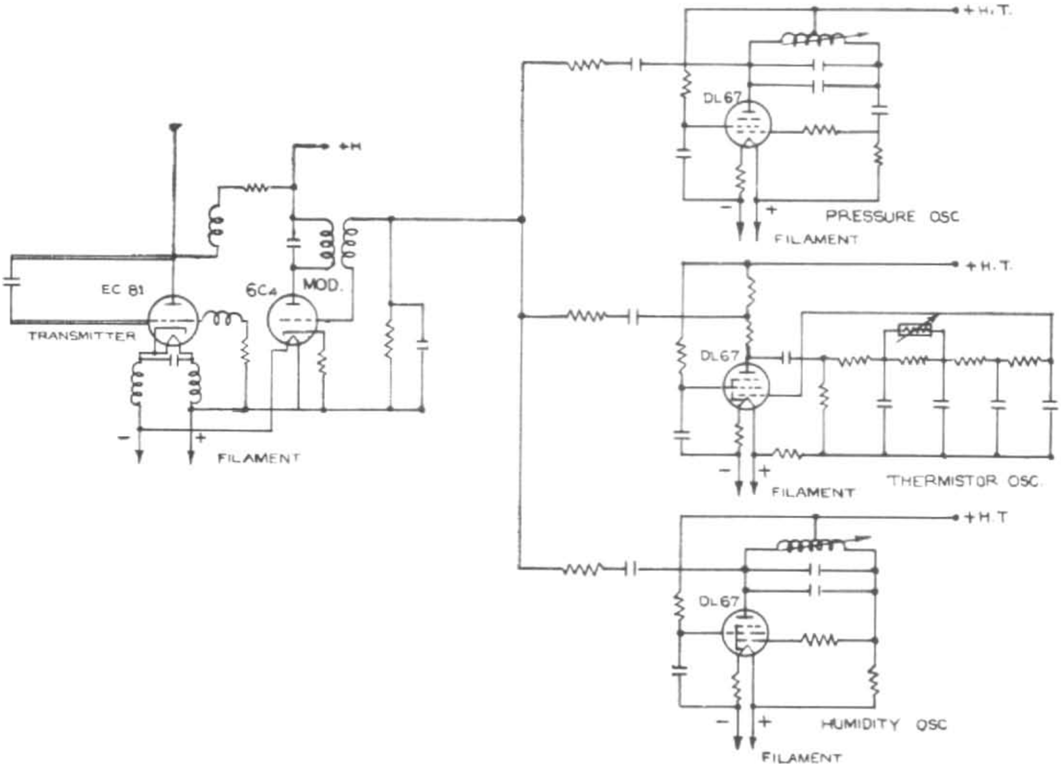

Fig. 3. Circuit diagram of Radiosonde

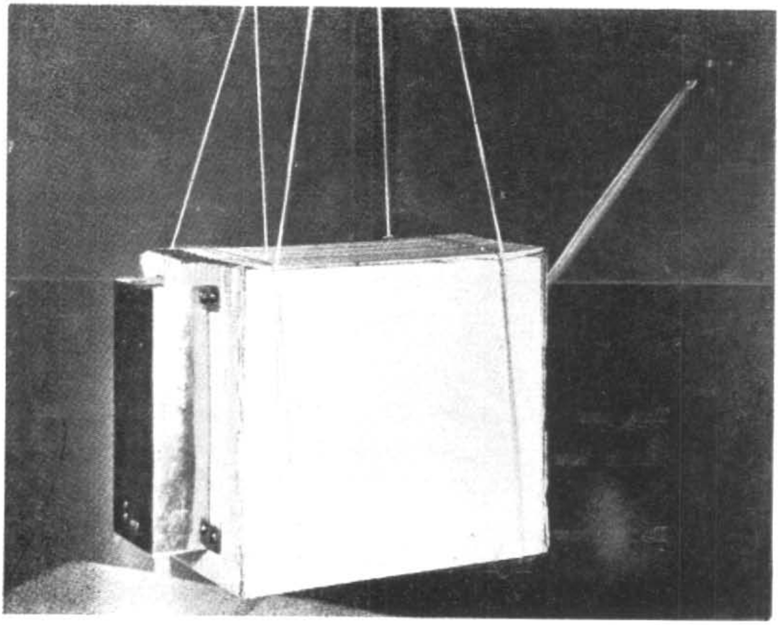

Fig. 4. The complete Radiosonde

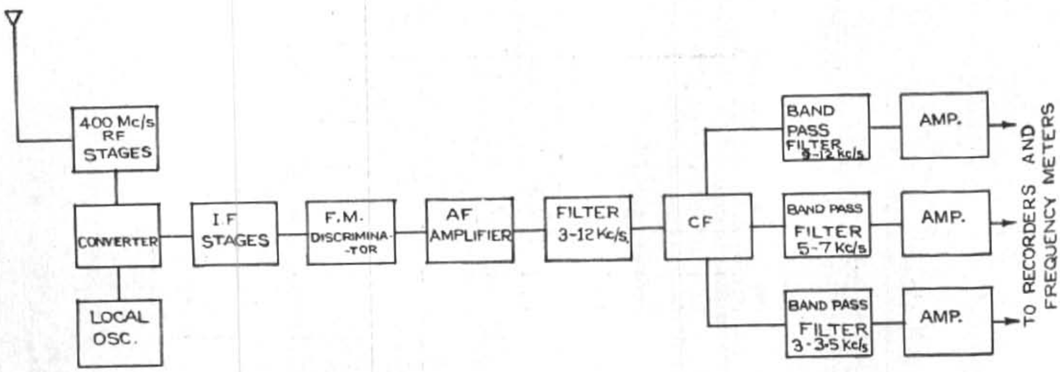

Fig. 5. Block diagram of receiver

same as are encountered in this type of material. The complete element also appears in Fig. 2. The humidity oscillator is similar to the pressure oscillator; only the operating range is different.

In Fig. 2 all the basic components of the new radiosonde are shown. The three audio-oscillators are mounted on a small board. Dry type battery packs are used both for filament and plate supplies. These can also be seen in the above figure. Excepting the humidity and thermistor elements, all other units together with the batteries are enclosed inside a cardboard box with 2 cm thick thermocole insulation. This is shown in Fig. 4. The whole assembly weighs about 1400 gm.

The outputs from the three oscillators are fed through three adding resistors into the grid circuit of 1 mc oscillator. The plate supply voltage to these and the 400 mc oscillator has been made through a small common resistor. The principle of frequency modulation is the same as used in the U.S.A. radiosonde. A grid input of 2 volts rms causes a frequency deviation of ± 75 kc of 400 mc oscillator. The power output of 400 mc oscillator tube is about 700 mw.

The complete airborne equipment employs a total of five tubes, three sub-miniatures for three audio oscillators, one power modulator and another radio frequency oscillator. The cost of production of the complete instrument together with all associated components etc compares favourably with the cost of the mechanical radiosonde with its clockwork. Except the pressure and the humidity probe, all mechanical parts have been reduced to a minimum; the trouble due to switching and risk of mechanical failure have been overcome