RADIO RECEIVERS

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CHAPTER I

INTRODUCTION

1. Uses for and Classes of Radio Receivers

Transmission of intelligence by radio is based on modulation. Modulation is a process by which the message to be transmitted is superimposed at the sending end of a radio link as a modulating signal (or simply, the signal) on a strong carrier wave, thereby changing the latter's amplitude, frequency or phase. The modulated carrier is radiated by a transmitting aerial as a wave of electromagnetic energy which propagates through space at the velocity of light.

At the point of reception, the modulated wave is picked up by a receiving aerial and is fed to the receiver input. In the receiver, the signal is separated from the radio-frequency carrier and drives the receiver load, which may be a speaker, a recorder, a cathode-ray tube, etc.

As an electromagnetic wave travels away from the transmitter it is weakened, or attenuated. This is why radio receivers should be capable of picking up relatively weak signals.

Uses for Radio Receivers. At present, radio serves a variety of purposes, such as communication, broadcasting, navigation, radar, and telecontrol.

Radio communication is the transmission and reception of messages without wires or waveguides. It includes communication by radio telegraph, radio telephone, radio teletype-writer, radio facsimile, and television. It is the only method of communication between stationary and mobile objects (such as from ship to shore, from ground to aircraft, from ship to ship, or from aircraft to aircraft, and more recently from ground to satellites or from satellites to ground, and between satellites, known as space communication).

Radio broadcasting is radio transmission for general reception, including speech, music and commercial television.

Radio navigation is the use of radio facilities for determining the position or direction or both of ships or planes.

Radar (which is an acronym for *Ra*dio *D*etection *a*nd *R*anging) is a technique for determining the range and bearings of objects (usually called *targets*) by the transmission of beamed high-power signals against reflective targets, the reception of the reflected signals, and the presentation of the resultant data on a dial or a cathode-ray display. Radar may be used for marine navigation, gun (fire) control, earth surveillance from the air, etc.

Telecontrol is a technique for control of machinery by radio.

Classes of Receivers. There are (a) communication and (b) broadcast receivers.

Communication receivers are used in point-to-point radio telephone and telegraph service, radio navigation systems, and radar.

Broadcast receivers are used for the reception of sound and visual programmes intended for the general public.

Communication receivers are usually classed according to operating principle, wavelength (or frequency), type of service, type of modulation, type of installation, and range of operation.

According to the operating principle, there are tuned radio-frequency (TRF), regenerative, superregenerative, and superheterodyne receivers.

According to wavelength (or frequency), there are long-wave (low-frequency), medium-wave (medium-frequency), short-wave (high-frequency), and ultra-short-wave (VHF, UHF, SHF, etc.) receivers. It may be added that although the trend has for some time been to drop the "wave" terms in preference to the "frequency" terms, the former are still in use in the Soviet literature on the subject.

According to the type of modulation, there are amplitude-modulated (AM) and frequency-modulated (FM) receivers.

According to the type of installation, there are stationary and mobile receivers.

According to the range of operation, there are long-distance, medium-range, and short-range receivers.

Review Questions

1. How is intelligence transmitted by radio?
2. What are the functions of radar?
3. What is the function of communication receivers?

2. Receiver Characteristics

The characteristics of importance to any receiver are: power output, output voltage, sensitivity, selectivity, bandwidth, frequency range, and fidelity.

Power Output and Output Voltage. The power output of a receiver is the power delivered to its load. It varies with the type of load which may be a speaker, a telegraph printer, an automatically controlled device, etc.

In television and radar receivers, in which a cathode-ray tube is the load, output voltage is specified instead of output power. Receiver output voltage usually ranges from a fraction of a volt to a few tens of volts.

Sensitivity. The sensitivity of a radio receiver is defined as the strength of the signal at its input required to produce a normal test output (which is a specified power at its load). The smaller the required input signal, the higher the receiver sensitivity. Sensitivity is expressed in microvolts.

For receivers (mainly, transistor) with built-in ferrite aerials the sensitivity is defined in terms of the minimum field intensity at the point of reception that produces the normal voltage applied to the load, and not in terms of the input signal. The sensitivity is then expressed in millivolts per metre of effective height of the aerial.

The sensitivity of a receiver is decided by the properties of each of its stages, but can be fully realised only if receiver noise at the output is lower than its signal. The signal-to-noise ratio specified for a particular type of receiver varies with the nature of the signal to be received.

Bandwidth and Selectivity. The signal arriving at the input of a receiver contains a spectrum of frequencies which are due to modulation at the sending end. The width of the frequency spectrum is different for different types of modulation. An AM (amplitude-modulation) transmitter radiates the carrier frequency, f_0, and a whole gamut of what are called *side frequencies*, or *side bands* which extend from $f_0 - F_{max}$ to $f_0 + F_{max}$. Together, they make up the bandwidth of the transmitter. As is seen, in amplitude modulation the bandwidth is $2F_{max}$. In wide-band frequency modulation, the bandwidth is mainly determined by the frequency deviation Δf_{max} and is equal to $2\Delta f_{max}$.

