

Figure 4.7 Basic tracking servo system – lateral lens movement type

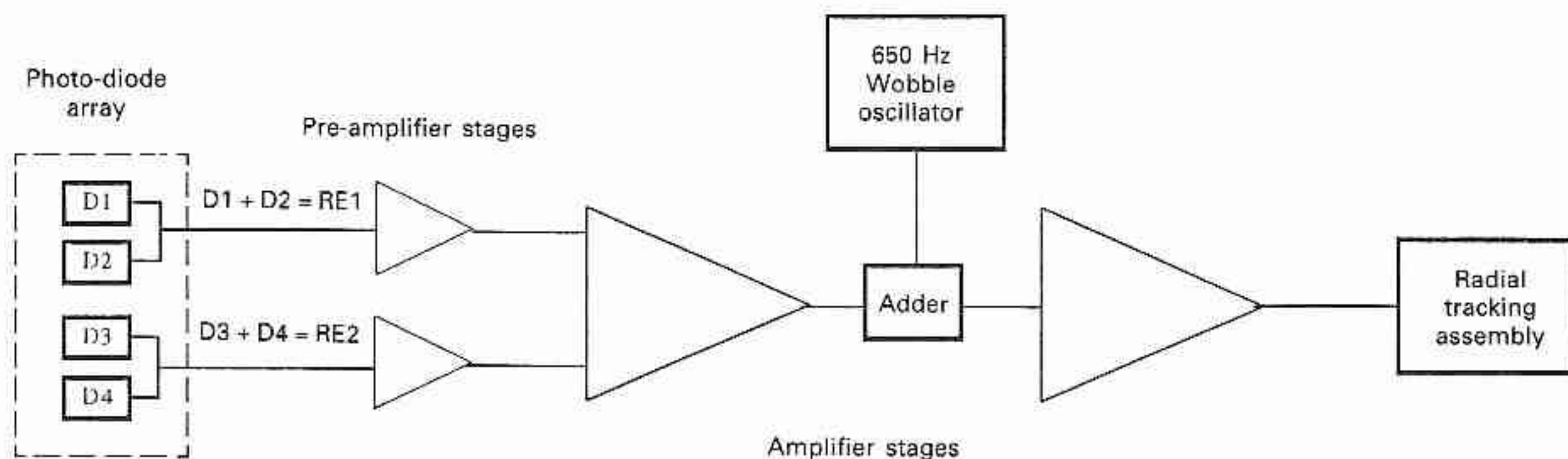


Figure 4.8 Basic radial tracking servo system – fixed lens system

of only a few millimetres, and therefore it is necessary to monitor the signal being applied to the tracking coil circuit. This signal will be in the form of an increasing potential, and will be in proportion to the lateral movement of the tracking coil and lens combination. As the signal reaches a certain level, a motor drive system will enable the optical block to gradually 'creep' across the surface of the disc. Therefore there is a continual compromise situation between the tracking coil and the motor drive system to effectively maintain efficient tracking across the surface of the disc.

The motor drive system has various identifications depending upon the manufacturer of the

CD player: carriage, sled, sledge and slider, and no doubt other options, are in existence.

Basic tracking servo: radial tracking system

The radial tracking type of tracking servo (Fig. 4.8) is usually associated with the Philips and Marantz players, as well as some Sharp and Technics players. Other manufacturers have also utilised this method.

The major difference with this concept is that the objective lens is fixed, and that the complete

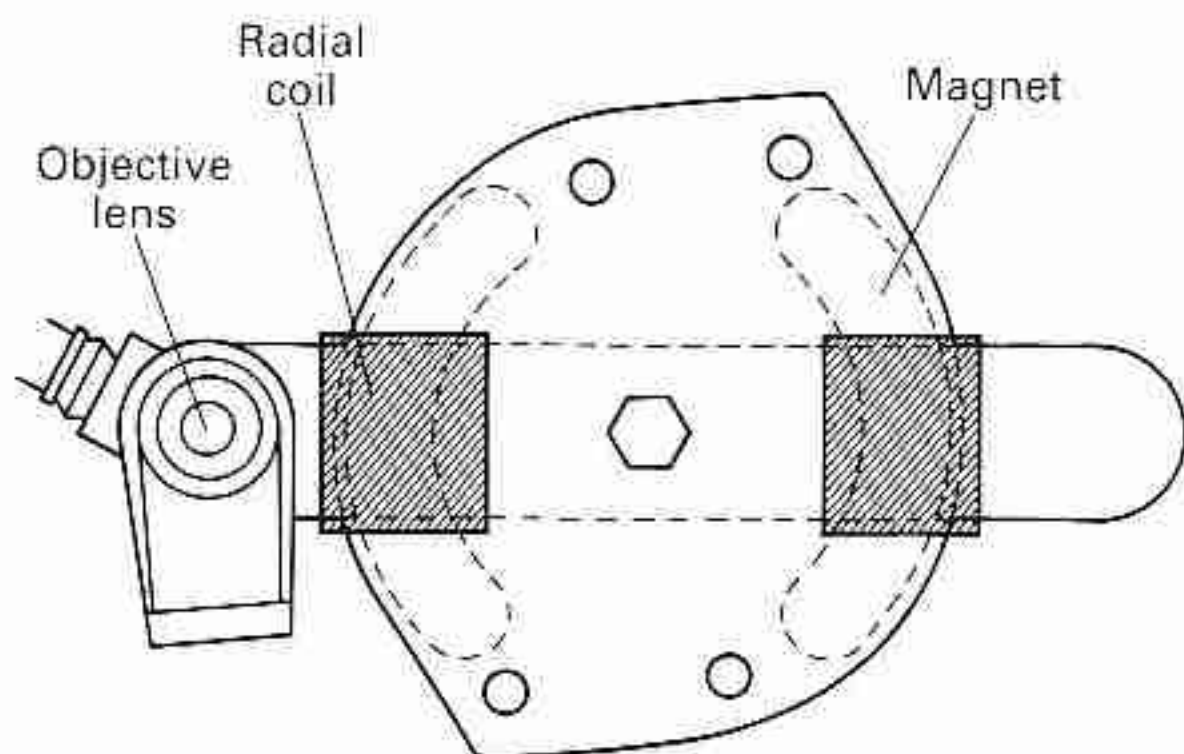


Figure 4.9 Diagram of radial tracking assembly

optical assembly moves laterally across the surface of the CD, in a manner similar to a moving coil meter (Fig. 4.9).

As this arrangement requires the complete optical assembly to move minutely in fractions of a micrometre, problems can occur with respect to tracking and friction. A term which some engineers may be familiar with relating to this type of friction in servo systems is static friction or 'stiction', which was quite common in early mechanical servo data transmission systems.

