

PART 1

◀ SECTION 3 — AI23D ▶

CHAPTER 3 — THE AERIALS AND SCANNER CONTROL

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Introduction

1. The scanner consists of two parabolic reflectors joined along a vertical edge, with the aerial assembly protruding from its centre. The scanner unit is mounted on a knuckle joint at the forward end of the roll axis assembly or roll shaft. It is controlled to move within the limits of $\pm 30^\circ$ in elevation and $\pm 50^\circ$ in azimuth relative to the roll shaft, and is roll stabilised under most operational conditions.

2. Scan direction is controlled either manually or automatically depending upon the operating phase of the system. Scanner drive is obtained from an azimuth and an elevation constant speed motor, and control is effected by error signals produce indirectly by the programme selector.

3. The I-Band aerials (Fig 1) consist of four horns projecting forward from the centre of the reflector, then turning back in pairs, so that the centre of each pair is directed to the focal point of the related reflector segment. Apertures in the horns direct transmitter pulses of energy on to the reflectors to produce a radiation pattern ahead of the aircraft.

During reception, the apertures in conjunction with waveguide couplers produce sum and difference signals from the echo returns. The sum and difference signals vary in amplitude and phase according to the direction from which echo returns are received; these signals are processed in the receiver to provide target position information. In elevation, because the apertures are above and below the foci, the reflected signals cross at approximately 5° . In azimuth, the lateral spacing between the apertures produces parallel beams. The I-Band aerial assembly is more commonly referred to as the four way feed.

4. Between each pair of apertures and the horn of the four way feed, an E/F-band aerial is mounted. Each aerial is directed to the focal point of its associated reflector and is used for receiving E/F-band jamming signals only.

The Four Way Feed and Waveguide Couplers

5. *Transmission.* During transmission, all four apertures are energised equally and in phase by each of the propagated pulses of transmitter energy.

6. *Reception.* The function of the four way feed and waveguide couplers is to produce sum and difference signals, which relate the direction and position of the echo source relative to the directional axis of the scanner. If the directional axis of the scanner is sighted directly at the echo source at the moment of reception, then the strength and phase of the signals at all four apertures is equal. If the echo source is displaced from the directional axis of the scanner at the moment of reception, then the signal strength and phase at each aperture varies. In elevation, angle sensing signal strength at the apertures is used, whilst in azimuth, angle sensing phase differences are used (phase differences in elevation angle sensing cannot be used because of interference introduced by ground returns picked up by the side lobes of the beam).

a. *Sum Signal.* This is a composite signal made up of the strength and phase of the signal at all four apertures. It is directed to the receiver as a phase reference in the discriminator and is also processed by the receiver to provide echo signals for display and ranging purposes and to further provide automatic gain control during the track phase.

b. *Difference Signals (Azimuth and Elevation).* These are resultant signals which, either by phase and signal strength in elevation or phase alone in azimuth, enable the receiver discriminator circuits to determine the direction and angle of misalignment of the echo source with respect to the scanner axis (Fig 2).

Scanner Drive

7. a. The control system drives the scanner into a required position in azimuth and elevation in response to demand signals. Scanner drive is effected by the azimuth and elevation constant speed servo motors, which drive the scanner left or right, up or down, in relation to the roll shaft. The drive from each motor is transmitted to the scanner by electro-magnetic clutches. When a demand for scanner movement is introduced the clutch(es) is energised and the scanner driven to the desired position. The axis of the roll shaft is the AI reference and it lies parallel to the missile longitudinal axis and 2° above the aircraft horizontal fuselage datum, to which the MRG is referenced.

b. The drive components are located at the forward end of the roll shaft (Fig 1). These components, together with the synchro resolvers, the programme switch unit, the roll shaft drive assembly and the support casting go to make up the roll axis casting assembly.

Scanner Stabilisation and Transmission of Demands

8. Azimuth and elevation integrating gyros are brought into use during the track phase to maintain the scanner stable in space, and to transmit demand signals to the drive system.

a. *Scanner Stabilisation.* Two single degree of freedom rate gyros are attached to the scanner with their axes in the azimuth and elevation planes. Any movement of the scanner relative to space is sensed by these gyros and pick-offs attached to the gimbals provide error signals which drive the scanner in a direction such as to zero these errors, thus maintaining the scanner position, irrespective of movement of the interceptor aircraft relative to the sightline.

