Chapter 1
Aerial Circuits

The conventional aerial circuit or *tuned circuit* comprises a variable capacitor in parallel with an inductance (physically, a coil). The frequency (f) at which such a circuit is *resonant* is given by:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

f = frequency in Hz
L = inductance in henrys
C = capacitance in farads

A practical version of this formula is :

$$f = \frac{160000}{\sqrt{LC}}$$

f = frequency in kHz
where L = inductance in microhenrys (μH)
C = capacitance in picofarads (pF)

It can be noted here that a practical inductance will also have a certain amount of *resistance,* and so the equivalent circuit is as shown in the second diagram in Fig. 1. The presence of such resistance does not affect the resonant *frequency* of the circuit but only the *sharpness* of the resonance of the circuit. This controls the *quality factor of the* tuned circuit *(see later).* The practical capacitance also has a certain amount of resistance, but this is normally negligible except at very high frequencies (30 MHz and above).

By fixing one component value (e.g. inductance) and making the other variable (e.g. capacitance) it is possible to adjust or tune the circuit over a range of resonant frequencies. Theoretically, on this basis, it is possible to design a tuned circuit to cover the whole range of broadcast frequencies from the 'top' (wavelength) end of the long wave band (30 kHz) to the 'bottom' (wavelength) end of the VHF band

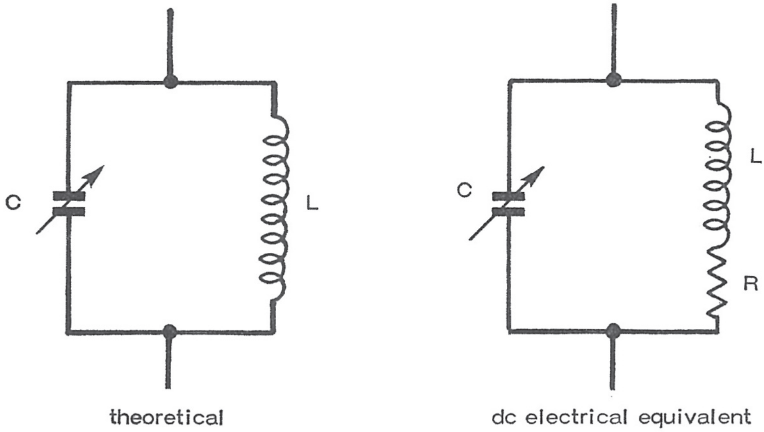

Fig. 1 Capacitance (C) and inductance (L) forming a tuned circuit.

(300 MHz). This is not a realistic solution, and so tuned circuits are designed separately to cover individual broadcast bands, e.g.

Long wave (or low frequency) – 30-300 kHz
Medium wave (or medium frequency) – 300-3000 kHz
Short wave (or high frequency) – 3-30 MHz
VHF – 30-300 MHz

In practice, tuned circuits are designed to cover the actual spread of broadcast stations operating in these bands, e.g.

Long wave – 50-150 kHz
Medium wave – 500-1500 kHz
Short wave – 18-28 MHz
VHF – 88-100 MHz

A significant fact is that the actual frequency range covered increases considerably with decreasing wavelength of these broadcast bands, e.g.

Long wave – range covered 100,000 Hz.
Medium wave – range covered 1,000,000 Hz.
Short wave – range covered 26,000,000 Hz.
VHF – range covered 12,000,000 Hz.

This makes the design of aerial circuits increasingly critical from long wave upwards (in frequency). Again, in practice, this means that home-made coils are seldom suitable for other than simple long wave and medium wave receivers. Even then, proprietary coils almost invariably give better results because of the better *quality factors* (or Q) achieved. Nevertheless it is interesting to cover the design of simple aerial coils.

The simplest type of inductance is an open coil of insulated wire wound on a former of insulating material, or it can even be self-supporting if the wire is thick enough. In the latter case the coil is wound on a mandrel and then slid off, being mounted on the wire ends (Fig. 2).

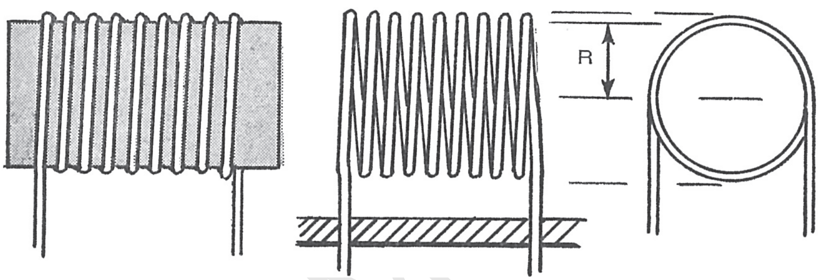

Fig. 2 Air-cored tuning coils. Coil on left is wound on a former.