Among other things, a good receiver should be capable of receiving the signal along with its side bands. In other words, it should perform satisfactorily within that band of frequencies, so that the natural relations between the amplitudes of the constituent frequencies will remain undistorted. This can be obtained only if a receiver has a constant sensitivity over that band, called its bandwidth.

On the other hand, a receiver should be able to discriminate against signals of frequencies differing from that of the desired signal. This is called the *selectivity* of a receiver.

The ideal *selectivity*, or *response*, *curve* (also called the *resonance curve*) is shown in Fig. 1.1*a*. A receiver with such a response curve, when tuned to a transmitting station, would readily pass the intelligence transmitted and reject all other signals.

The ideal response curve, however, is impossible to produce in practice. Normally, practical receivers have the sort of response shown in Fig. 1.1*b*. At f_0 is the resonant frequency of the receiver tuned circuits. The amount off resonance, Δf, is laid off as abscissa, and the ratio of the signal at a given frequency off resonance to the signal at resonance, Y, as ordinate.

As is seen, the frequencies removed from resonance contribute less and less to the signal. The band of frequencies which are still important to faithful reproduction of the signal make up the radio-frequency (r. f.) bandwidth of a receiver. The limiting frequencies are usually defined for a specified value of the ratio Y. In Fig. 1.1*b*, the bandwidth is for $Y = 0.7$.

The response curve provides a basis for comparison of receivers from the view-point of their selectivity. The smaller the ratio Y at a given amount off resonance, the weaker the signal at that frequency, and the greater the desired signal. For com-

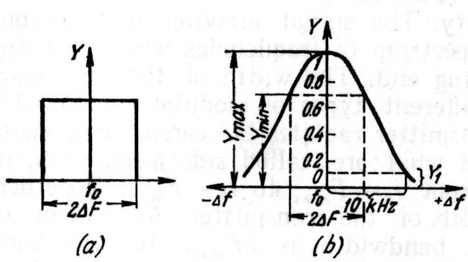

Fig. 1.1. Selectivity or response curves of radio receivers

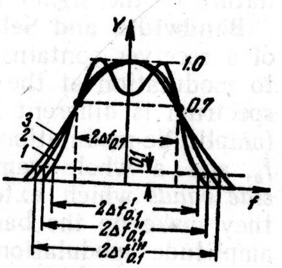

Fig. 1.2. Resonance curves of various oscillatory systems with similar bandwidth

munication and broadcast receivers the selectivity is specified at 10 kilohertz off resonance, because carrier frequencies are spaced that amount apart by international agreement. In Fig. 1.1*b*, $Y_1 = 0.1$ (20 db down) shows that the signal from an adjacent station is only one-tenth in strength compared with the desired signal. In modern communication and broadcast receivers, adjacent frequencies are attenuated from 10 to 1000 times (from 20 to 60 decibels down).

A wide bandwidth and a high selectivity are conflicting requirements—widening the former impairs the latter, and vice versa. A sort of balance between them can be struck by making the response curve approach the ideal square one.

Figure 1.2 shows the response curves for various types of r. f. circuits. They all have the same bandwidth at 0.7 level, or between 3 db points. Outside the bandwidth, however, they differ in slope. Obviously, there must be an additional criterion for comparison of these circuits. Such a criterion is the bandwidth ratio (or relative bandwidth), defined as the ratio of the bandwidth at the frequency of interest to that at 3 decibels down

$$K_{bw} = 2\Delta f / 2\Delta f_{3db} = \Delta f / \Delta f_{3db} \tag{1.1}$$

It is usual to specify the ratios of the 20-db and 40-db bandwidths (between 0.1 and 0.01 points, respectively) to the 3-db one (at 0.7 level)

$$K_{bw20db} = \Delta f_{20db} / \Delta f_{3db}$$

and (1.2)

$$K_{bw40db} = \Delta f_{40db} / \Delta f_{3db}$$

The closer the value of K_{bw} to unity, the closer the response curve is to a square (ideal) one. Of the three resonance curves shown in Fig. 1.2, curve *1* comes closest to the ideal characteristic and has the lowest value of K_{bw}.

Fidelity of a Radio Receiver. This is a degree with which a radio receiver reproduces at its output the envelope of the modulated wave applied to its input.

The signal picked up by the receiver aerial goes through a succession of circuits which contain linear and non-linear elements. These elements cause distortion to the signal, so that a fully faithful reproduction is unfeasible.

Radio receivers are subject to frequency distortion, non-linear distortion, and phase distortion.