WARNING: Power to the gyros is supplied via the AI main on/off switch on the hand control unit. If this switch is off, or if AC failure occurs in flight, the scanner is not stabilised and damage may occur during manoeuvres.

b. *Transmissions of Demands.* Errors between the scanner axis and the true sightline are converted into error signals that are applied to the scanner rate gyros. They precess the gyro axes in the appropriate direction. As in para 8 a. above, the gyro pick-off signals detect the error in relative position between the precessed gyro axis and the scanner, thus causing the scanner to be driven into alignment with the true sightline. The scanner servo system is designed such that no lag occurs between the true sightline and the scanner axis, when the former is rotating at constant angular velocity.

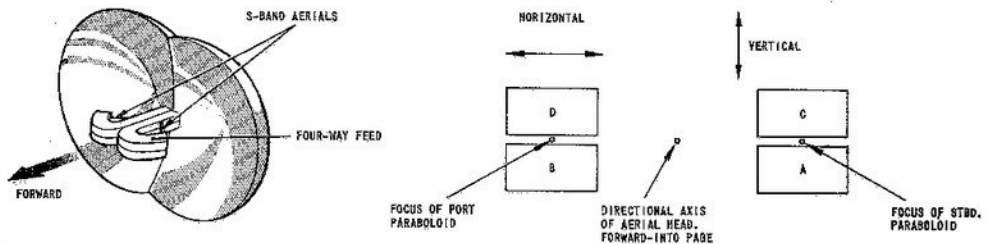
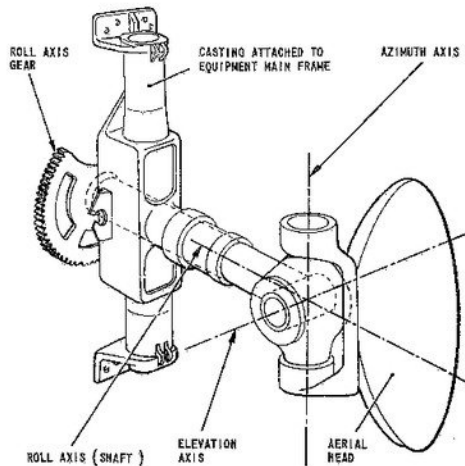
Scanner Pick-Offs and Velocity Generators

9. *Velocity Generators.* The rate of scanner movement in azimuth and/or elevation in response to demands is damped by means of associated velocity generators.

10. *Pick-Offs.* There are three pick-offs on the scanner assembly, each giving an output proportional to the angular displacement of the scanner from the radar axis. The azimuth narrow angle and the azimuth wide angle pick-offs measure deflection up to $\pm 30^\circ$ and $\pm 60^\circ$ respectively; the elevation angle pick-off measures deflections up to $\pm 30^\circ$. Azimuth angle information for the Red Top slaving circuits is provided by the more sensitive narrow angle pick-off.

◀ Switch Electronic ▶

11. The two switches in this unit are operated by the azimuth drive and are only effective during the search phase. One switch effects wide angle scan

**PROPERTIES OF FOUR-WAY FEED**

Transmission: Produces narrow beam. In elevation same effect as two tilted beams which cross at angle of 5°. In azimuth two closely spaced parallel beams.

Reception: Elevation
Return along directional axis, signal strength equal at all four apertures.
Return from above directional axis, signal strength increases at A and B decreases at C and D.
Return from below directional axis, signal strength increases at C and D decreases at A and B.

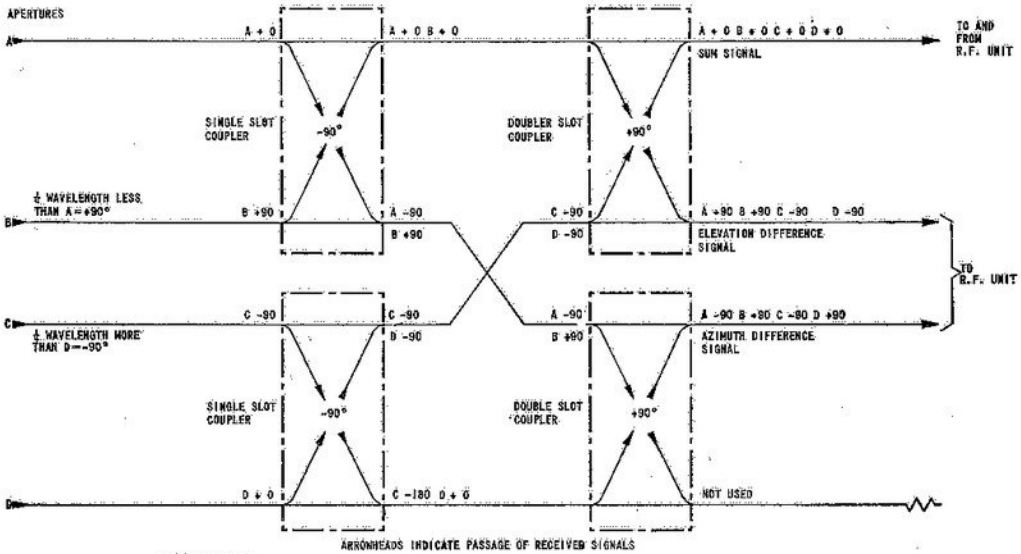
Difference between signal strength of each horizontal pair varies with, and in proportion to, the misalignment angle, and is also an indication of direction of misalignment.