These early systems were used very much in the armed forces to relay such information as compass bearings from one central source to indicators situated in remote areas within a specific environment such as a ship or aircraft. To overcome the 'stiction' problem it was necessary to inject a high audible frequency source. This was referred to as a 'dither' frequency, and enabled the indicators to respond to small movements of information such as a gradual change in compass bearing as the ship or aircraft changed direction.

A similar method is introduced in the radial tracking system with the insertion of a 650 Hz wobble frequency, which causes the optical assembly to continually 'wobble' or oscillate either side of the track on the disc.

The radial optical assembly moves in an arc (as indicated in Fig. 4.10). When the optical unit is at the start or centre of the disc, the angle of the photo-diode array will be at right angles to the track, whilst towards the outer edge of the disc the angle will alter to approximately 45° – a situation which could cause problems with respect to discerning the tracking error signal.

The four-element photo-diode array is arranged

as two pairs of photo-diodes side by side, and the radial tracking error is developed from the signals $D1 + D2 = RE1$ and $D3 + D4 = RE2$.

The 'on-track' condition will enable $(D1 + D2)$ and $(D3 + D4)$ to receive equal amounts of the reflected laser beam from the disc, causing equal potentials of RE1 and RE2 to be produced, which will result in a zero radial tracking error signal.

As the disc rotates and tracking errors are developed, the resulting levels of the RE1 and RE2 potentials will vary according to the direction and amount of deviation of the reflected beam from the centre of the track, which will result in a radial tracking. The error signal will vary in level and polarity, depending upon the amount and direction of tracking error.

Because of the changing angle of the photo-diode array with respect to the track as the optical block travels across the surface of the disc, the tracking error signal will not vary in proportion to the actual radial movement of the optical block, and can cause possible asymmetry of the reflected signal.

If the optical block, and consequently the photo-diode array, were to traverse gradually across the surface of the disc, a tracking error signal would be produced that would vary depending upon the position of the photo-diode array in relation to the individual tracks. Optical blocks that move linearly at right angles to the track will develop a consistent quality of tracking error signal across the disc that is proportional to the amount of movement of the optical assembly (Fig. 4.11). But with the radial tracking method, the quality of the tracking error signal will deteriorate towards the outer edge of the disc as the angle of the photo-diode array alters with respect to the track. To minimise this undesirable effect, it is possible to make use of the effect of the 650 Hz wobble frequency that is applied into the radial tracking circuit. Fig. 4.12(a) illustrates the variation in level of the reflected light output or eye pattern waveform, which is related to the position of the photo-diode array compared to track position. When the array is effectively 'on track' the reflected signal will be at a minimum due to deflection of the laser beam onto the 'pits' or 'bumps' resulting in a reduction of actual reflected light, and consequently the resultant signal.

When the photo-diode array is between tracks, maximum reflection occurs, due to the mirror surface between tracks, and therefore results in a maximum signal level developing.

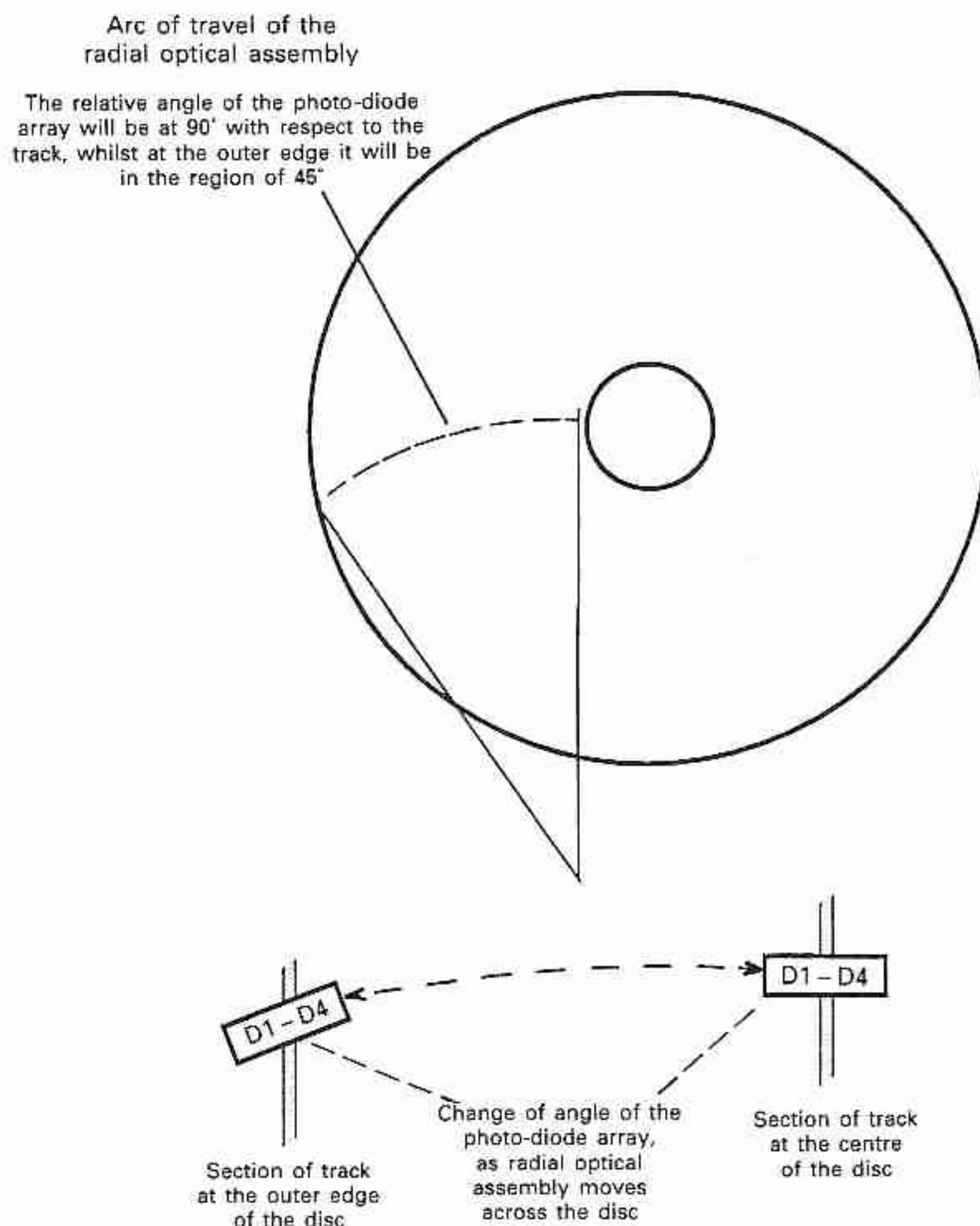


Figure 4.10 Radial optical assembly

On-track condition

By enabling the radial assembly to wobble or oscillate at a frequency of 650 Hz either side of the track, and assuming an 'on-track' situation, the basic minimum reflected signal which will increase in level as the radial assembly oscillates either side of the track centre to produce the waveform (a), which will modulate slightly the eye pattern waveform.

