OSCILLOGRAPHIC STUDY OF R/F OSCILLATIONS IN 'SILENT' ELECTRICAL DISCHARGES

by P. S. VENKATASWAMY SETTY,* *Senior National Research Fellow*

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ABSTRACT

The paper furnishes oscillographic evidence of the radio-frequency oscillations produced at suitable exciting voltages of 50 cycles/sec. in (i) iodine vapour and (ii) hydrogen gas discharge tubes fitted with external 'sleeve'-electrodes. A beat-frequency amplifier was employed in which the r.f. oscillation of a particular discrete frequency in the 'silent' electrical discharge was amplified and made to 'beat' with the oscillation of a suitably adjusted radio-frequency from an oscillator, yielding an intermediate frequency which was delineated, after amplification, on the fluorescent screen of a cathode-ray oscillograph.

The above oscillographic study of the r.f. oscillations in iodine vapour and hydrogen gas under 'silent' electrical discharge was made with and without light falling on the discharge tubes. The experimental results are described and discussed in the paper.

1. INTRODUCTION

It was shown by Khastgir and Setty (1952) that when ozonizer tubes containing iodine vapour, hydrogen and nitrogen and discharge tubes fitted with external 'sleeve'-electrodes and filled with hydrogen, chlorine and iodine were excited by a suitable high voltage of 50 c/s, there was distinct evidence of r.f. oscillations of various discrete frequencies. Each discrete frequency was clearly indicated by a well-defined resonance maximum observed with a superhet receiver, when the deflection of the galvanometer placed in the anode circuit of the second detector was plotted for the different positions of the tuning condenser in the receiver. Recently M. B. Karnik (1957) detected a large number of discrete radio-frequencies in discharge tubes with internal and external electrodes and in ozonizers filled with different gases by the Lissajous figure method and also by a superheterodyne frequency-meter. In the present paper an oscillographic evidence is given of the r.f. oscillations set up in 'silent' electrical discharges by delineating the intermediate frequency produced by amplifying a particular discrete frequency of the r.f. oscillations and 'beating' it with a suitably adjusted radio-frequency obtained from a local oscillator. The effect of light on the r.f. oscillations in 'silent' electrical discharges is also shown for different exciting voltages of 50 c/s.

2. EXPERIMENTAL ARRANGEMENTS

(*a*) *Discharge tubes and their excitation*

Experiments were performed with two discharge tubes fitted with external 'sleeve'-electrodes and filled with (i) iodine vapour and (ii) hydrogen gas. The details of the discharge tubes are given in Table I.

* Assistant Professor of Physics, Central College, Bangalore (*on leave*).

TABLE I

Details	Iodine vapour tube	Hydrogen tube
1. Length of the discharge tube ..	14·5 cm.	20 cm.
2. Sectional diameter	1·7 cm.	1·5 cm.
3. Pressure	Saturation pressure	97 mm. of mercury
4. Adjustable external 'sleeve'-electrodes	Few turns of No. 24 copper wire.	

Each discharge tube was excited by varying voltages of 50 c/s. For this purpose, the d.c. line voltage of 220 volts was converted into a.c. 110 volts (50 c/s) by a suitable rotary converter. A range of voltage was obtained with a potentiometric device and a suitable step-up transformer. A transformer with a voltage transformation ratio of 1: 20 was used for the iodine vapour tube, giving a voltage-range of 0–3,000 volts. For the hydrogen gas tube, another transformer of transformation ratio 1: 68 was used, giving a voltage-range of 1–15,000 volts.

A long copper wire was connected to a coil of few turns wound round each discharge tube under investigation to act as the radiating aerial. The position of the coil was conveniently adjusted.

(*b*) *Beat-frequency amplifier*

A beat-frequency amplifier was employed for amplifying the r.f. oscillations set up in the 'silent' discharge and for converting them into i.f. by 'beating' them with r.f. oscillations from an oscillator unit. The beat-frequency amplifier consisted of two pentode valves (6AC7) in its first stage of amplification. These two valves were used in push-pull, the control grid of each valve being connected through a suitable leak-resistance to the earth. The biasing voltage to the control grid was supplied by means of a self-biasing resistor in the cathode lead. The primary coil of an h.f. transformer joined the anodes of the valves in the usual way. The secondary coil was tuned by a variable tuning condenser. The output from this stage was

