receiver makes use of an LC tuned circuit with L_1 = 58.6 μH and C_1 = 300 pF. Calculate the frequency of oscillations.

Solution.

$$L_1 = 58.6\ \mu\text{H} = 58.6 \times 10^{-6}\ \text{H}$$

$$C_1 = 300\ \text{pF} = 300 \times 10^{-12}\ \text{F}$$

Frequency of oscillations,
$$f = \frac{1}{2\pi\sqrt{L_1 C_1}}$$

$$= \frac{1}{2\pi\sqrt{58.6 \times 10^{-6} \times 300 \times 10^{-12}}}\ \text{Hz}$$

$$= 1199 \times 10^3\ \text{Hz} = \mathbf{1199\ kHz}$$

Example 14.2. *Find the capacitance of the capacitor required to build an LC oscillator that uses an inductance of L_1 = 1 mH to produce a sine wave of frequency 1 GHz (1 GHz = 1 × 10^{12} Hz).*

Solution.

Frequency of oscillations is given by ;

$$f = \frac{1}{2\pi\sqrt{L_1 C_1}}$$

or
$$C_1 = \frac{1}{L_1 (2\pi f)^2} = \frac{1}{(1 \times 10^{-3})(2\pi \times 1 \times 10^{12})^2}$$

$$= 2{\cdot}53 \times 10^{-23}\ \text{F} = \mathbf{2{\cdot}53 \times 10^{-11}\ pF}$$

The LC circuit is often called *tuned circuit* or *tank circuit.*

14.10 Colpitt's Oscillator

Fig. 14.10 shows a Colpitt's oscillator. It uses two capacitors and placed across a common inductor L and the centre of the two capacitors is tapped. The tank circuit is made up of C_1, C_2 and L. The frequency of oscillations is determined by the values of C_1, C_2 and L and is given by ;

$$f = \frac{1}{2\pi\sqrt{LC_T}} \qquad \text{....}(i)$$

where
$$C_T = \frac{C_1 C_2}{C_1 + C_2}$$

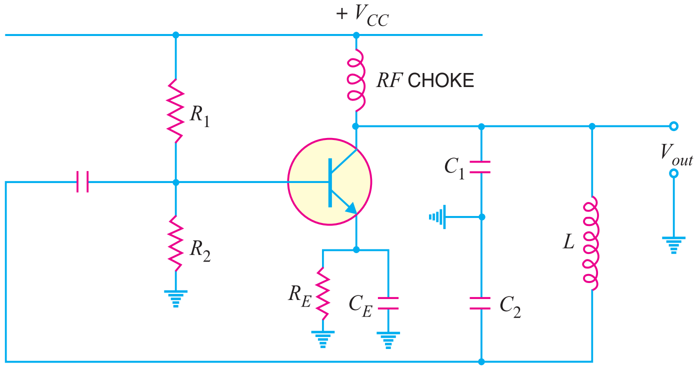

Fig. 14.10

*Note that $C_1 - C_2 - L$ is also the feedback circuit that produces a phase shift of 180°.

Circuit operation. When the circuit is turned on, the capacitors C_1 and C_2 are charged. The capacitors discharge through L, setting up oscillations of frequency determined by exp.** (*i*). The output voltage of the amplifier appears across C_1 and feedback voltage is developed across C_2. The voltage across it is 180° out of phase with the voltage developed across C_1 (V_{out}) as shown in Fig. 14.11. It is easy to see that voltage fedback (voltage across C_2) to the transistor provides positive feedback. A phase shift of 180° is produced by the transistor and a further phase shift of 180° is produced by $C_1 - C_2$ voltage divider. In this way, feedback is properly phased to produce continuous undamped oscillation.

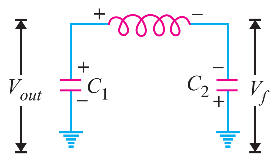

Fig. 14.11

Feedback fraction m_v. The amount of feedback voltage in Colpitt's oscillator depends upon feedback fraction m_v of the circuit. For this circuit,

$$\text{Feedback fraction, } m_v = \frac{V_f}{V_{out}} = \frac{X_{c2}}{X_{c1}} = \frac{C_1}{C_2}{}^{***}$$

$$\text{or} \qquad m_v = \frac{C_1}{C_2}$$

Example 14.3. *Determine the (i) operating frequency and (ii) feedback fraction for Colpitt's oscillator shown in Fig. 14.12.*

Solution.