Azimuth

Return along directional axis, phase at all four apertures is the same. Return from side, phase in one vertical pair advanced, and retarded by same amount in others.

Difference between phases at each vertical pair varies with, and in proportion to, the misalignment angle, and is also an indication of direction of misalignment.

1-3-3 Fig 1 Aerial Head and Angle Sensing



RECEPTION

Elevation

- Echo on directional axis:** Signal strength of $A + B$ equals $C + D$. $A + B$ is advanced 90° on sun, $C + D$ is retarded 90° . Paired components of difference signal therefore in anti-phase and of equal magnitude which cancels and does not produce a difference output.
- Above directional axis:** Signal strength at $A + B$ increased and $C + D$ decreased. Resultant is a signal with a strength proportional to angle of misalignment (up to 2°) and of a phase advanced 90° on the sun which, after conversion to i.f. in the r.f. unit, produces an output at the discriminator representing angle of misalignment above the directional axis (elevation radar error).
- Below directional axis:** Signal strength at $C + D$ increased and $A + B$ decreased. Resultant is a signal lagging sun by 90° , passed via r.f. unit to discriminator, and giving output equal to angle of misalignment below directional axis.

Azimuth

- Echo on directional axis:** Phase at $A + C$ same as at $B + D$. $A + C$ retarded 90° on sun, $B + D$ advanced 90° , i.e. anti-phase with each other and cancelled therefore output zero.
- Right of directional axis:** Phase of $A + C$ advanced and $B + D$ retarded by equal amount. Phase of sun signal unaltered. Difference signal output now has total lag between $A + C$ and sum of less than -90° and total advance between $B + D$ and sum of less than $+90^\circ$. Signal, via r.f. unit to discriminator, is shifted towards sun phase, amount of shift being proportional to misalignment angle, and discriminator produces output representing angle of misalignment to right of directional axis (azimuth radar error).
- Left of directional axis:** Phase of $B + D$ advanced and $A + C$ retarded by equal amount. Total advance of $B + D$ in difference signal greater than $+90^\circ$ and total lag of $A + C$ greater than -90° , i.e. shift away from sun. The amplitude and direction of shift gives output at discriminator equal to angle of misalignment to left of axis.

TRANSMISSION

Transmitter output is fed via r.f. unit to the sun signal line. Phase changes, similar to those during reception, are applied by the coupling system and all four apertures are energized equally and in phase.

1-3-3 Fig 2 Waveguide Coupling

in azimuth so that drive is applied for correct re-direction as the scanned approaches its end stops. The second switch operates alternately as the scanner is driven onto the starboard end stop, indirectly causing the programme selector to supply the appropriate step signals for 2 or 4 bar scan as selected.

Elevation Angle Bias in Search and Acquisition Phases

12. The total scanner elevation angle which can be demanded by the hand controller is 35° . It is desirable that the elevation angle coverage is biased to look upwards and for this attitude to be maintained relative to the MRG horizontal plane. It is arranged that the area of control of elevation is not $\pm 17.5^\circ$ about the MRG horizontal but is biased electronically by a $+7.5^\circ$ signal about the roll axis, which is $+2^\circ$ up on the MRG datum. The angle of coverage therefore is $+27^\circ$ to minus 8° relative to the MRG horizontal. Movement is nevertheless restricted to ± 30 about the roll shaft; for example, a maximum up demand of 27° with respect to the horizontal cannot be met if the aircraft is in a dive angle of greater than 3° .

Control During Search

13. *Azimuth Control.* The programme selector switch is isolated from the scanner azimuth control circuit during the search phase. Drive power is routed as the wide angle signal, via the wide angle switch in the programme switch unit, to the azimuth clutch to effect wide angle sweep.