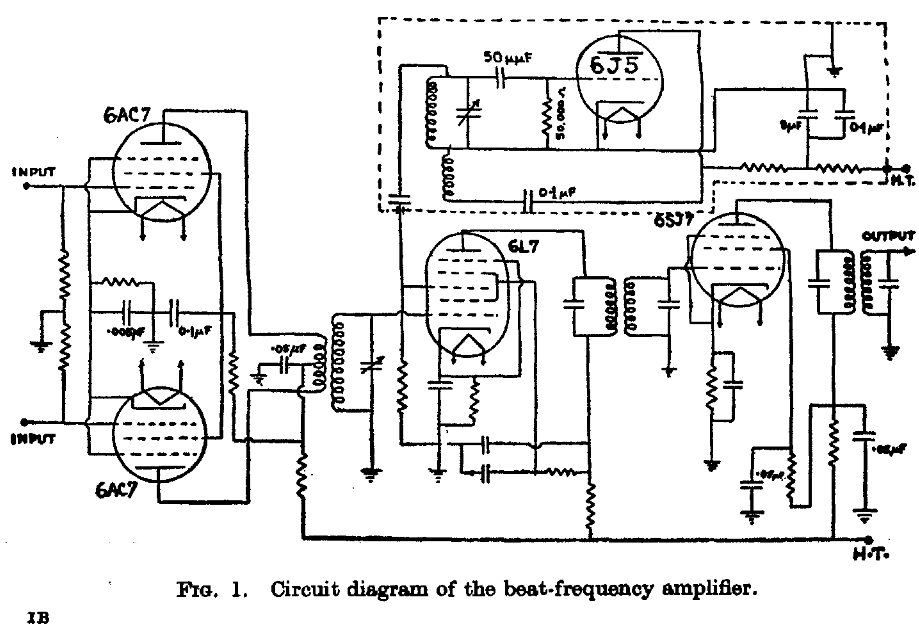

FIG. 1. Circuit diagram of the beat-frequency amplifier.

given to the signal grid of the penta-grid mixer (6L7). Oscillations from a separate oscillatory unit (with 6J5 valve) were fed into the oscillator grid of the mixer. After the signal frequency was converted to i.f., provision was made for one stage of i.f. amplification with a pentode valve (6SJ7) and an inter-stage i.f. transformer. There was provision for varying the gain of the amplifier unit by working a volume control in the last stage of the amplifier. The circuit diagram of the amplifier unit and that of the oscillator unit are shown in Fig. 1. The amplifier worked in the range of 500 kc/s to 1,500 kc/s.

3. Experimental procedure

The aerial wire from the discharge tube under examination was directly fed into the linear beat-frequency amplifier. The amplifier was then tuned to one particular frequency of the r.f. oscillations produced in the 'silent' discharge. This particular frequency was determined with the help of a standard signal generator and was estimated to be of approximately 1 Mc/s. The output of the amplifier was then fed to the Y-plates of a cathode-ray oscillograph and a linear time-base was applied to the X-plates. The beat-frequency oscillation delineated on the oscillographic screen was then synchronized and photographed for different voltages applied to the external 'sleeve'-electrodes of the discharge tubes.

To study the effect of light on the amplitude of the r.f. oscillations in 'silent' discharges, the photographs of the oscillographic patterns delineating the waveforms of the oscillations after their conversion into i.f. with and without light falling on the 'silent' discharge, were taken after proper synchronization. The method of irradiation was as follows: A 200-watt incandescent bulb was kept inside a wooden box with a light-shutter. The box was kept at a distance of 18 inches from the discharge tube under examination. The bulb was kept on all the time and the light-shutter was inserted and removed as desired. For a suitable exciting voltage, the photograph of the oscillographic pattern obtained with light-shutter on was first taken. Immediately after, for the same exciting voltage, the photograph of the pattern obtained with the light-shutter off was taken.

4. Experimental results

The beat-frequency oscillations obtained in the manner described above and delineated on the oscillographic screen can be regarded as a definite evidence of the r.f. oscillations in the 'silent' electrical discharge. The photographs of the oscillographic patterns showing i.f. oscillations obtained after conversion of the r.f. oscillations produced in the iodine vapour and hydrogen gas discharge tubes were taken for five different exciting voltages with the light-shutter on and off. These photographs are shown in Figs. 2 and 3.

The general features of the r.f. oscillations produced in the 'silent' discharges, as revealed in the oscillograms, are:

(i) The r.f. oscillations started suddenly at some critical 'threshold' voltage.

(ii) A number of r.f. oscillations of the same frequency was produced. The frequency corresponded to the particular frequency of the oscillations to which the beat-frequency amplifier was tuned.

(iii) The amplitudes of the r.f. oscillations were found to vary between zero and a limiting value.

