CHAPTER V.

ASYNCHRONOUS AND SWITCHED OSCILLATIONS IN A TUNED ANODE OSCILLATOR

5.1. Introduction:

In the previous chapters studies have been made on oscillators having more than two frequencies of oscillation and it has been found that with certain adjustments in these oscillators, simultaneous oscillations are excited at two non-harmonically related frequencies. This may be due to the high equivalent transconductance of the oscillator tube used and the grid leak bias. It was therefore considered to be of interest to examine whether simultaneous asynchronous oscillations are exhibited in an oscillator, having two possible frequencies of oscillation using a tube of high mutual conductance and with grid leak bias arrangement. The oscillator used for the purpose is essentially a tuned anode oscillator coupled to a tuned load.

A tuned anode oscillator coupled to a tuned load has two possible frequencies of oscillation and exhibit interesting phenomena. It has been known from earlier days that as the resonant frequency of the load is varied, the frequency of oscillation jumps from one value to another at a particular setting of the load frequency. This jump phenomena has been named Zeihen Effect and was explained by van der Pol by considering a cubic non-linearity in the oscillator tube characteristics. van der Pol's analysis has been extended by Fontanna, Skinner and Schaffner to the case of a general type of polynomial non-linearity. It has been theoretically shown and also
experimentally verified that simultaneous oscillations at two harmonically related frequencies and also hard excited asynchronous simultaneous oscillations may be exhibited. However, the polynomial type of non-linearity may be considered to be a realistic description of the oscillator non-linearity only if the oscillator tube is operated in a fixed bias midway between zero and cut-off. In practice, on the other hand, an oscillator is operated with a grid leak bias usually well above the cut-off bias. Some attempts have recently been made\textsuperscript{26-28} to analyse the characteristics of an oscillator with two degrees of freedom when operated with grid leak bias. It has been found that for grid leak bias the oscillator may exhibit self-excited asynchronous oscillations. This theoretical prediction has been confirmed experimentally by using an oscillator with two loads tuned nearly to same frequencies and placed in series with the plate of the oscillator tube. However, as far as the present author is aware, self-excited asynchronous oscillations have not been shown experimentally to be executed by the simple tuned anode oscillator coupled to a tuned load.

Experiments were performed on a tuned anode oscillator using an oscillator tube of very high equivalent transconductance and two new phenomena were observed. One of the phenomena is simultaneous oscillation at two non-harmonically related frequencies, the other is automatic switching from one frequency to the other. These phenomena are described in the present chapter.

5.2. Circuit Description of the Oscillator:

The circuit arrangements of the oscillator is shown in Fig. 5.1. It is essentially a tuned anode oscillator coupled to a tuned load. The

\textit{(99)}
FIG. 5.1

SCOPE

100 kΩ

3 PF

50 - 1000 pF

5 × ECC 84

10 - 70 pF

15 Ω

5 μH

5 μH

7 μH

ML

7 μH

MG

40 μF

+ H.T.

+ 100 mA

-
coil in the tank circuit of the oscillator is constructed in two sections to avoid couplings between the tuned load and the grid coil. It should also be noted that five tubes each having two sections operated in parallel from the oscillator valve. This has been done to obtain a high mutual conductance since the phenomena described in the following sections have been observed for high values of mutual conductance. Mutual inductance between the plate and grid coils and also between the tuned load in the plate coils could be varied by sliding one coil inside the other. These mutual inductances called respectively \( M_L \) and \( M_G \) are denoted in arbitrary units in terms of the distances of the end of one coil from that of the other.

5.3. Experiments Performed with a Fixed Bias:

The oscillator was first biased with a bias midway between cut-off and zero. With a given combination of \( M_L \) and \( M_G \), the oscillation frequencies for various values of the tuned load capacitance was noted. As the capacitance was decreased slowly, i.e., as the tuned load frequency was increased, the oscillator frequency increased up to a certain value of the tuned load capacitance and then it switched to the lower of the two possible frequencies and continued to oscillate in the same mode with further decrease of capacitance. When the tuned load frequency is decreased, i.e., by turning the capacitor dial in the reverse direction, the frequency switched back to the original value but at a higher setting of the capacitance. This phenomena is illustrated in Fig. 5.2, and has been known for a long time as the Zeihen Effect. Under these biasing conditions simultaneous oscillations were not observed. The experiment thus shows that the non-linearity of the oscillator...
FIG 5.2 - ZEIHEN EFFECT (M_L = M_G = 40, E = -4.5 V)

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is of such a character that van der Pol's analysis in general applies.

In the next set of experiments a bias voltage exceeding the cut-off value was applied. The oscillator was first excited by increasing the plate voltage. The plate voltage was brought back to the original value and the tuned load frequency was increased. At a particular load frequency the frequency of oscillation switched from the higher to the lower frequency of oscillations and continued to oscillate in this mode for further increase in load frequency. On decreasing the tuned load frequency, it was observed that at a particular value of the tuned load frequency, the frequency of oscillation instead of jumping back to the original mode switches automatically from one to the other as shown in Fig. 5.5. This switching continues over a range of tuned load frequency. At lower setting, the switched oscillation disappear and the oscillator executes oscillation at the higher of the two frequencies only.

