Electronic systems — 6

More about reception and demodulation

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A good a.m. receiver must be both sensitive and selective. To improve the selectivity of the receiver it is necessary to design sharp tuning characteristics. This can only be achieved by using more tuned circuits. The sensitivity can be improved by introducing radio frequency amplification prior to the demodulation stage. The tuned radio frequency receiver (t.r.f.) achieves these objectives by employing tuned amplifiers prior to demodulation. In general there are two, three or more of these tuned amplifiers in the receiver. The frequency response of this block of tuned amplifiers has a much steeper slope than that of a single tuned stage. This response is far more able to reject adjacent stations and thus the selectivity is vastly improved. The amplification given by each stage enables the demodulation of weak signals from very remote transmitters.

Fig. 1 shows the block diagram of a t.r.f. receiver capable of driving a loudspeaker. The dotted lines connecting the arrowheads show that the tuning of the stages is mechanically linked. If all the tuned stages were identical this mechanical linkage would ensure that in tuning over a wide frequency range the response curves of each individual stage would remain in step. This is referred to as "tracking".

The major disadvantage with a t.r.f. receiver is that the tracking is extremely difficult to achieve. To be successful the tuned stages would be required to track accurately over a large frequency range, say from 150kHz up to 10MHz.

Superheterodyne principles

The superheterodyne (superhet) receiver overcomes the tracking difficulties of a tuned radio frequency receiver. It employs amplification at a constant frequency irrespective of the carrier frequency of the received signal. These amplifiers are termed intermediate frequency (i.f.) amplifiers.

The i.f. is produced by multiplying the received signal with the output of an oscillator. The oscillator frequency is set a fixed amount away from the received carrier frequency. Part 4 (July 1976) described how two frequencies can be multiplied to produce sum and difference frequencies. The sum and difference frequencies become the input to the i.f. amplifier section of the receiver. Generally the i.f. amplifier is tuned to amplify the difference frequency and reject the sum frequency.

Most domestic a.m. receivers utilize the superhet principle. The intermediate frequency in common usage is 470kHz. A typical block diagram as shown in Fig. 2.

The multiplier circuit is generally referred to as the "mixer". The oscillator is termed the "local oscillator". If it is desired to listen to a programme which is transmitted on a carrier of 2.4MHz, then the oscillator has to be set at a frequency of 2.87MHz. The difference frequency produced by the mixer is at 470kHz and is subsequently amplified by the i.f. amplifier. The output of the i.f. amplifier is demodulated using similar circuits to those used in the crystal set.

Radio frequency amplifier

Fig. 2 shows that the input signal is partially selected and amplified by a tuned r.f. amplifier, prior to the mixing process. The reason for the inclusion of this circuit is as follows. Suppose that we wished to receive a transmission which has a carrier frequency of 1MHz. The local oscillator would be set at a frequency of 1.47MHz and the sum and difference frequencies produced by the mixer would be 2.47MHz and 470KHz. If there exists a transmitter with a carrier frequency of 1.94MHz, then the outputs of the mixer, due to the presence of this signal, would be 3.41MHz and 470kHz. The i.f. amplifier would amplify the 470kHz components from both of these stations. The result would be an intolerable interference from the second station. It can be seen that this state of affairs will exist for each station selected, and that the desired transmission will be received along with the signal from any transmitter with a carrier frequency differing by twice the i.f. value. To eliminate this source of interference the superhet needs a pre-mixing stage of r.f. tuning. This stage does not have to be highly selective and the bandwidth can generally be much wider than the transmission bandwidth. The bandwidth must be narrow enough to reject the unwanted signal. This technique is known as "image rejection". The r.f. amplifier is usually a single tuned circuit. It is desirable to have the r.f. amplifier and the oscillator tracking and thus maintaining the image rejection when tuning over the radio spectrum.

Intermediate frequency amplifier

In the t.r.f. receiver, selectivity was achieved by employing multiple tuned

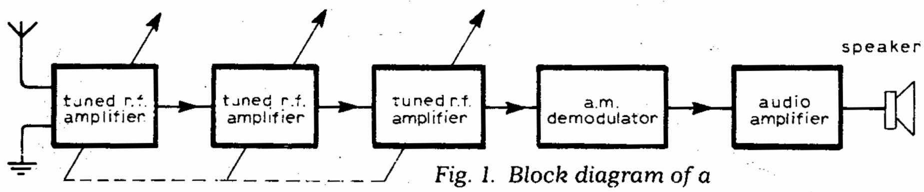


Fig. 1. Block diagram of a tuned-radio-frequency (t.r.f.) receiver.