(*i*) Operating Frequency. The operating frequency of the circuit is always equal to the resonant frequency of the feedback network. As noted previously, the capacitors C_1 and C_2 are in series.

$$\therefore \qquad C_T = \frac{C_1 C_2}{C_1 + C_2} = \frac{0.001 \times 0.01}{0.001 + 0.01} = 9.09 \times 10^{-4}\ \mu\text{F}$$

$$= 909 \times 10^{-12}\ \text{F}$$

$$L = 15\ \mu\text{H} = 15 \times 10^{-6}\ \text{H}$$

$$\therefore \quad \text{Operating frequency, } f = \frac{1}{2\pi\sqrt{LC_T}}$$

$$= \frac{1}{2\pi\sqrt{15 \times 10^{-6} \times 909 \times 10^{-12}}}\ \text{Hz}$$

$$= 1361 \times 10^3\ \text{Hz} = \mathbf{1361\ kHz}$$

(*ii*) Feedback fraction

$$m_v = \frac{C_1}{C_2} = \frac{0.001}{0.01} = \mathbf{0.1}$$

* The RF choke decouples any ac signal on the power lines from affecting the output signal.

** Referring to Fig. 14.11, it is clear that C_1 and C_2 are in series. Therefore, total capacitance C_T is given by;

$$C_T = \frac{C_1 C_2}{C_1 + C_2}$$

*** Referring to Fig. 14.11, the circulating current for the two capacitors is the same. Futher, capacitive reactance is inversely proportional to capacitance.

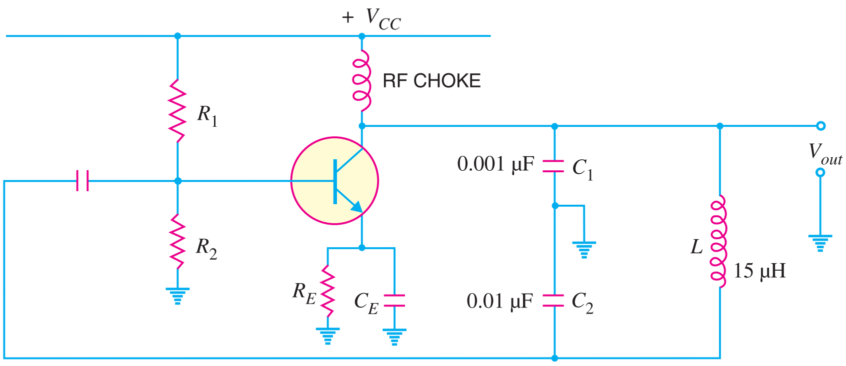

Fig. 14.12

Example 14.4. *A 1 mH inductor is available. Choose the capacitor values in a Colpitts oscillator so that f = 1 MHz and m_v = 0.25.*

Solution.

Feedback fraction, $$m_v = \frac{C_1}{C_2}$$

or $$0.25 = \frac{C_1}{C_2} \qquad \therefore \; C_2 = 4C_1$$

Now $$f = \frac{1}{2\pi\sqrt{LC_T}}$$

or $$C_T = \frac{1}{L(2\pi f)^2} = \frac{1}{(1\times10^{-3})\,(2\pi\times1\times10^6)^2} = 25.\,3\times10^{-12}\text{ F}$$

$$= 25.3\text{ pF}$$

or $$\frac{C_1 C_2}{C_1 + C_2} = 25.3\text{ pF} \qquad \left[\because\; C_T = \frac{C_1 C_2}{C_1 + C_2}\right]$$

or $$\frac{C_2}{1 + \dfrac{C_2}{C_1}} = 25.3$$

or $$\frac{C_2}{1+4} = 25.3 \qquad \therefore\; C_2 = 25.3\times5 = \mathbf{126.5\ pF}$$

