Electronic systems — 5

Reception and demodulation

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Electronic systems 3 and 4 discussed the various techniques, advantages and disadvantages of both amplitude and frequency modulation of carrier signals. This section will describe some of the methods of receiving and demodulating amplitude-modulated carrier waves.

Station selection

To receive a particular broadcast from amongst the many different transmissions within the radio broadcast bands it is necessary to have a receiver tuned to the carrier frequency of the desired transmitter. In order to achieve optimum reception of this transmitted signal the bandwidth of the receiver must match that of the transmitter. If the bandwidth of the receiver is too wide the demodulated signal will contain undesirable interference from the adjacent channels. Reducing the receiver bandwidth will decrease the adjacent-channel interference but will restrict the reception of the high frequency components of the wanted station. The solution is that a compromise has to be made between the two above conditions, the term "selectivity" being introduced to describe the success of the receiver in rejecting the adjacent channels.

To demodulate a transmitted signal successfully the demodulator must be provided with an input signal of sufficient amplitude and therefore it is necessary to provide radio frequency amplification prior to demodulation in order to receive weak or distant transmissions.

The crystal set, which is the simplest form of a radio receiver, is constructed from a parallel tuned circuit and a crystal detector or demodulator. The crystal has semiconducting properties similar to the semiconductor diode which has since replaced it. This receiver does not need power from batteries or the mains supply because the power required to drive the earpiece is derived from the electrical signals induced in the aerial, consequently it is desirable to operate the set with a long aerial and a good earth connection. Voltages will be induced in the aerial due to the presence of signals from all transmitting stations, therefore a circuit is needed which will single out (tune to) the desired frequency — a circuit which will do this is called a tuned circuit.

This series of articles is based on a proposed Advanced Level course for schools and is prepared in consultation with Professor G. B. B. Chaplin, University of Essex. The next article will deal with more complex systems of reception and demodulation and will include the f.m. receiver.

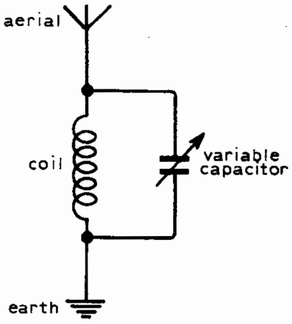
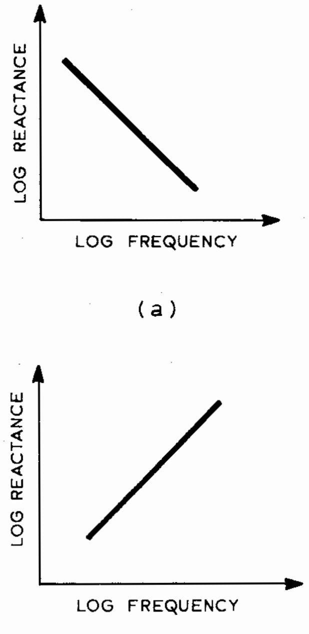


Fig. 1. Tuning circuit, shown connected between aerial and earth, consisting of an inductor in parallel with a variable capacitor.



(a)

(b)

Fig. 2. Graphs of reactance against frequency for (a) capacitor and (b) inductor.

The tuned circuit used in a crystal set is an inductor connected in parallel with a variable capacitor, see Fig. 1. Let us now consider how this simple arrangement can single out a particular broadcast from a complex and full radio spectrum. Fig. 2 shows the plots of reactance against frequency for both the inductor and the capacitor. The equations for these impedances, for a capacitor C and an inductance L at a frequency f, are

$$\text{Capacitor: Impedance} = \frac{1}{2\pi fc}$$

$$\text{Inductor: Impedance} = 2\pi fL$$

For a given inductor/capacitor pair there will be a frequency at which the impedance of both components will be the same.

$$\text{i.e. when:} \quad \frac{1}{2\pi fC} = 2\pi fL$$

$$\text{therefore:} \quad f = \frac{1}{2\pi\sqrt{LC}}$$

At this frequency the parallel tuned circuit, made from the components L and C, are said to be in resonance and are tuned to the frequency f. The frequency response of the parallel tuned circuit described above is given in Fig. 3.

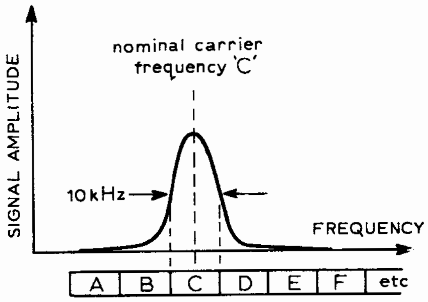


Fig. 3. Frequency response of the tuned circuit shown in Fig. 1, when tuned to station C. Ideally the response required would be a rectangular one with maximum amplitude within the bandwidth of C and zero amplitude at frequencies above and below C, so that all of the frequencies within channel C could be received with no interference from the adjacent stations.

The blocked frequency markings represent the channels allocated to a number of different transmitting stations. It can be seen that, for the conditions shown in Fig. 3, the tuned circuit would have very little response from stations A or E, some response from stations B and D, but the most response from station C. Although the circuit is capable of rejecting all stations whose carrier frequency is below that of B and above that of D, it has a poor selectivity, due to only partial rejection of the adjacent stations. The response from stations B and D is considered as adjacent-channel interference when attempting to receive station C only.

If the value of the capacitor is changed, the frequency at which the impedances of the inductor and the capacitor are equal will also change, hence the resonant frequency will be different. Reducing the value of the capacitor will increase the resonant frequency, conversely increasing the value of the capacitor will decrease the resonant frequency. The variable capacitor allows the resonant frequency of the tuned circuit to be altered so that it is coincident with any particular transmitted carrier frequency, thus allowing any chosen broadcast to be received.

