Rubidium Self-oscillating Magnetometer for Earth's Field Measurements

A self-oscillating rubidium vapour magnetometer, in which measurements of the total field magnitude are obtained by counting the frequency of self-oscillation in the radio-frequency range, has been developed for rocket and satellite experiments. Field trials have recently demonstrated that this type of rubidium magnetometer can be used in certain observatory applications and other ground investigations of the geomagnetic field.

The instrument utilizes circularly polarized filtered rubidium light to optically pump[1] a rubidium gas cell to a state of magnetization, which in turn is destroyed by the depumping effect of a radio-frequency field applied to the gas cell. The frequency of this radio-frequency field is the Larmor resonance frequency corresponding to transitions between the Zeeman sub-levels arising from spectral splitting in the ambient field[2]. The resonance signal, observed by photocells as a modulation of the source light viewed through the gas cell, is amplified and shifted in phase by 90° before reapplying to the radio-frequency field coils. The system thus self-oscillates at a frequency which varies according to the degree of Zeeman splitting in the ambient field.

The magnetometer is dependent in orientation inasmuch as maximum signal/noise occurs when the optical axis is at 45° to the field direction and there is a slight change in frequency (approximately 10γ for an orientation of 180° in the Earth's field), so that although the instrument is free from any form of drift, it is not strictly absolute. Self-oscillation only continues under optimum conditions of vapour pressure temperature (25°–45° C) requiring environmental temperature control within these limits.

The sensing head, consisting of the optical system including lamp, lamp excitation, gas cell and photocells, is a circular cylinder 12 in. long and 3 in. in diameter, weighing 1 lb. As used for ground investigations the power consumption of the electrodeless lamp is 3 W. A four-stage transistorized amplifier is used with a flat phase characteristic over the working range (0·05–0·75Γ), the 90° phase shift between light modulation and radio-frequency current being provided by the photocell capacitance. A low-field instrument has been constructed to operate in fields below 100γ and up to 0·1Γ. The frequency of oscillation is 4·67 c/s/γ, amounting to approximately 200 kc/s in the Earth's field in the United Kingdom. The signal-level is 1·0 V peak to peak with a signal-to-noise ratio of 10 : 1 in a band-width of 500 kc/s.

The field magnetometer is composed of the sensing head and amplifier together with a counting and recording system. For a sensitivity of 0·05γ in the total field, 2×10^5 cycles of the signal are used to gate a 10^6-c/s oscillator (for 1 sec) and the resulting count (10^6) is decoded and displayed on an analogue recorder. The total weight of the equipment is less than 100 lb. and power consumption is 100 W from mains or batteries.

A vector version of the instrument has also been constructed. If the vertical field is annulled by the field of a Helmholtz system, the magnetometer then responds to changes in the resultant horizontal field. In this arrangement a sensitivity of 0·02γ can be attained with a counting time of only 1/10 sec, giving a frequency response to changes in field of better than 1 c/s. Similar arrangements are possible for the other field components.

Recent micropulsation studies at various observatories demonstrated that this type of magnetometer could usefully be applied to observatory work. The sensitivity, continuous signal, large signal-to-noise ratio, fast response, wide range and freedom from drift are advantages not easily achieved in comparable types of magnetometer.

The rubidium magnetometer can measure very low-level rapid fluctuations in total field strength and by utilizing biasing fields can be operated as a vector instrument. Suitable programming of such a system could provide complete observatory information from normal magnetograms to rapid-run records resolving 1-c/s pulsations of 0·1γ amplitude at the same time, in both analogue and binary form.

A self-oscillating low-field magnetometer using optically pumped helium has also been constructed. This instrument, which operates on the same principle as the rubidium magnetometer, requires no temperature control and is also suited to biased field applications. A fuller account of the self-oscillating rubidium magnetometer is in preparation.

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Observation of the OH Day-glow

In 1960 Noxon and Vallence Jones[1] with the co-operation of the Canadian Armament Research and Development Establishment launched a balloon-borne spectrometer and observed bands of the $\Delta v = 1$ sequence of upper atmospheric hydroxyl emission for the first time. Since then several balloon flights have been made from the Canadian Armament Research and Development Establishment for photometric measurements of the night air-glow from 2 to 4μ. A description of the spectrometer used and the results of these flights will appear soon[2].

On July 10, 1962, the spectrometer was flown during the day. Fig. 1 shows an average of several spectra obtained during 11.30–noon E.D.T.; at this time the balloon was at 95,000 ft. At wave-lengths shorter than 2·75μ a very strong signal was present due to scattered sunlight. The synthetic spectrum in the figure was constructed from the line position and intensities of Richardson and Gush[3]; Chamberlain and Smith's[4] values were used for the relative band intensities. In addition to the emission due to OH there appears to be features centred at 2·9 and 3·3μ which have not been identified.

The zenith intensity of the 1–0 band of OH is estimated at 400 kR, though this value may be in error by as much as a factor of two.

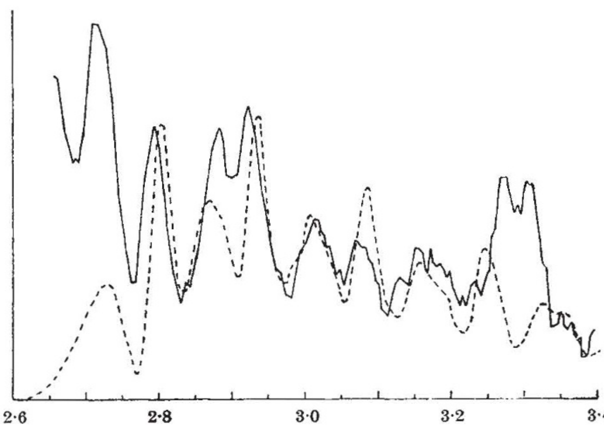

Fig. 1. ——, Day-glow; – – –, OH synthetic spectrum