The *inductance* of such a coil is found as follows:

$$\text{inductance, microhenrys} = \frac{R^2 \times N^2}{9R + 10L}$$

where R is the mean radius of the coil in inches
L is the length of the coil in inches
N is the number of turns

The effect of wire *diameter* is not significant, provided the coil diameter is reasonably large, i.e. 1 in. (25 mm) or more. It is therefore logical to use quite thick wire (18 s.w.g. or 16 s.w.g.) in order to minimize coil resistance.

Suppose such a coil is to be designed as the inductive component in a *medium wave* tuned circuit. The resonant frequency range required is 500 to 1500 kHz. Considering the requirements, first in terms of the product of L and C, from the resonant frequency formula:

$$LC = \frac{(160\,000)^2}{f^2}$$

Thus at f = 500 kH_2,
$$LC = \frac{(160\,000)^2}{(500)}$$
$$= 102\,400, \text{ say } 100\,000$$

at f = 1400 kHz,
$$LC = \frac{(160\,000)^2}{(1500)^2}$$
$$= 11{,}300, \text{ say } 11{,}000$$

For a fixed value of inductance, maximum capacity will be required to tune to the lowest frequency, i.e. the highest calculated value of LC required. Typically available variable capacities offer a range of 0-200 pf or 0-500 pf. Choosing the 0–500 pf size, at maximum capacity:

$$L \times 500 = 100{,}000$$
or inductance required = 200 microhenrys.

Using the same inductance, the *minimum* capacitance required to tune to the other end of the band (1500 kHz) would be:

$$200 \times C\ \text{min} = 11{,}000$$
or C min = 55 microhenrys

Thus a 200 μH inductance would be a suitable match to a 0-500 pf capacitor to cover the range required.

To simplify the coil design we can 'guesstimate' a length of 1 in. and a coil diameter of 1 in. Inserting these values in the appropriate formula:

$$\text{inductance, } \mu H = \frac{(0{\cdot}5)^2 \times N^2}{9 \times 0{\cdot}5 + 10}$$
$$\mu H = 0{\cdot}0172 N^2$$

Inserting the value of inductance required (200 μH) and solving for number of turns :

$$N = \frac{200}{0{\cdot}0172}$$
$$= 108 \text{ turns, or say } 100 \text{ turns.}$$

Close winding 100 turns of wire the length of 1 in. would permit the use of a maximum wire size of 0·01 in., say 36 s.w.g. To use a larger wire size it would be necessary to increase the length of the coil and recalculate the number of turns required accordingly.

A *long-wave* coil would require *more* turns; and a short-wave coil less turns (perhaps only one or two turns).

Q Factor

The effect of *resistance* in the tuned circuit is shown in simple diagrammatic form in Fig. 3, representative of a resonant circuit. The current

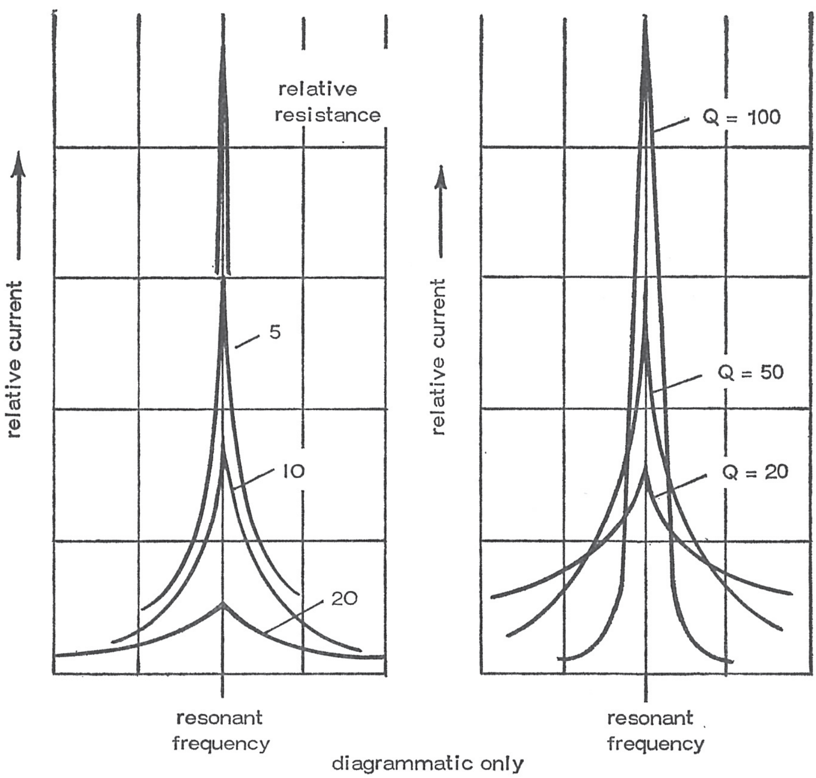

Fig. 3 The effect of resistance and Q factor on sharpness of tuning.

flowing in a resonant circuit peaks at the resonant frequency and falls off sharply on either side. The lower the *resistance* present, the *higher* the peak (more current flowing) and the sharper it is (the sharper the tuning). Resistance values shown are nominal only to illustrate this effect.