The waveform (a) is applied to the input of the synchronous detector circuit shown in Fig. 4.12(b), as signal X. The synchronous detector switch, which is operated by the $650 \text{ Hz} + 90^\circ$

wobble frequency, will alternately provide at the output as signal Z, either the direct signal X or the inverted signal Y.

Therefore during the on-track condition, the output signal Z will comprise alternate positive and negative half cycles which when applied to an integrating circuit will result in zero output.

Off-track to the right

Assuming an off-track condition, say to the right, will result in waveform (b) being applied to the synchronous detector input, which will result in

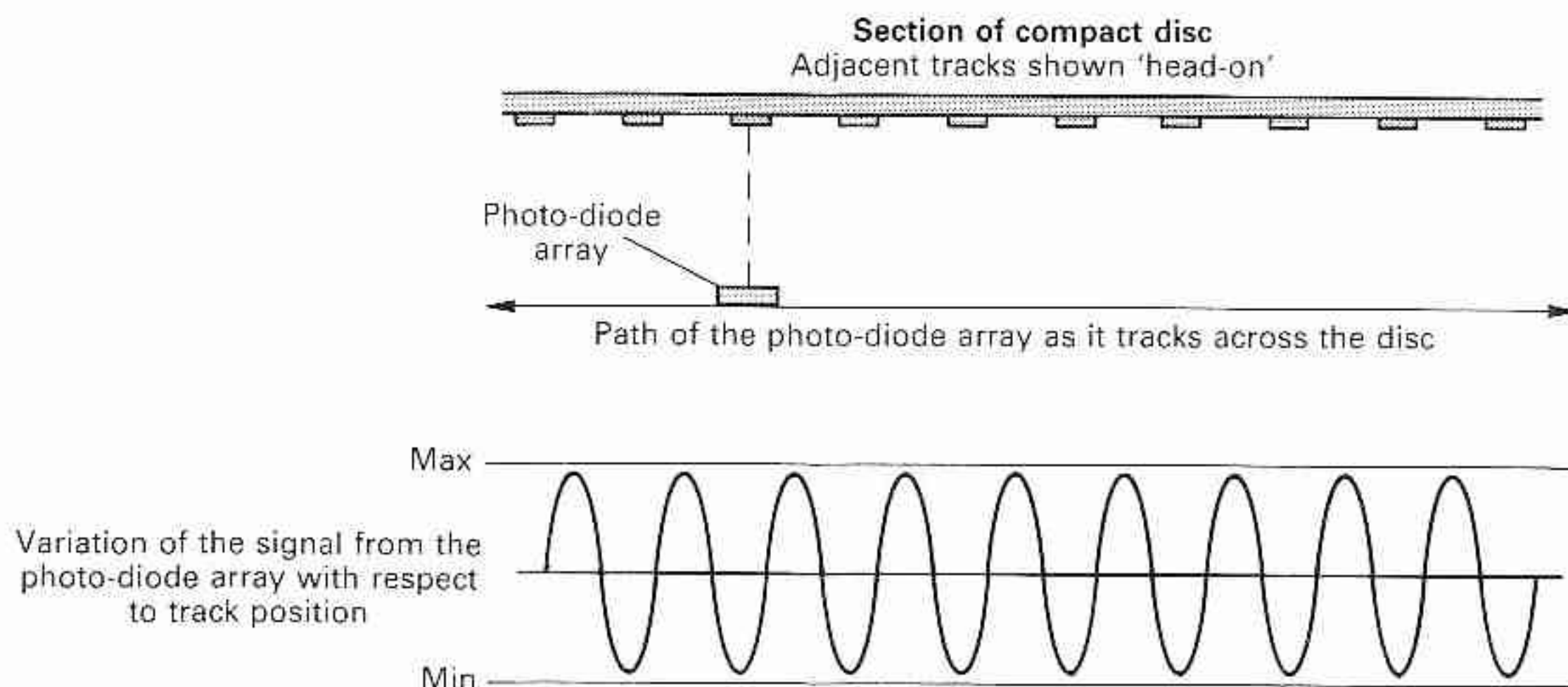


Figure 4.11 Photo-diode/track relationship

the output as waveform (d), and in turn provide a positive signal after integration.

Off-track to the left

For this situation, waveform (c) is now applied to the input of the synchronous detector, which in turn will result in waveform (e), i.e. a negative signal when integrated.

Therefore this method will enable a generally consistent quality of radial tracking error signal to be developed as the radial optical assembly gradually tracks towards the outer edge of the disc.

However, it is possible for other factors to affect the efficient operation of this tracking method, and these are related to the laser power, the reflective qualities of the disc itself, and possible phase differences of the wobble signal applied to the radial assembly when they are compared to the resulting wobble frequency that must be present on the radial tracking error signals at either the beginning or the end of the CD as the photo-diode angle alters.

These factors can influence the overall gain of the radial tracking servo system, and can result in inefficient and unstable operation. Therefore it is necessary to maintain a consistent gain throughout the overall operation of the radial tracking servo.

To achieve an effective gain control it is necessary to compare the phase of the wobble frequency applied to the radial assembly to that present on

the radial tracking error signal, and as the phase alters the gain is varied accordingly.

The 650 Hz wobble oscillator is fed via adder (5) into the radial servo system which will cause the radial motor to oscillate by the extremely small amount of $0.1 \mu\text{m}$, and will result in radial error signals which are developed via the four photo-diodes, D1–D4, to be 'modulated' with the 650 Hz wobble frequency (Fig. 4.13).

The signal outputs from the four photo-diodes, D1–D4, are connected after amplification and via the adders (1) and (2) to provide the two radial error signals $(D1 + D2) = \text{RE1}$ and $(D3 + D4) = \text{RE2}$.

The amplifiers for each of the diodes are gain controlled in relation to the sum of the radial error signal, and the level of the RF signal determined from the sum of the four diodes.

From Fig. 4.13 it can be determined that the sum of D1–D4 is passed to the RF amplifier stages, which includes a high frequency stage and an equalisation stage to provide the standard RF eye pattern waveform, for further processing in the decoder circuits, but it is also fed via the HF slice stage to maintain specific limits, to the gain control stage.

The sum of RE1 and RE2, which is derived via adder (3), is passed through a low pass filter (LPF) to remove the 650 Hz content, and fed to the gain control stage. The resulting sum from these two signals will provide a d.c. level to maintain the gain of the first amplifier stages within defined limits.