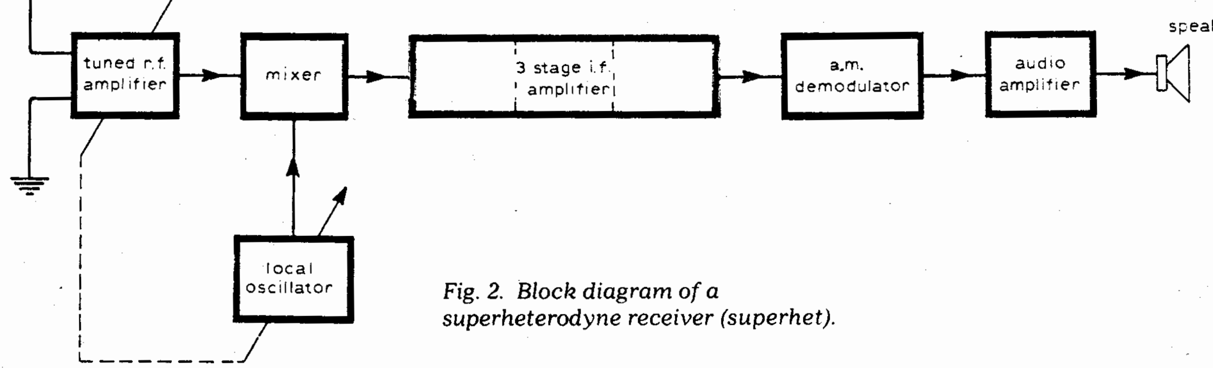


Fig. 2. Block diagram of a superheterodyne receiver (superhet).

Fig. 3. Frequency responses for an intermediate frequency (i.f.) amplifier showing the ideal case and the coincident and staggered responses expected in practical circuits.

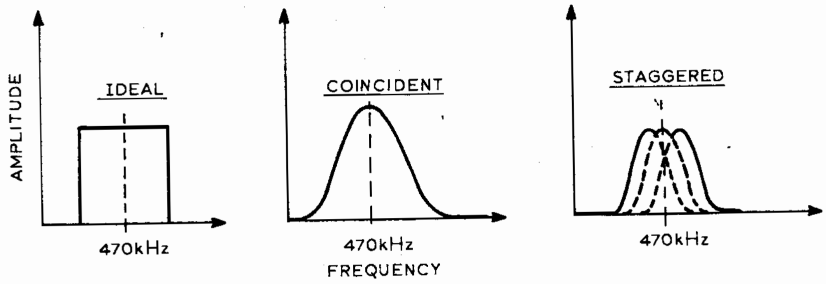
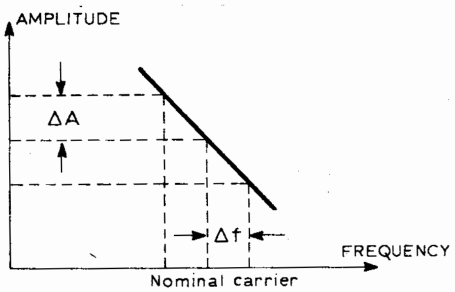


Fig. 4. Ideal response curve for an f.m. demodulator.



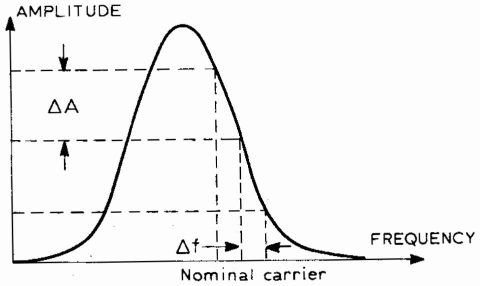


Fig. 5. The f.m. demodulator characteristic, shown in Fig. 4, can be approximated by operating on the flank of a tuned circuit's response curve, as shown. Demodulator is tuned so that the nominal frequency is halfway down the response curve