14. Elevation Control.

a. A composite signal, representing the required elevation position, is made up from the pilot's demand from the hand controller, the pitch output from the MRG (which references the demand to the MRG horizontal), and the elevation step signals from the programme selector if either 2- or 4-bar scan is selected. The composite signal is compared with the scanner elevation angle signal (representing the actual position) in the programme selector, and the algebraic difference between the two signals becomes the elevation position error. The direction and amount of error is sensed from the polarity and amplitude of the position error signal and drive in the appropriate direction is applied to the scanner.

b. When a 2- or 4-bar scan is selected the step signals are superimposed on the pilot's demand. In 2-bar scan the signal causes the scanner to sweep alternately 1.8° below and above the mean demanded position. When 4-bar scan is selected the scanner sweeps 1.8° below and above the mean,

followed by a sweep 5.4° below and above the mean, and so on.

Control During Acquisition and Onset of Track

15. *Azimuth Control—Acquisition.* The azimuth position error becomes the difference between the wide angle signal and a composite signal made up from the pilot's demand and the narrow angle signal from the transmitter. This results in a scan of $\pm 5^\circ$ about the mean demanded position.

16. *Azimuth Control-Onset of Track.* When track is selected, the narrow angle signal is isolated and effective transfer to the track phase is held off for 0.5 seconds. This allows the scanner to settle at the demanded position dictated by the acquisition circle.

17. *Elevation Control.* Control in elevation is achieved as in search but the step signals are isolated and scan becomes single bar.

Control During Track

18. When tracking commences, the scanner is sighted at the target. Hand control (pilot's) demand is isolated and scanner control is transferred to respond to azimuth and elevation error signals from the receiver. The demands require scanner movement equivalent to the sightline rate of the target, thereby maintaining the scanner sighted at the target (angle lock-on). The sum and difference signals converted to radar error by the receiver are related to the particular target in the range gates, hence angle lock-on cannot generally be maintained until range lock has occurred. The exception is during jamming when, regardless of the range gate position, angle lock-on can be achieved.

19. The radar error signals are routed to the related gyro torque motor by either of the azimuth or elevation control channels. An output is produced by the gyro pick-off if the scanner rate is incorrect. The gyros are still effectively stabilising the scanner and, therefore, modify pick-off as necessary in order to counteract random movement. The pick-off outputs are returned to the programme selector where they become azimuth and elevation position error, increasing or decreasing scanner drive rate to that required. The maximum rate at which the scanner can be driven in track is $19^\circ/\text{second}$.

Control During Radar Ranging

20. With LFS selected on the LFS/CRT switch and the MAS away from the OFF position, the scanner is controlled to locate and then remain in the radar ranging position appropriate to the MAS selection. If any deflection from straight ahead

occurs, the azimuth wide angle pick-off and the elevation angle pick-off produce outputs; the difference between these outputs and the inserted demand becomes the position error signal which causes the scanner to be driven back to the demanded position. ◀ Inserted demand for radar ranging GW is dead ahead and for radar ranging guns is ahead in azimuth and 1.9° down in elevation. ▶

Roll Stabilisation

21. To prevent roll from adversely affecting the display and, in the track phase, to minimise the corrective action applied to the scanner gyros and drive mechanism, the azimuth scan must be kept horizontal. This is achieved by maintaining the elevation axis at 90° to the MRG horizontal. The horizontal reference is effected by two roll synchros, such that, if the elevation axis is displaced from its relationship to the horizontal, an error signal is routed to the associated roll motor which drives the roll shaft until the error is zero.

22. The limits of roll stabilisation are ±110° bank. If the limit is exceeded, stops carry the scanner

assembly around with the aircraft until the bank angle is again within 110° of the horizontal.

Roll Axis Lock

23. The roll axis is locked in a central position and roll stabilisation is isolated when the roll axis lock signal is generated under one of the following conditions:

- a. Issued by the computer red from Launch Warning to breakaway in an automatic Red Top attack (ie the MAS at GW, the COMPUTER mode switch at any of positions 2, 3, 4, 5 or 6, and the radar locked on in range).
- b. Issued during radar ranging (ie LFS selected on the LFS/CRT switch).