The complete radial servo signal path comprises

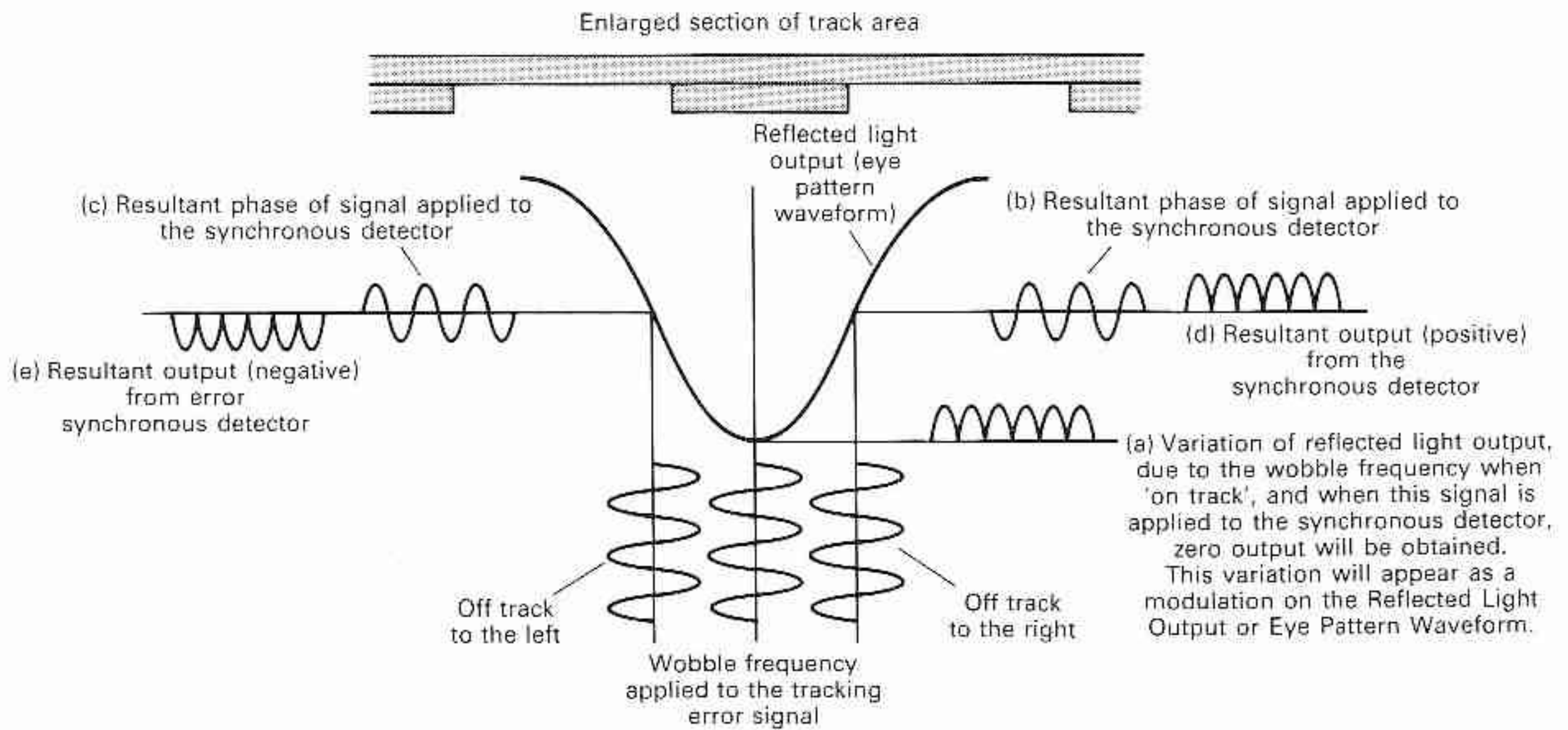


Figure 4.12(a) Relative phase of the 650 Hz wobble frequency, in relation to track position