completely. Attempts have been made to ensure that the balloon borne equipment uses maximum number of commercially available components with normal tolerances. As the circuitry is electrical and electronic, better standardisation and quality control can be ensured than in a mechanical system.

4. Receiving equipment

Fig. 5 shows the block diagram of the receiving equipment. The aerial system is the same as the Metox radio-theodolite. The direction finding of the balloon is done on 400 mc carrier. The 400 mc r.f., local oscillator, converter, intermediate frquency and f.m. discriminator stages are all conventional and constitute the part of the normal radio-theodolite receiver. The subsequent amplifier stages have been modified to handle audio frequency band upto 12 kc/s as against 200 cycles in the existing equipment. The radio sonde signals are first passed through a band pass filter of 3-12 kc. They are subsequently fed to three sets of band pass filters covering the range for each meteorological element. The first filter F_1 allows audio frequencies from

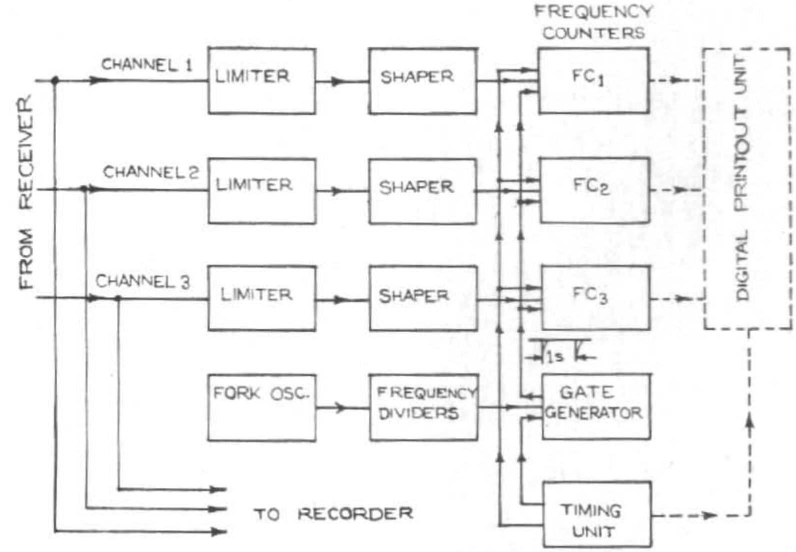

Fig. 6. Block diagram of frequency measuring equipment

the humidity oscillator to pass with a cut off at 3·5 kc/s. The band pass filter F_2 permits the frequencies from the thermistor oscillator to pass with a band width of 2 kc/s from 5 to 7 kc/s. The last filter F_3, allows a band from 9-12 kc so that it allows only audio signals from the pressure oscillator. Attempts have been made to reduce the harmonic interference between the three bands of frequencies by making the response of the filters sharp, by ensuring that the waveforms oscillators are pure sine waves and by keeping the distortion caused by modulator and discriminator as low as possible. The three frequencies after being further amplified are fed to frequencies measuring and recorder systems.