and $$C_1 = C_2/4 = 126.5/4 = \mathbf{31.6\ pF}$$

14.11 Hartley Oscillator

The Hartley oscillator is similar to Colpitt's oscillator with minor modifications. Instead of using tapped capacitors, two inductors L_1 and L_2 are placed across a common capacitor C and the centre of the inductors is tapped as shown in Fig. 14.13. The tank circuit is made up of L_1, L_2 and C. The frequency of oscillations is determined by the values of L_1, L_2 and C and is given by :

$$f = \frac{1}{2\pi\sqrt{CL_T}} \qquad \ldots(i)$$

where $L_T = L_1 + L_2 + 2M$

Here M = mutual inductance between L_1 and L_2

Note that $L_1 - L_2 - C$ is also the feedback network that produces a phase shift of 180°.

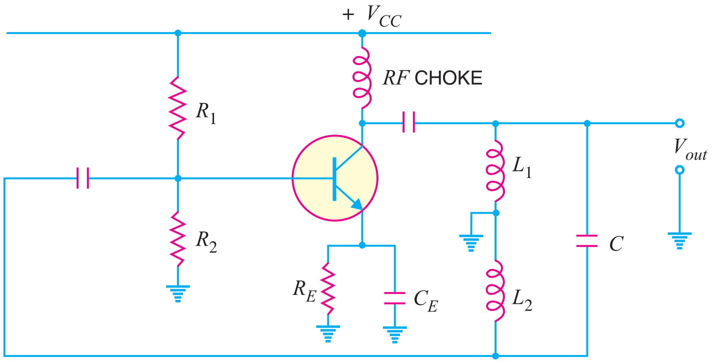

Fig. 14.13

Circuit operation. When the circuit is turned on, the capacitor is charged. When this capacitor is fully charged, it discharges through coils L_1 and L_2 setting up oscillations of frequency determined by *exp. (i). The output voltage of the amplifier appears across L_1 and feedback voltage across L_2. The voltage across L_2 is 180° out of phase with the voltage developed across L_1 (V_{out}) as shown in Fig. 14.14. It is easy to see that voltage fedback (*i.e.*, voltage across L_2) to the transistor provides positive feedback. A phase shift of 180° is produced by the transistor and a further phase shift of 180° is produced by $L_1 - L_2$ voltage divider. In this way, feedback is properly phased to produce continuous undamped oscillations.

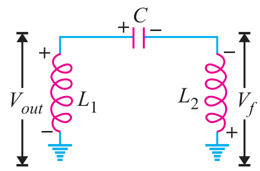

Fig. 14.14

Feedback fraction m_v. In Hartley oscillator, the feedback voltage is across L_2 and output voltage is across L_1.

$$\therefore \qquad \text{Feedback fraction, } m_v = \frac{V_f}{V_{out}} = \frac{X_{L_2}}{X_{L_1}} \stackrel{**}{=} \frac{L_2}{L_1}$$

$$\text{or} \qquad m_v = \frac{L_2}{L_1}$$

Example 14.5. *Calculate the (i) operating frequency and (ii) feedback fraction for Hartley oscillator shown in Fig. 14.15. The mutual inductance between the coils, M = 20 µH.*

Solution.

(i) $\qquad L_1 = 1000\ \mu\text{H}\ ;\quad L_2 = 100\ \mu\text{H}\ ;\quad M = 20\ \mu\text{H}$

$$\therefore \quad \text{Total inductance, } L_T = L_1 + L_2 + 2M$$

$$= 1000 + 100 + 2 \times 20 = 1140\ \mu\text{H} = 1140 \times 10^{-6}\text{H}$$

$$\text{Capacitance, } C = 20\ \text{pF} = 20 \times 10^{-12}\ \text{F}$$

* Referring to Fig. 14.14, it is clear that L_1 and L_2 are in series. Therefore, total inductance L_T is given by : $L_T = L_1 + L_2 + 2M$

** Referring to Fig. 14.14, the circulating current for the two inductors is the same. Further, inductive reactance is directly proportional to inductance.