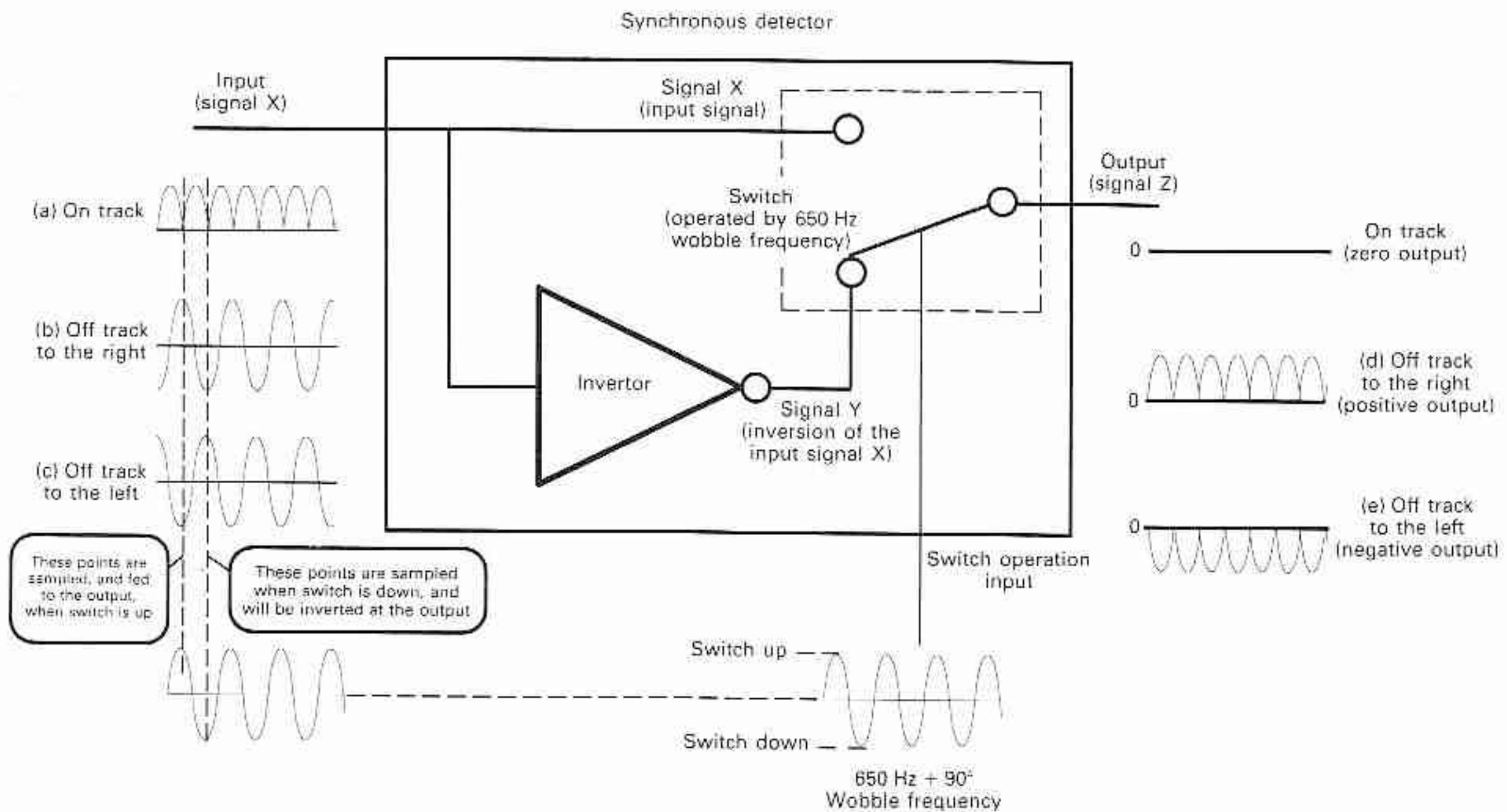
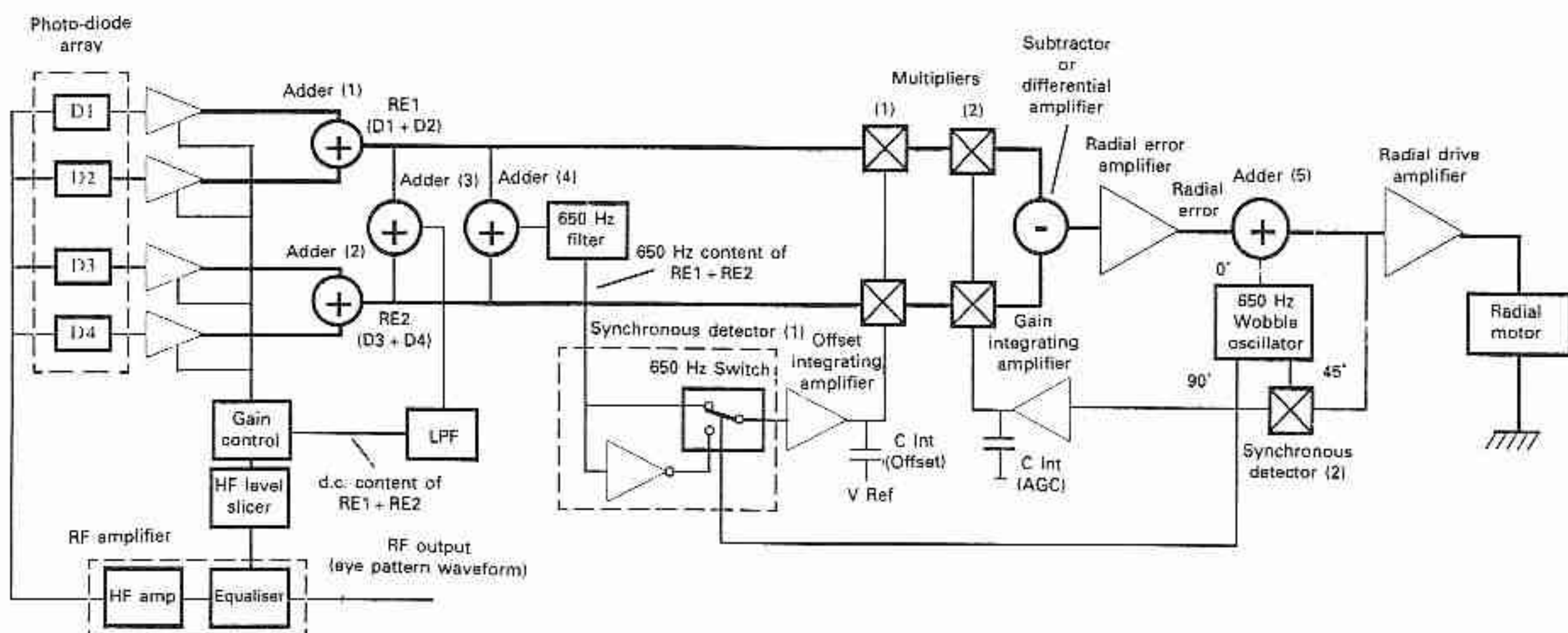


Figure 4.12(b) Operation of the synchronous detector

Figure 4.13 *Radial tracking servo*

the error signals RE1 and RE2 passing through multipliers (1) and (2), into a subtractor or differential amplifier to provide a radial tracking error signal which continues via the radial error amplifier and adder (5) to the radial motor drive circuit.

Fundamentally, the radial tracking error signal will be a d.c. level which will relate to the amount and direction of the tracking error. However, because of the various problems caused by the movement of the optical assembly (as described above), it is necessary to provide additional processing to maintain a consistent and efficient radial tracking operation.

Radial error signals RE1 and RE2 are combined via adder (4) and filtered via the 650 Hz filter to provide the wobble frequency content of the radial tracking error signals, which is now fed to the synchronous detector (1) to provide outputs in relation to the amount of radial tracking error (as illustrated in Fig. 4.12).

An output from the wobble oscillator is fed to the synchronous detector to operate the 650 Hz switch, which will enable the required error signal to be developed. The detector output is passed to the offset integrating amplifier to provide a level, which is related to radial tracking error, and when combined at multipliers (1), together with the RE1 and RE2 signals, will enable an effective error signal to be achieved.

It was previously mentioned that it was also necessary to maintain a consistent gain which is related to the phase of the original wobble fre-

quency, and the wobble frequency content of the radial tracking error signal being applied to the radial drive circuit. This is achieved at the synchronous detector (2) resulting in an output which after processing in the gain integration circuit provides a level which is passed to the multipliers (2).

The following tracking servo descriptions are now related to the method of moving the optical assembly laterally across the surface of the CD, where the photo-diode array is consistently maintained at right angles to the track. With the exception of the phase difference method (Fig. 4.15), these alternative tracking servo methods prove to be a simpler method of operation than the radial tracking system.

The four photo-diode arrays always relate to single-beam optical assemblies, whereas the five and six photo-diode arrays are used in the three-beam optical assemblies, which would generally appear to be more widely used types of optical assemblies.

With the push-pull tracking servo (Fig. 4.14) the photo-diodes are connected in pairs (A + C) and (B + D). When the laser beam is on track, there will be equal amounts of reflected light received by the two pairs of diodes, which when applied to the first tracking, or differential amplifier, will result in zero output.