It should be mentioned that the automatically switched oscillations shown in Fig. 5.5, as far as the author is aware, is a new type of phenomenon, which had not been reported in the literature. The following important characteristics of these oscillations were observed.

(a) Switched oscillations occur when the grid coupling and the transconductance of the oscillator tube have high values. Switched oscillations were found to be absent for values of $M_{G}$ less than 20. The tube transconductance could be varied by altering the number of tubes operated in parallel. It was observed that for 5 tubes, switched oscillations occur when the fixed bias is larger than the cut-off value. For four tubes the
(1) Characteristics with $M_L = 40$, $M_G = 20$
Grid Bias $= -9$ V.

(ii) Characteristics with $M_L = 40$, $M_G = 30$
Grid Bias $= -7.5$ V.

(iii) Characteristics with $M_L = 40$, $M_G = 30$
Grid Bias $= -9$ V.

Fig. 5.3.
Oscillograms showing switched oscillations.
fixed bias is required to be lower for switched oscillations. As the number of tubes is reduced below four, switched oscillations were not found under any condition. The nature of this dependance is illustrated in Fig. 5.4, in which the above-mentioned quantities are plotted for different settings of the load capacitance.

(b) The repetition rate of switching, the duration of each half in a complete period depend on the grid bias, tuned load frequency setting and grid coupling.

(c) The occurrence of the switched oscillation also depend on the resistance of the plate supply source. In the experiments described here, the source was an unregulated filtered full wave rectifier using a 5U4 tube. The source resistance varies from 800 - 900 Ω. It was observed that if the source resistance is increased by connecting a resistance of 150 Ω in series with the filter choke, switched oscillations are completely eliminated.

(d) The basic period of oscillations are determined by the plate supply filter capacitance, and may be altered over wide limits by altering this capacitance.

5.4. Experiments Performed with Grid Leak Bias:

In addition to the fixed bias a grid leak bias was applied and the frequencies of oscillation were studied for different load frequencies. For low values of load coupling and the fixed bias only Zeihen Effect were observed. However, when the fixed bias was a value nearly equal to and more than the cut-off bias and for higher values of grid and load coupling the following phenomenon was observed. As the tuned load frequency is increased
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Fig 5.4

DUTY RATIO
the frequency of oscillation increases and at particular setting switches to the low frequency. It continues to oscillate at the low frequency mode for further increase in load frequency. However, as the load frequency is decreased, the frequency of oscillation decreases; and for a particular value, instead of jumping to the high frequency mode, the oscillator executes oscillations at two frequencies simultaneously. If the two possible frequencies of oscillation are related by a nearly harmonic ratio when the simultaneous oscillations are excited, an exact harmonic ratio of the frequencies are established. Such simultaneous oscillations for ratio of 5 : 4, 5 : 6, 3 : 4 are observed. If, on the other hand, the two possible frequencies of oscillation are not harmonically related the oscillator exhibits asynchronous simultaneous oscillations. These synchronous or asynchronous simultaneous oscillations continue for a short range of the load capacitance beyond which only the high frequency oscillation remains. The above phenomenon is illustrated in Figs. 5.5 and 5.6. It should be noted that asynchronous simultaneous oscillations as mentioned above are obtained under very restricted conditions. Its excitation requires a high equivalent transconductance of the tube and a fixed bias equal to or more than the cut-off value and also a high value of grid coupling. On the other hand, the synchronous simultaneous oscillations are excited at comparatively low value of load coupling, bias and tube transconductance.

5.5. Conclusion:

As described in the earlier sections a tuned anode oscillator coupled to a tuned load exhibit in addition to the phenomena of Zeihen Effect and synchronous simultaneous oscillations two other phenomena.
(i) asynchronous simultaneous oscillations.  
(ii) synchronous simultaneous oscillations (ratio 5 : 4).  
(iii) synchronous simultaneous oscillations (ratio 3 : 4).

Fig. 5.5.
Oscillograms showing asynchronous and synchronous simultaneous oscillations.
FIG 5.6

Variation of oscillator frequency with the tuned load capacitance in grid leak bias arrangement.

Characteristics with $M_L = 35$, $M_Q = 40$, Grid Bias = -10V.
Variation of oscillator frequency with tuned load capacitance in grid leak bias arrangement.
Characteristics with $M_1 = M_2 = 40$, Grid Bias $= -8.3V$. 

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FIG 5.6
These are simultaneous oscillations at two non-harmonically related frequencies and a mode of oscillation in which the frequency switches from one to the another automatically. The conditions under which these phenomena are exhibited has also been described. In general, an oscillator using a tube of high transconductance and operated with a bias near the cut-off value exhibit switched frequency oscillations under fixed bias conditions. Asynchronous simultaneous oscillations are excited if in addition to the near cut-off fixed bias a grid leak bias is applied.