(iv) The intensity of the oscillographic pattern appeared to increase with the increase of the exciting voltage.

The main experimental results regarding the effect of light on the r.f. oscillations in the iodine vapour and hydrogen gas discharge tubes fitted with external 'sleeve'-electrodes are summarised as follows:—

(i) In the case of the iodine vapour tube the initiation of the r.f. oscillations was found to take place at a slightly lower voltage under the action of light than in the dark.

The oscillograms Nos. 1 and 2 in Fig. 2 for the iodine vapour discharge tube were taken at 500 and 600 volts respectively. Both these oscillograms show that there were no r.f. oscillations in the dark and that they appeared when the discharge tube was irradiated.

(ii) At some higher exciting voltage, the oscillograms with the iodine vapour discharge tube showed similar r.f. oscillations in the dark. When the discharge tube was irradiated, these oscillations remained unaffected, their amplitude being sensibly unchanged.

The oscillograms Nos. 3, 4 and 5 in Fig. 2 for the iodine vapour discharge tube were taken at 800, 1,000 and 1,400 volts respectively. These photographs show that the r.f. oscillations remained unaffected when the discharge tube was irradiated.

(iii) With the hydrogen gas tube the initiation of the r.f. oscillations did not take place at a lower voltage under the action of light than in the dark, as in the case of the iodine vapour tube.

(iv) In the case of the hydrogen gas tube the r.f. oscillations were quenched completely on irradiation over a certain range of exciting voltage near the 'threshold' voltage.

The oscillogram No. 1 in Fig. 3 for the hydrogen gas discharge tube was taken at 3,400 volts. The r.f. oscillations observed in the dark were completely quenched when the hydrogen discharge tube was illuminated by light.

(v) At higher exciting voltages the r.f. oscillations in the hydrogen gas tube remained unaffected on irradiation. The r.f. oscillations were neither quenched completely nor did they appear reduced in their amplitude.

The oscillograms Nos. 2, 3, 4 and 5 in Fig. 3 were taken at 4,100, 4,800, 5,500 and 6,800 volts respectively.

5. Conclusions

The oscillograms taken with the light-shutter on and off have thus revealed that in the iodine vapour discharge tube with external 'sleeve'-electrodes there is *positive* light effect with regard to the r.f. oscillations produced in it, when the exciting voltage is slightly lower than the 'threshold' value and is not sufficient to produce such oscillations. This is similar to the positive Joshi effect in iodine vapour with regard to the pulses observed near the crest of the sinusoidal current through the discharge tube. The oscillograms do not, however, show any *negative* light effect with regard to the r.f. oscillations in the iodine vapour discharge tube at the 'threshold' voltage and at higher voltages. The oscillograms have also shown that there is no *positive* light effect on the amplitude of the r.f. oscillations produced in the hydrogen discharge tube fitted with external 'sleeve'-electrodes near the 'threshold' voltage, as in the case of the iodine vapour tube. Further, they have unmistakably shown that there is cent-per-cent *negative* light effect on the amplitude of the r.f. oscillations produced in the hydrogen discharge tube over a certain range of exciting voltage near the 'threshold' voltage, as is known in the case of the Joshi effect in hydrogen with regard to the pulses observed near the crest of the exciting sinusoidal voltage.

It was previously shown by Khastgir and Setty (1953) that the pulses observed near the crest of the alternating current through the iodine vapour and hydrogen discharge tubes (fitted with external electrodes) were of a duration of $10^{-3}-10^{-4}$ sec. and that under certain conditions they were of the damped oscillatory type. The

(1) 500 volts
(2) 600 volts
(3) 800 volts
(4) 1,000 volts
(5) 1,400 volts

← DARK →
← LIGHT →

(1) 3,400 volts
(2) 4,100 volts
(3) 4,800 volts
(4) 5,500 volts
(5) 6,800 volts

Fig. 2. Iodine vapour **Fig. 3. Hydrogen**

Fig. 2. Oscillograms of oscillations with and without light on the iodine vapour discharge tube fitted with external electrodes.

Fig. 3. Oscillograms of oscillations with and without light on the hydrogen gas tube fitted with external electrodes.

fact that the effects of light on these pulses are similar to that on the r.f. oscillations produced in the 'silent' electrical discharge suggests that the pulses and the r.f. oscillations are interlinked in their origin. This is envisaged in the theory of the origin of the r.f. oscillations in a 'silent' electrical discharge given by Khastgir and Srivastava (1954), where the observed r.f. oscillations are regarded as trains of electronic oscillations of the Barkhausen type, maintained intermittently, each train being followed by a pulse.

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