Demodulation

Demodulation is the process of recovering the information, impressed on the carrier wave, from the composite transmitted signal developed across the tuned circuit which, see diagram referring to point X in Fig. 4, is of the same form as the output of the modulator in the transmitter.

The average d.c. value of the waveform, over a complete cycle of the modulated carrier signal, is zero, and it is therefore necessary to remove all the negative going, or positive going, voltages in order to recover the modulating signal. This is achieved using a device such as a diode which will pass current in one direction only. Fig. 4 shows a circuit which achieves this result.

The signal at Y is a rectified version of the signal at X.

Since the signal at X has a mean d.c. level it is now only necessary to remove the remaining carrier components and the information which was transmitted will have been recovered. This is done by using a capacitor to filter out the high frequency components of the carrier signal. Because a capacitor has the property that its impedance decreases as frequency increases, selection of a suitable value of capacitance will ensure that it has a relatively low impedance to the high-frequency carrier signal and a relatively high impedance to the much lower frequency modulation signal. So that the broadcast stations can be heard, the load resistor is replaced by a pair of high impedance headphones which convert the tiny electrical currents into audible sound waves.

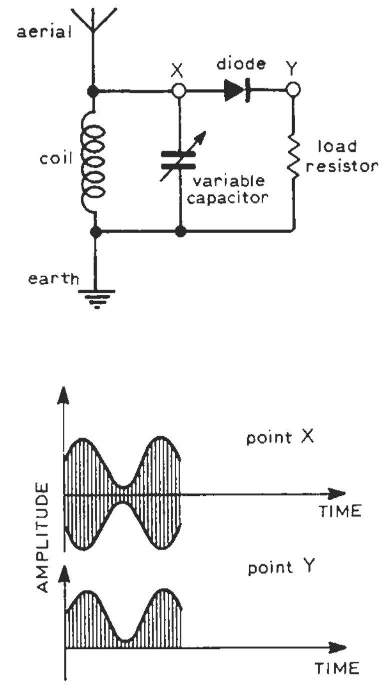


Fig. 4. Demodulating circuit. Signal at point X is of the same form as the output of the modulator in the transmitter – it is a modulated carrier signal. In order to recover the modulating signal it is necessary to rectify the carrier signal to remove all of the negative going, or positive going, voltages to obtain an average d.c. level. Resulting rectified signal is shown at point Y.

A suitable capacitor value may be chosen relative to the impedance of the headphones; it must have a lower impedance than the headphones at the carrier frequency and a high impedance at the frequency of the modulating signal. This is summarised in the equation given below.

The impedance of the capacitor C at a frequency f is:

$$\text{Impedance} = \frac{1}{2\pi f C}$$

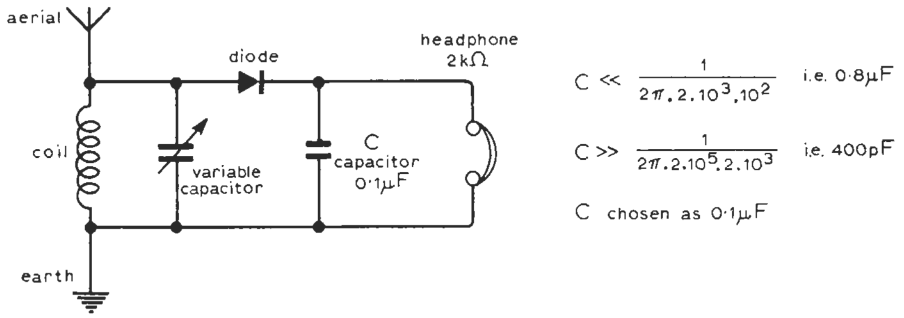
Let the carrier frequency be f_c, the modulation frequency be f_m and the impedance of the headphones be R, then

$$\frac{1}{2\pi f_c C} \ll R \ll \frac{1}{2\pi f_m C}$$

Fig. 5 shows the complete circuit of the crystal set with typical component values. In order to comply with the above conditions the value of capacitor C has been chosen as 0.1μF, see conditions formulated in Fig. 5.

A receiver of this kind will drive a pair of headphones, if the aerial and earth are sufficient, but it is unlikely that it will provide enough output to drive a loudspeaker; it is also lacking in sensitivity and selectivity. The next article will describe receivers which are designed to improve these characteristics.

Fig. 5. Crystal set showing typical component values and the conditions for estimating a value for C. First condition says that the value of C should be such that its impedance is high, at the modulating frequency (in this case 100Hz), compared to the impedance of the headphones (in this case 2kΩ). Second condition says that the value of C should be such that its impedance at the carrier frequency (in this case 200kHz) should be low compared to the impedance of the headphones.



Further reading

Obtainable from Mr R. A. Smith, Department of Electrical Engineering Science, University of Essex, Wivenhoe Park, Colchester CO4 3SQ, Essex, are the teaching texts for the electronic system pilot A-level course.

Correction

It has been pointed out to us that in Part 4 of "Electronic Systems" (July issue), Fig. 3 and the associated text give the impression that 9kHz channels are used all over the world in the l.f. and m.f. bands. In fact, 9kHz is used only in ITU Region 1 and the position in the Far East, Australia and Canada is that 10kHz channels are used. Fig. 3 also suggests, incorrectly, that adjacent channels are allotted on an inter-continental basis. Apologies to readers for these errors.