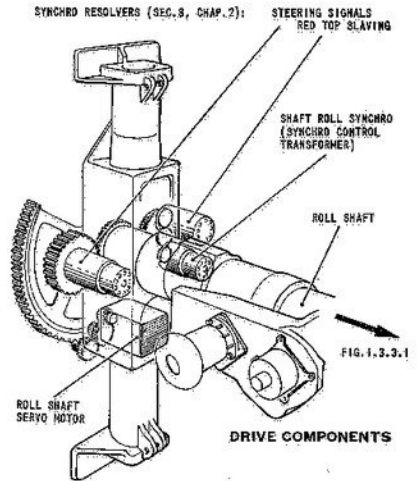
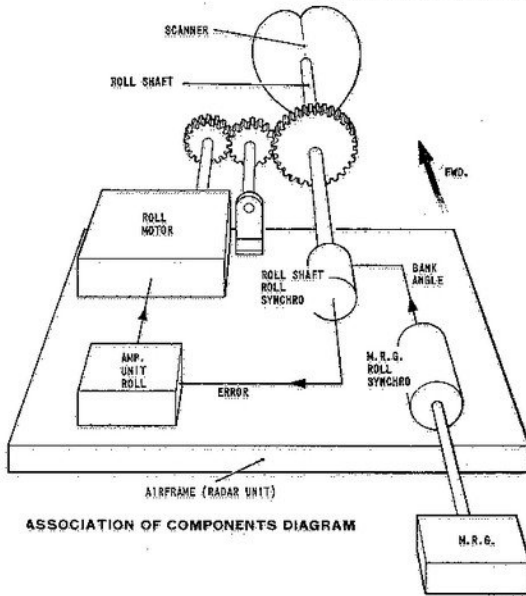
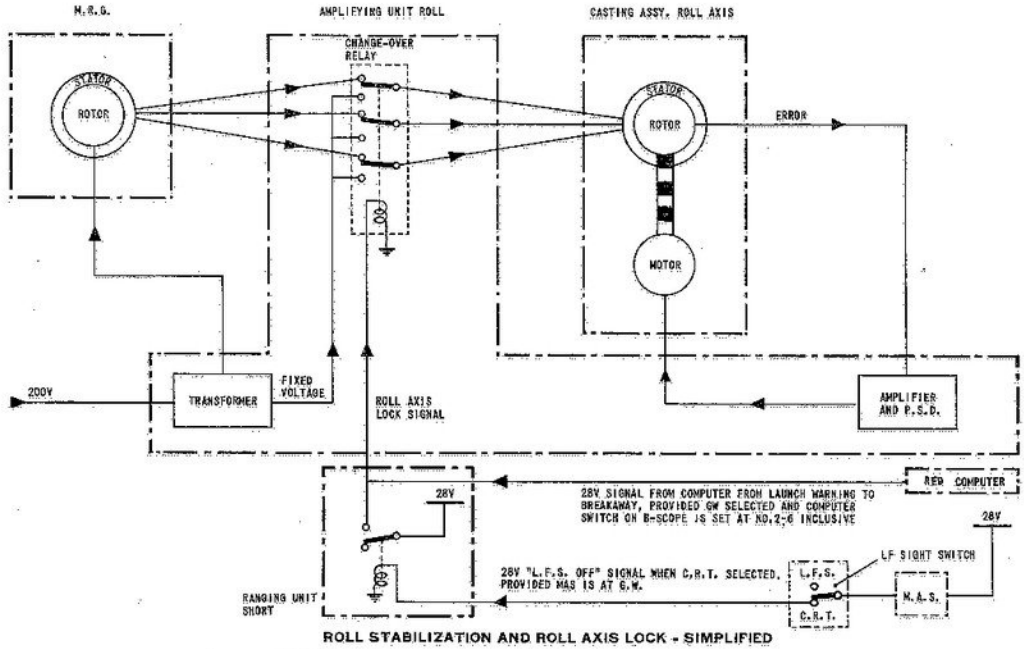
Note: Roll axis lock is prevented from occurring during the search, acquisition, and kinematic ranging modes.

Summary of Scanner Control

24. Scanner control for the various modes and phases is shown in Table 1.

Table 1 — Scanner Control Modes and Phases

<i>Mode</i>	<i>Phase or Weapon</i>	<i>Azimuth</i>	<i>Elevation</i>
Radar	Search	Wide angle scan between end stops at ±50° to aircraft fore and aft axis. Sweep rate 160° / sec approx.	Mean angle controlled by pilot ◀ between +27° and minus 8° ▶ relative to MRG horizontal and within the limits of ±30° relative to the axis of the roll shaft. 2 or 4 bar scan as selected, spacing between bars 3.6°.
	Acquisition	Narrow angle scan of ±5° about mean bearing selected by pilot. Approx 5 paints per second.	Angle controlled by pilot between limits as for search. Single bar scan only.
	Track	Tracks target in response to azimuth radar error from receiver. Space stabilised by scanner azimuth gyro.	Tracks target in response to elevation radar error from receiver. Space stabilised by elevation gyro.
Radar Ranging	GW	Held straight ahead relative to axis of roll shaft.	Held straight ahead relative to axis of roll shaft.
	GUNS	Held straight ahead relative to axis of roll shaft.	Depressed 1.9° from straight ahead position relative to axis of roll shaft.
	RB		Not used



1-3-3 Fig 3 Roll Stabilisation and Roll Axis Lock

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