As the track moves to one side as the disc rotates, the proportions of reflected light on the two pairs of diodes will differ, providing a tracking error (TE) output from the differential amplifier

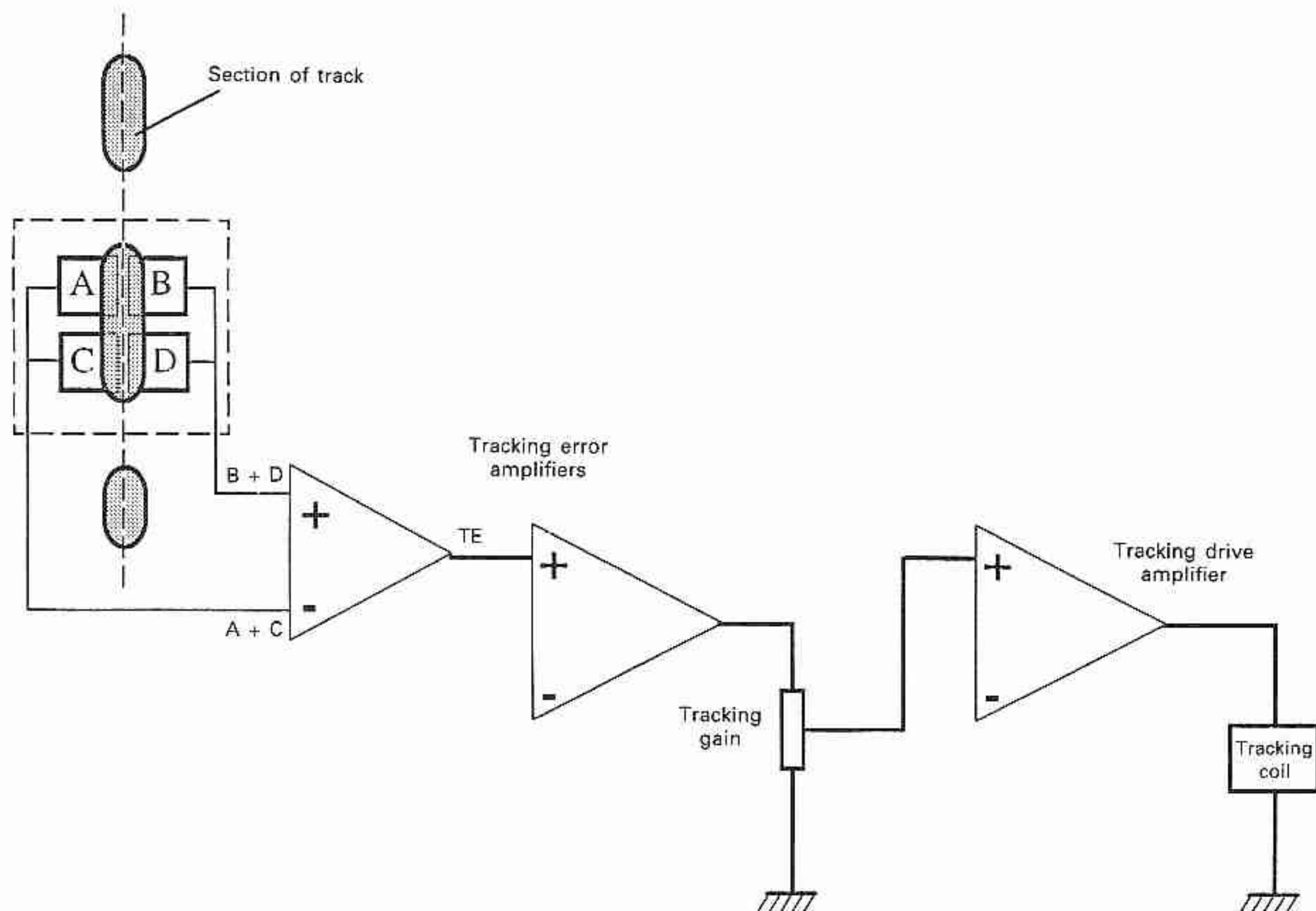


Figure 4.14 Push-pull method of tracking servo

that will relate to the amount and direction of tracking error, which in turn will enable the tracking coil to move in the correct direction to maintain its position on the track.

With the phase difference method of tracking servo (Fig. 4.15), again the photo-diodes are connected in pairs, but this time as $(A + D)$ and $(B + C)$. The outputs from the two pairs are fed to a differential amplifier and also a summing amplifier, with the differential amplifier producing at the output the difference between the two inputs, i.e. $(B + C) - (A + D)$, and the summing amplifier producing an output of $(A + D) + (B + C)$.

Referring to the graphical representation in Fig. 4.16, and considering the two waveforms drawn to represent the effect as a 'pit' passes through the photo-diode array, the output from the differential amplifier will indicate zero output for the 'on-track' condition, whilst a maximum amplitude signal will be produced from the summing amplifier.

For the 'off-track' conditions the differential amplifier will produce a varying amplitude signal, depending upon the 'pit' position, whilst the summing amplifier will produce a reduced amplitude signal. If a series of 'pits' were considered, then the resultant outputs would be similar, but the frequency intensity would increase in proportion to the periodicity of the 'pits'.

The output from the summing amplifier is passed to a signal processing stage to produce the RF eye pattern waveform, but an output is also passed to the zero cross detector, which will enable the sample and hold circuits to detect the the output from the differential amplifier as the RF signal passes through zero.

When the the laser beam is 'on track', with the output from the differential amplifier being zero, then the sample and hold circuits will detect zero levels, resulting in zero output from the tracking error amplifier.

During the 'off-track' situations, the phase of the differential amplifier outputs will be different