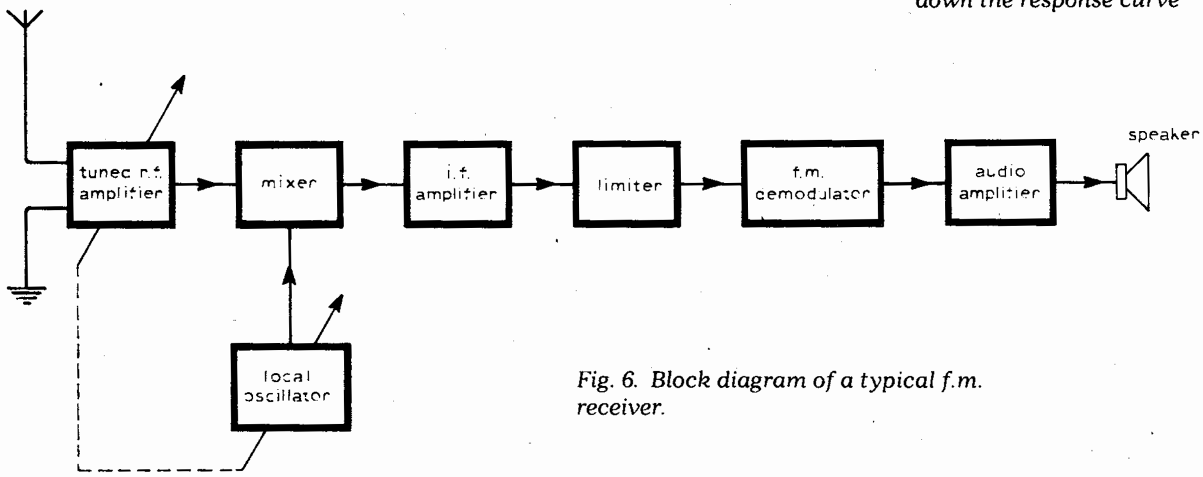


Fig. 6. Block diagram of a typical f.m. receiver.

circuits all of which had to track together over the radio spectrum. This combination of amplifiers had a combined frequency response curve which was very sharp and centred on the carrier frequency of the received signal. In the superhet the i.f. amplifiers are all tuned close to a fixed frequency which does not change when the radio is tuned to different transmitters.

The response of the i.f. amplifier is set at the time of manufacture and does not generally need to be re-adjusted. Most domestic receivers have three i.f. amplifiers. The resonant frequencies of the circuits are not all coincident, but are staggered either side of the intermediate frequency. This staggering produces a better response curve which more nearly matches the ideal curve. Fig. 3 shows the frequency response for an intermediate frequency amplifier along with coincident and staggered tuned responses.

Frequency modulated receiver

In Part 4, frequency modulation techniques were discussed briefly. Most domestic f.m. receivers use the superhet principle to achieve sensitivity and selectivity. One of the basic differences between a.m. and f.m. superhets is that the latter has circuits which are designed to have a much higher bandwidth. The higher bandwidths used in f.m. transmissions require the use of a higher intermediate frequency to achieve adequate image rejection in the r.f. amplifier. The i.f. is generally 10.7MHz.

Demodulation of an f.m. signal

The signal radiated by an f.m. transmitter has an instantaneous frequency deviation from a nominal carrier frequency, which is directly proportional to the instantaneous amplitude of the modulation signal. Conseqeuently to demodulate the received f.m. signal requires a circuit which produces a voltage proportional to instantaneous frequency deviation. Fig. 4 shows the response curve for an ideal f.m. demodulator. The nominal carrier frequency is marked on the curve.

This characteristic can be approximated by operating on the flank of a tuned circuit's response curve. This requires tuning the demodulator so that the nominal carrier frequency is halfway down the response curve. Fig. 5 shows this characteristic. It can be seen that for small frequency deviations the frequency versus amplitude response approximates to a straight line.

Unfortunately a circuit of this kind would still be sensitive to any amplitude variations in the input signal. This problem is overcome by incorporating a limiting or clipping amplifier prior to demodulation. This limiter will provide a constant amplitude signal to the demodulator for a wide variation in input amplitude, thus ensuring that amplitude variations caused by noise or atmospheric attenuations do not reach the demodulator. Fig. 6 shows a block diagram of a typical f.m. receiver.

Announcement. See news item on p42 regarding Schools Council's approval for the proposed 'A' level syllabus to run as a full Mode 1 syllabus.