Frequency distortion is due to non-uniform amplification over the bandwidth of the receiver. This upsets the natural relation between the amplitudes of the harmonics contained in the composite signal. Frequency distortion is expressed in terms of the frequency distortion factor which shows how much the signal is attenuated at the boundary of the bandwidth.

In the selectivity curve of Fig. 1.1*b*, the distortion factor

$$M = Y_{min}/Y_{max}$$

shows how much the signal at the limiting frequency of the bandwidth is attenuated.

The a.f. section of a receiver cannot provide for uniform amplification of the signal either. As a result, the signals at the limiting frequencies of the bandwidth may be attenuated appreciably.

The attenuation of the upper frequencies in the signal may be as great as 50 per cent throughout a receiver.

Non-linear distortion is due to the fact that on its way through a receiver the signal passes through circuit elements whose volt-ampere characteristics are not a straight line (valves, transistors, iron-cored inductors, etc.). Because of this, undesirable frequencies, not present in the input signal, might appear in the output, and its waveform might be distorted.

Phase distortion appears as a result of upsetting phase relations between the harmonic components of a non-sinusoidal signal, because of which the signal waveform differs from that of the input.

Non-linear and phase distortions are dealt with in detail in Chapter II.

Apart from the characteristics listed above, a radio receiver has to meet a number of requirements in respect to its construction. These above all are size and weight, reliability, mechanical and electrical strength, and ease of control.

Review Questions

1. Define the selectivity of a receiver.
2. Define the bandwidth of a receiver.
3. Which circuits of a receiver control its selectivity (frequency response)?
4. Describe the ideal response (selectivity) curve.

5. List the circuit elements responsible for frequency distortion in a receiver.
6. List the circuit elements responsible for non-linear distortion in a receiver.

3. Functional Units of a TRF Receiver

A general idea about operation of a receiver can be obtained by reference to its block diagram showing the various functional units.

We shall begin with the straight or tuned radio-frequency (TRF) receiver whose block-diagram appears in Fig. 1.3.

The input circuit of the receiver extracts the desired signal and attenuates other signals.

The radio-frequency (r.f.) amplifier amplifies the extracted signal and further attenuates the unwanted signals. The detector D converts the modulated radio wave into an audio-frequency signal. The detector may be a vacuum valve or a crystal diode.

The audio-frequency amplifier builds up the audio-frequency signal to deliver the power output or output voltage necessary for the operation of the terminal equipment (load).

A TRF receiver is not quite sensitive or selective, particularly on short and ultra-short waves.

The bandwidth $2\Delta F$ of a single tuned circuit and its quality-factor Q are related thus

$$2\Delta F = \frac{f_0}{Q} \tag{1.3}$$

where f_0 is the signal frequency.

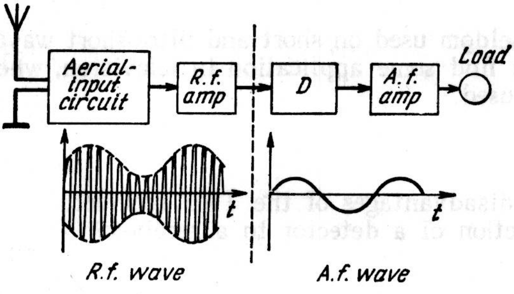

Fig. 1.3. Block-diagram of a TRF receiver

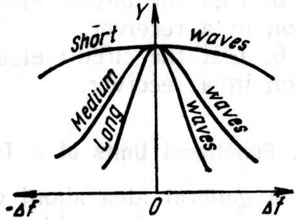

Fig. 1.4. Resonance curves of tuned circuits on different wave bands

The Q-factor of the tuned circuit may be made almost constant on all the bands. This will improve the bandwidth but the selectivity will be impaired. For instance, at $f_0 = 300$ kilohertz and $Q = 100$, the bandwidth is

$$2\Delta F = \frac{300}{100} = 3 \text{ kilohertz}$$

A tuned circuit possessing a similar Q at a frequency of $f_0 = 30{,}000$ kilohertz will have a bandwidth of 300 kilohertz. It should be noted that a TRF receiver has several circuits tuned to the signal frequency. Therefore, the selectivity and bandwidth of a practical TRF receiver considerably differ from the values indicated in the example. The example only gives a general idea of the cause for poor selectivity in TRF receivers. Actually, the selectivity in a commercial receiver is better and the bandwidth, narrower. However, on short and ultra-short waves the resonance curve of the receiver remains broad and the selectivity of the receiver is insufficient. Fig. 1.4 shows the resonance curves of tuned circuits on different wave bands. High selectivity and the required bandwidth may be obtained in superheterodyne receivers.

TRF receivers are seldom used on short and ultra-short waves. Receivers of this type find some application in television, where a wide bandwidth is used.

Review Questions

1. Name the main disadvantages of the TRF receiver.
2. What is the function of a detector in a receiver?