5. Frequency Counting System

As has already been mentioned, for the desired accuracy of pressure and temperature, the frequency should be recorded correct to one cycle. The existing type frequency meters cannot record frequency with such high accuracy. It was, therefore, decided to employ counter type frequency meters capable of recording correct to ± 1 count for the thre respective audio channels. Readings are automatically registered at every half minute interval by sequence timing device which resets the counters before each counting sequence. The three frequency counters are simultaneously opened by a precision gating pulse of one second duration. This gating pulse is derived from a hermetically sealed and electrically maintained tuning fork with an accuracy of 1 part in 20,000. Readings can then be entered in the form by the operator. As a special innovation, a print out system can also be incorporated, making the whole system automatic. Fig. 6 indicates the block diagram of the frequency measuring system.

The three audio frequencies from the receiver are first passed through a limiter and then through a shaping circuit. These are then fed to three Decatron type counters capable of recording upto 20,000 pulses per second with an accuracy ± 1 count. Each counter contains a gating circuit which is opened by a negative pulse and closed by a second negative pulse following the first. These gating pulses, spaced accurately at one second interval are derived from the fork oscillator by a chain of multivibrator dividers.

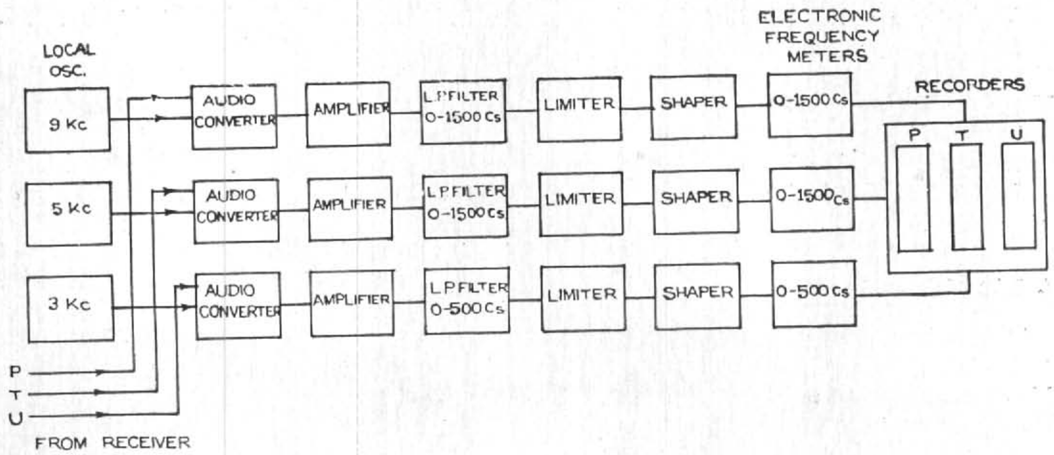

Fig. 7. Block diagram of frequency recording equipment

The fork oscillator would ultimately be replaced by a crystal oscillator maintained in a temperature controlled oven. A sequence timer resets the counters one second before each set of reading and also connects the output of the gate generator, the first pulse of which starts counting and the subsequent one stops counting. This pulse coincides with each thirtieth second. As a further refinement it is proposed to incorporate a three channel five figures digital print out unit to these frequency meters. Readings would in that case be taken automatically every half minute and printed on a chart against time. It is also possible as a further improvement in the system, to provide a digital to analogue converter and to get the data directly plotted on a tephigram making the whole system entirely automatic.

6. Recording system

It may be seen that the frequency meter registers readings only at discrete time intervals of thirty seconds from which no idea can be obtained regarding the nature of variation of temperature and humidity, any abrupt changes, changes in lapse rate etc which are essential for selecting points for evaluation of sounding. It was therefore necessary along with precision frequency meters to provide some sort of recording arrangement for continuous recording of frequency pertaining to each element which may not necessarily be very accurate. A device to meet this requirement has, therefore, been incorporated in the system and is shown in block schematic diagram (Fig. 7).

Audio signals from three channels after amplification are fed to three frequency converters. Here, the signal frequencies are mixed with three fixed frequency audio oscillators having frequencies of 3, 5 and 9 kc respectively. The difference-frequency outputs varying from 0 to a maximum of 1500 c/s, are passed through three low pass filters. They are then fed to three electronic frequency meters with full scale deflection of 0-1 ma for a frequency range of 0-1500 c/s, after passing through limiter and shaping stages. Outputs from the frequency meters are put into three recording type milliameters. With an accuracy of 2 per cent, it is possible to detect a change of 3°C in temperature which is considered sufficient to detect any change of lapse rate. The chart on the recorder is examined by the operator for selection of proper points, after which the precise value of frequency corresponding to the nearest minute interval is read from the digital printout unit in the frequency counter. This provides high degree of accuracy and also ensures that no important point is missed in the record.

The instrument as such, together with the recording arrangement has not yet reached the final stage and is still being developed. Many modifications would be necessary and refinements incorporated before it can emerge as a standard production model. Test runs and system evaluation are being carried out at present.

7. Acknowledgement

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