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1919 Proc. Phys. Soc. London 32 84

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XI. *On some Experiments in which Two Neighbouring maintained Oscillatory Circuits affect a Resonating Circuit.* By J. H. VINCENT, M.A., D.Sc.

RECEIVED DECEMBER 29, 1919.

The Ideally Simplified Problem.

IF two valve maintained circuits (Bench 1 and Bench 2, Fig. 1) are so far apart as to have no influence upon each other and one of them (Bench 2) is capable of having its frequency adjusted as desired, then the combined effect on a

FIG. 1.

resonating circuit such as shown in Fig. 1 when this is assumed to be so distant from each of the maintained circuits as to eliminate any coupling is merely the sum of the effects of the maintained circuits taken separately.

Thus when the Bench 2 circuit is tuned so as to be in absolute unison with the Bench 1 circuit the E.M.F.s and the currents in the resonating circuit will be the sums of the E.M.F.s and the currents due separately to the maintained circuits.

In particular the resultant current in the resonating circuit will be a function of the phase difference between the maintained circuits, and on this view this will be a mere matter of chance. If one induced current in the resonator were of the same amplitude but of opposite phase to the other then no resultant current would flow in the resonating circuit ; while if the separate induced currents were of the same amplitude and phase then the combined current would be twice the magnitude of either.

The Actual Problem.

In these experiments the two-valve-maintained circuits are near enough to exert an appreciable effect on each other, which effect may be enhanced by a possible amplifying or minifying influence due to valves.

The resonating circuit (Fig. 1) had its condenser shunted with a carborundum crystal in contact with brass in series with a micro-ammeter (G_3) and a telephone. At times a vibrating galvanometer of low natural frequency, kindly lent to me by Mr. Jordan, was inserted in this circuit. The resonating circuit was not sufficiently distant for us to neglect the possible effects of coupling between this circuit and the maintained circuits ; in consequence, a new coupling exerted on one maintained circuit by the other through the effect on the resonating circuit, may exist.

Finally, no direct measure of the current in the resonating circuit was made ; the readings of the galvanometer G_3 in series with the detector were the subject of the observations so that the properties of the detector are involved in the work.

Apparatus.

The two maintained circuits were set up on two work benches placed a few feet apart as shown diagrammatically in Fig. 1.

There was no method available of measuring the alternating currents in the oscillators directly, but each main oscillating coil was wound with a few turns of insulated wire in series with a micro-ammeter and crystal detector. These micro-ammeters are referred to as G_1 and G_2 respectively.

The axes of the main oscillating coils of these two circuits were parallel and were connected up to the high potential batteries so that the currents through the valves made the

end of Bench 1 coil nearer the resonating circuit have south-seeking polarity and the corresponding end of the Bench 2 coil have north-seeking polarity.

The axis of the coil of the resonating circuit was parallel to the line joining the ends of these two coils and a few feet away; so that if the two maintained circuits were in the same phase the induced E.M.F.s in the resonating circuit would be conspiring together.

The frequencies used in drawing the Figures 2, 3, and 4 were of the order of 100,000 per second, but widely differing frequencies have given similar effects.

Results.

As the frequency of the Bench 2 circuit is lowered by gradually increasing its capacity we pass from a condition in which Bench 2 is sharp on Bench 1 to that in which it is flat. We thus pass through the state of absolute unison. The capacity change per degree of small condenser in the Bench 2 circuit is about one-tenth of a centimetre, the main capacity being about 450cm. Thus a very slow adjustment of frequency is possible.

When the resonating circuit is carefully tuned to the Bench 1 circuit the circumstances are illustrated in Figure 2. When valve on Bench 1 only is alight the deflection of G_3 , the galvanometer in the resonating circuit, is given by the line AB . When that on Bench 2 only is operating the deflection of G_3 is given by the curve CD , in which the ordinates are the deflections and the abscissæ the settings of the small condenser.

When both valves are lit the effects are shown by the curve EF . As the capacity increases the deflection G_3 increases; the pitch of the telephone note falls uniformly with the increase of the Bench 2 capacity as indicated by the line LM . Such lines were drawn from observations with standard forks by R. Koenig. As the point G is approached G_3 shows signs of vibrating. This vibration decreases in frequency until M is reached. The oscillatory current in the resonating circuit is practically zero, the deflection of G_3 is zero and the needle shows no signs of vibration. In the observations any direct-current galvanometer can be used. The description applied particularly to the behaviour of a Paul Uni-pivot instrument giving a deflection of 1 scale division for two micro-amperes. The two maintained circuits are now vibrating in unison and in the opposite phase.