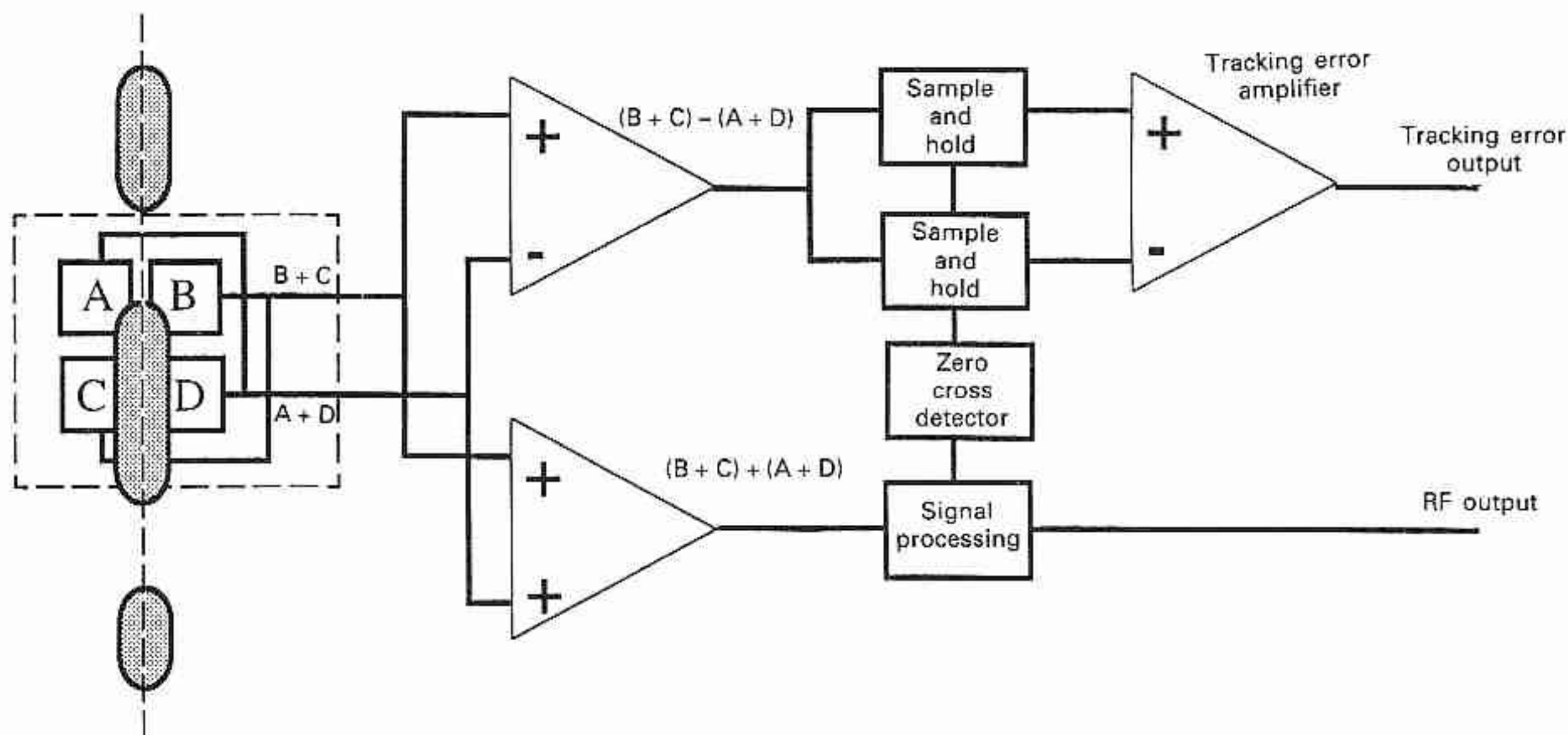


Figure 4.15 Phase difference method of tracking servo

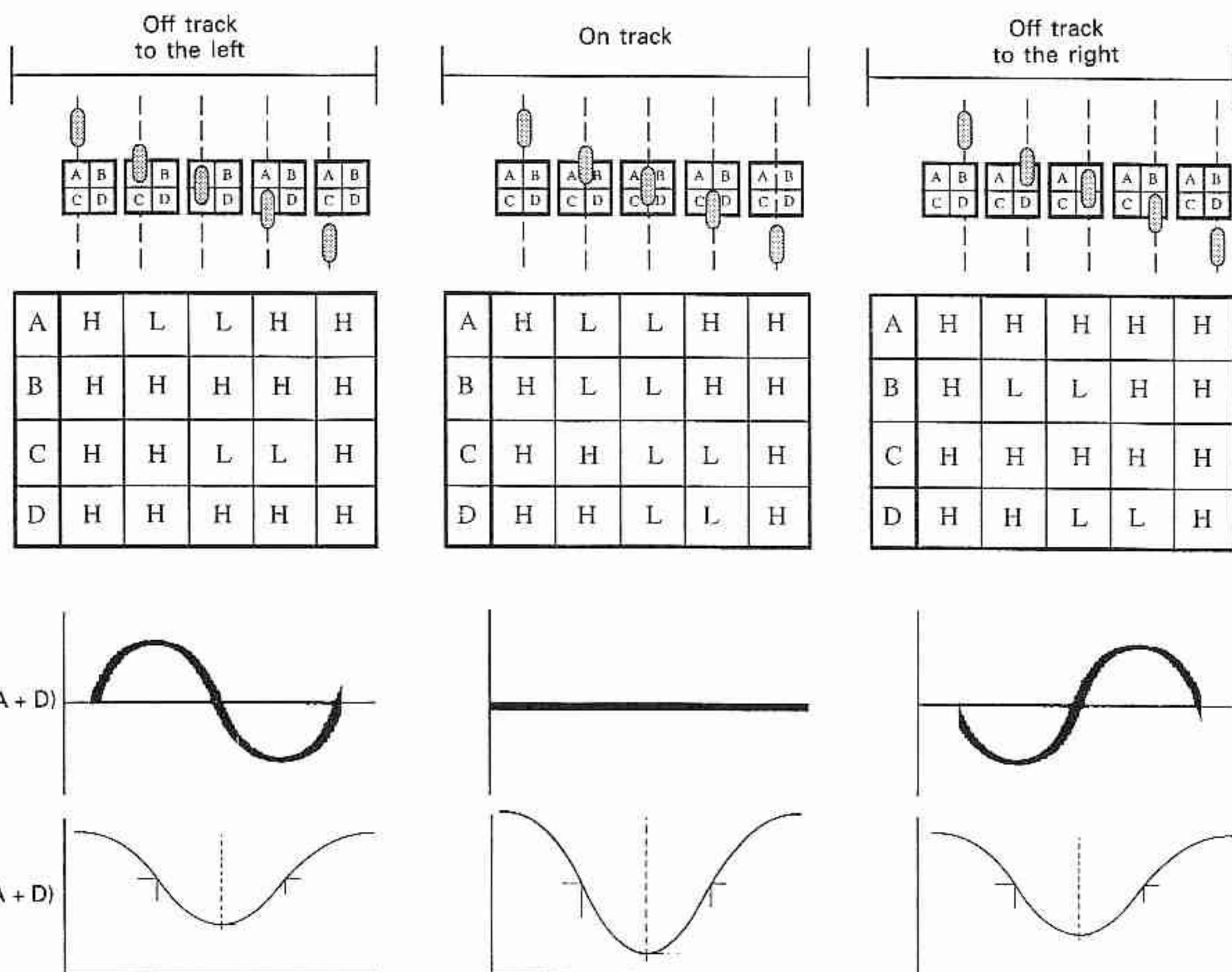


Figure 4.16 Graphical representation of the phase difference method of tracking error detection