This can be put another way. The shape of the resonant curve is dependent on the respective values of the *reactance* on either the coil or capacitor and the resistance present. The ratio of the two is known as the Q factor, when

$$Q = \frac{\text{reactance (X)}}{\text{resistance (R)}}$$

Reactance, in ohms, can be calculated from the following formulas:

In the case of an inductance, $X_L = 2\pi fL$
In the case of a capacitor, $X_C = 1/2\pi fL$

At resonant frequency the reactance of a coil and capacitor are the same, so it does not matter which is considered. A simple calculation will prove this, taking the previous values calculated and a resonant frequency of 500 kHz, namely:

$$\text{inductance} = 200\ \mu\text{H}$$
$$\text{capacitance} = 500\ \text{pF}$$
$$\text{Thus } X_L = 2\pi \times 500 \times 10^3 \times 200 \times 10^{-6} = 628\ \text{ohms}$$
$$X_C = 1/2\pi \times 500 \times 10^3 \times 500 \times 10^{-12} = 628\ \text{ohms}$$

The *resistance* refers to the *dynamic* resistance to *rf* currents in the circuit, not the *dc* resistance. Dynamic resistance is generally known as *impedance*. In the case of a simple air-cored coil, dynamic resistance may rise up to 100 ohms or more, yielding a Q of less than 10. Very much more efficient coils can be produced with Q factors ranging up to 100 (or very much higher in certain cases). These are invariably wound on a non-conducting magnetic core, either of ferrite or iron dust bound together with an insulator. The actual value of Q achieved has the same effect as that illustrated in Fig. 3. The higher the Q value the sharper, and higher, the peak of the curve. With decreasing Q value the tuning becomes *broader* and the peak value is reduced as shown in Fig. 3. Sharpness of tuning is always desirable in radio receivers as it

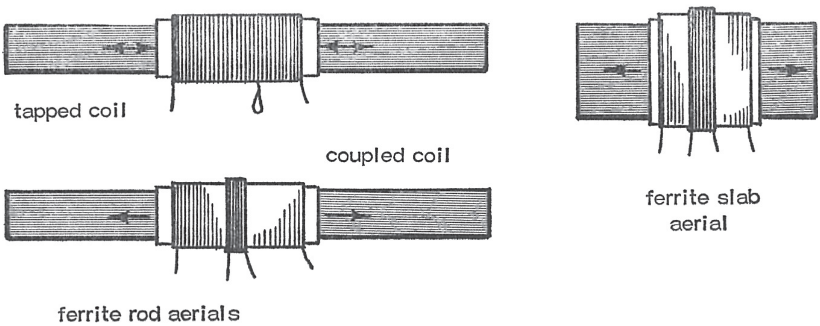

Fig. 4 Basic forms of aerial coils wound on a ferrite rod or ferrite slab.

gives good *selectivity,* or the ability to separate one station from another when the two are closely spaced on the frequency band, but see later under *Modulated Signals.*

Ferrite Rod Aerials

In simple terms introduction of a ferrite or similar magnetic material core to a coil greatly increases its inductance. This means that the coil can be made much more compact thus requiring less wire length and less resistance. A smaller wire size can also be used without introducing excessive resistance. Unfortunately no simple formulas apply for the design of such coils, for the size and number of turns required are related to the size and type of magnetic core material used. They are therefore designed on empirical or semi-empirical lines, the latter using charts related to the specific material properties.

Simple coils of this type are wound on standard sizes of ferrite rod or ferrite slab, either as tapped coils or inductively coupled coils – Fig. 4. Some design data are given in Table 1 (end of chapter).

One other advantage offered by 'cored' coils is that their inductance can be varied, if necessary, by altering the position of the coil on the core. This can be a very useful feature for adjusting the resonant frequency range of a tuned circuit independent of the variable capacitor, e.g. for setting up or 'trimming' purposes. Once adjusted in this way, the coil is then usually locked to the core (e.g. with adhesive or hard wax) to ensure that it remains at a fixed inductance.

The 'Q' of a coil can be further influenced by special forms of