On further increasing the capacity the two circuits are gradually brought into phase, at *J* this is complete. The change in Fig. 1 from *M* to *J* is brought about by an increase

FIG. 2.

in capacity of a twentieth of a centimetre in a total capacity of 450cm. During this change from *M* to *J* the needle of *G*₃

does not vibrate; nor does a very low frequency galvanometer oscillate if included in the circuit.

Fig. 3.

When the capacity is made still greater G_3 shows oscillations and the deflection falls.

The line NM is again a practically straight line, the dead space from M to the projection of J , during which change in

FIG. 4.

capacity does not alter the frequency, being too small to show clearly on records of the tuning fork observations.

The question immediately arises as to what settles whether the minimum or the maximum deflection of G_3 occurs first as the capacity increases.

It was found that when the amplitude of the oscillations in either circuit were sufficiently reduced (as judged by the galvanometers G_1 and G_2) the minimum occurred first or second according as the Bench 1 or Bench 2 circuit was weakened.

When a resistance is put into the Bench 2 circuit in series with the main oscillator coil the minimum occurs at a higher setting of the condenser than for the maximum. (Fig. 3.)

It was also found that accurate adjustment of the resonating circuit was not necessary. Similar results are obtained even when the resonating circuit is purposely mistuned in either direction to a considerable degree.

The curves giving the deflection of G_3 as a function of the setting of the small condenser are very much altered by introducing coupling between the two maintained circuits. In particular the dead space over which the capacity can be adjusted without change in frequency is very much increased by joining the negative ends of the valve filaments to the terminals of an air condenser of 12cm. capacity. (Fig. 4.)

Conclusion.

The experiments described above provide a means of observing small changes of frequency which have hitherto been studied by the method of beats. The observer merely has to note the setting of the condenser when the maximum or minimum deflection on the galvanometer occurs. This method is one requiring little training, and which is not fatiguing to the observer. It has been tried on previously known curves with success.

These experiments were carried out in Dr. Eccles' laboratory at Finsbury Technical College. I have great pleasure in thanking him for the encouraging interest he showed during their progress.

ABSTRACT.

Two valve-maintained oscillating circuits, one of which is provided with an adjustable subsidiary condenser of small capacity, each cause oscillations in a third resonating circuit. The third circuit has its condenser plates connected through a crystal detector and galvanometer. When the maintained circuits are in unison a very small change in the capacity of the subsidiary condenser causes the galvano-

meter needle to move through a large angle. The method provides a means of observing small changes of frequency previously studied by the method of beats.

DISCUSSION.

Dr. ECCLES pointed out that Dr. Vincent's addition of the second high-frequency oscillation generator to the ordinary wave-meter method of working had resulted in an extraordinary enhancement of the accuracy of measurement of wave-length. It was very surprising to watch the sudden drop of the pointer of the table galvanometer in the crystal circuit as the second oscillator was brought into exact tune with the first. In this tuning process variations of capacitance of less than one-tenth of an electrostatic unit could be made evident by the table galvanometer in a total capacitance of 250 cm.—equivalent to detecting a change of radius of 1 mm. in a sphere of 25 metres radius. The method was far more accurate than that of the ordinary heterodyne wave-meter, and abolished the tediousness of using telephones. It promised to become a standard method of measuring wave-lengths.

Prof. O. W. RICHARDSON said he was struck by the similarity of the curves to those representing anomalous dispersion in the neighbourhood of an absorption band. The explanation was doubtless similar in the two cases.

Mr. WEBB said he had been working with the apparatus, and it was so sensitive that anyone moving even at a considerable distance caused large movements of the indicator. Despite this the method gave constant results for periods extending over several hours.

Prof. LEES asked if it mattered whether the condenser C_3 was in front of or behind the oscillating coil.

Dr. VINCENT thought Prof. Richardson's simile was very suggestive. He had not been able in the present Paper to go into the detailed theory of the experiments, but he thought the theory when fully investigated would confirm Prof. Richardson's view. It was necessary to get good results, of course, to use all the tricks of the trade to maintain constant conditions in the circuits. Dr. Eccles and he had discovered a simple expedient for maintaining the frequency of the oscillations constant over long periods. This was to adjust the filament current so as to secure the maximum wave-length for the circuit in which the valve is employed. He could not answer the President's question off-hand.