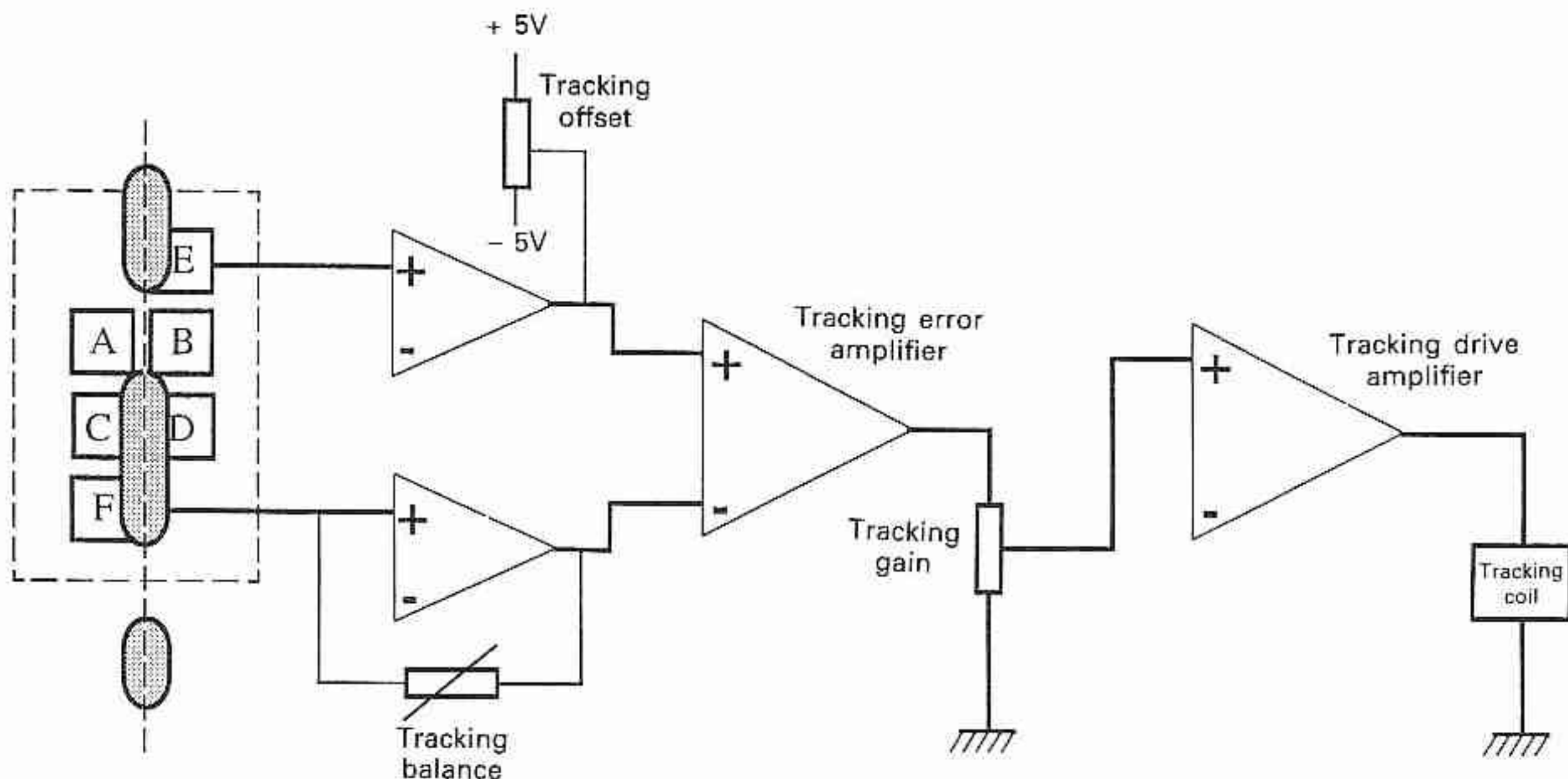


Figure 4.17 Three-beam device tracking servo

when 'off track' to the left is compared to 'off track' to the right. Therefore as the RF signal passes through zero, despite its reduced amplitude, it will be able to enable a positive or negative error signal to be developed in relation to the direction of tracking error.

This relatively complex method was used in earlier players, especially Pioneer in-car players, such as the CDX-1 and CDX-P1, and proved quite effective in maintaining track control in a somewhat hostile environment.

Three-beam device tracking servo

The three-beam device (Fig. 4.17) is probably one of the more common methods of tracking servo with the outputs from the (E) and (F) photo-diodes detecting any tracking errors as the track passes through the centre line of the photo-diode array. Each diode signal is amplified with the outputs being passed to the tracking differential amplifier to produce the tracking error output.

To ensure that the tracking error amplifier produces a signal that will be equal in value but opposite in phase when the same amount of error occurs either side of the track, it is necessary to ensure that the amplifier stages are balanced, this being achieved by the tracking balance control.

With the new Pioneer '92 optical block (Fig.

4.18) photo-diodes (D1) and (D5) fulfil the same function as the (E) and (F) diodes.

Carriage servo

Apart from the radial tracking assembly, all optical blocks allow the objective lens to move sideways

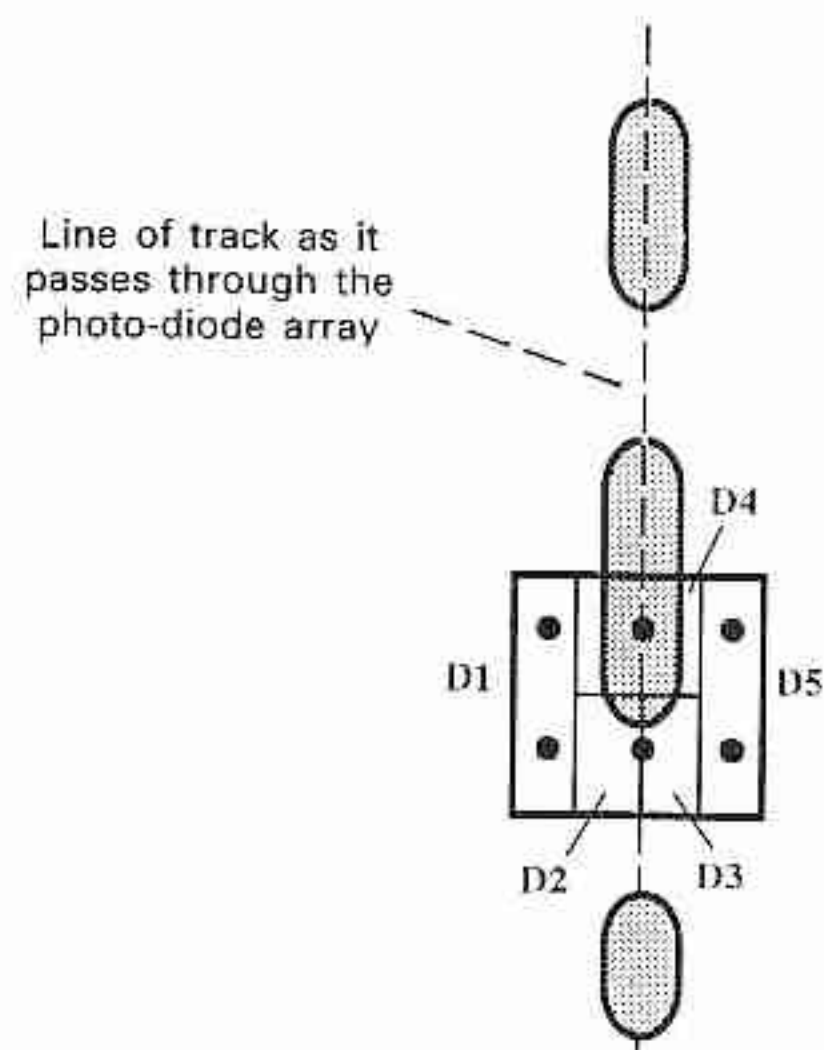


Figure 4.18 Five-element photo-diode array