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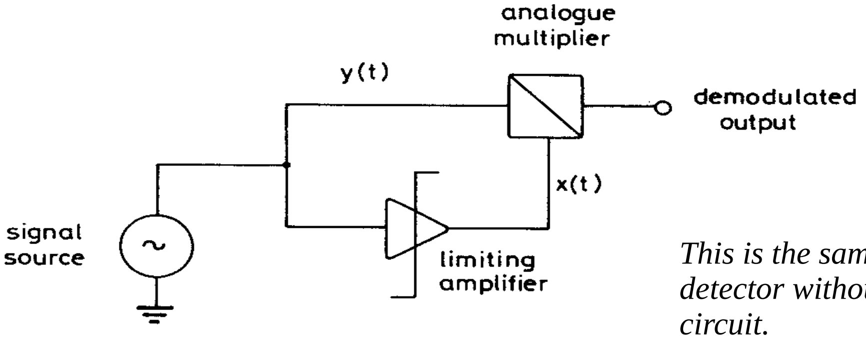
Early texts on the diode demodulator devote much space on the problems arising when the diode has a reactive load. This problem – referred to as the 'DC to AC load ratio' problem – arose because of the practice, 20 or 30 years ago, of connecting reactive elements of the lowpass filter direct to the diode load. Careful choice of circuit values was necessary to avoid distortion under conditions of full modulation at maximum modulating frequency. Today one would follow the diode demodulator with a buffer amplifier, securing a resistive load.

A more useful type of demodulator for AM, now in widespread use, is the so-called 'AM product demodulator'. The name is unsatisfactory, since all AM demodulators function by generating the $x(t)$ $y(t)$ product, however it is now well established. This type of demodulator relies on explicitly generating a waveform $x(t)$ which is then multiplied by $y(t)$ in a conventional and analogue multiplier (Fig. 6.2).



This is the same as an FM detector without the quad circuit.

Fig. 6.2 *Product AM demodulator*

Demodulators of this type are based on extraction of the carrier component of the AM spectrum, however early attempts to do so by bandpass filtering are unsatisfactory, because a relatively narrow filter is needed and small timing errors will produce phase shifts between $y(t)$ and $x(t)$, with consequent loss of democulated signal. However, it is possible, as an alternative, to exploit the fact that the instantaneous frequency of the AM wave is equal to the carrier frequency. Hard limiting of the AM signal generates a square wave of frequency ω_c, which is continuous provided that the modulation index m does not reach unity (100%).

The demodulator is therefore in two parts: a hard limiting amplifier and an analogue multiplier. The latter need only be two quadrant, and since one of its ports is driven by a square wave it is required to have a linear transfer characteristic only in respect of the other. A simple long-tail pair will suffice, with $x(t)$ switching the 'tail' and $y(t)$ presented between the bases of the upper pair. However, a twin pair with tails driven in antiphase and collectors of the pairs cross-connected provides substantial cancellation of the carrier component and eases post-demodulator filtering. All of this can, of course, be constructed on a single chip very easily, using an appropriate bipolar process. Commercial chips are readily available for this service.

The principle advantage of this type of demodulator is that the input signal can be very small, the lower limit only being set by the noise characteristics of the input devices in the limiter and demodulator. The limiter can be given a large enough gain to ensure satisfactory square wave output even for small inputs – typical designs limit well at 100 microvolts RMS input or less, giving satisfactory operation at unmodulated carrier levels of the order of 1 millivolt (assuming 90% modulation). Although much higher signal levels occur at the output of the limiter, comparable with those encountered in a diode demodulator, this voltage is kept on-chip, easing stability, and relieving the designer of problems resulting from high IF gain. The IF amplifier is now required to generate an output perhaps 60 dB smaller than for a diode, permitting the use of single superhet configurations where double conversion had hitherto proved unavoidable. For these reasons this type of demodulator is rapidly replacing the diode, except perhaps in but the simplest applications, or at high frequencies where suitable integrated circuits are not available.

It is not without its own disadvantages, however. The most important of these is that it will normally continue to demodulate in the absence of signal because the limiter amplifier usually limits fully on noise. The output of the demodulator is therefore very noisy when no signal is present, and the use of a mute (squelch) circuit is almost obligatory. Thus AM product demodulator chips very frequently incorporate this facility. A second, but minor, disadvantage is that because the $y(t)$ input to the demodulator is of the order of a millivolt, the DC output component (proportional to the carrier amplitude) is of the same order. Generally, however, a DC level of the order of a volt or two is needed to operate receiver AGC (as described in the next chapter). The obvious, and effective, solution is to use a simply DC amplifier following the demodulator, and again this may be an independent amplifier of the 741 type, may be incorporated on the demodulator chip, or may be a purpose designed AGC generator chip.

The response of an AM product demodulator to multiple carrier inputs is virtually identical with that of a diode: the various carriers are completely intermodulated in the limiting amplifier and an $x(t)$ is generated which contains components at all the carrier frequencies. Thus in this case also post-demodulator filtering cannot compensate for want of IF selectivity.

At higher frequencies it becomes increasingly difficult to design a satisfactory limiting amplifier. With currently available silicon processes (1985) about 20 MHz seems to be the practical limit, and hence also the highest IF for which a product demodulator can be designed. As the limit is approached, phase shift in the limiting amplifier becomes significant, causing the cos (ϕ) term in eqn. 6.10 to deviate significantly from unity. This can be countered by introducing a phase delay network between the input to the limiting amplifier and the input to the multiplier – a simple *LC* section being all that is necessary. Where phase shift in the limiter is significant it will invariably be amplitude dependent, however, the cos(ϕ) term then becomes amplitude dependent and nonlinear distortion of the baseband output results. Conservative design avoids significant limiter phase shift at the operating IF.

However, despite these limitations, the simplicity, low level operation and excellent linearity of the AM product demodulator have resulted in its widespread adoption by radio designers, and today it is more frequently seen in new designs than any other.

Another AM demodulator which shares most of the advantages of the product type and avoids one or two of the drawbacks is attracting increasing attention. This is the phase-locked loop demodulator (Fig. 6.3).

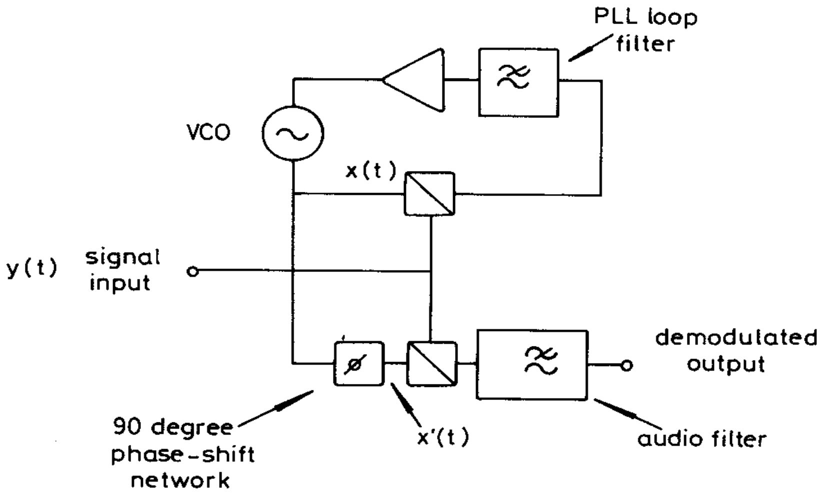


Fig. 6.3 *Phase-locked loop AM demodulator*