PART 1

◀ SECTION 3 — AI23D ▶

CHAPTER 4 — THE RANGING SYSTEMS

(Completely revised at AL5)

Contents

Introduction

1. Range information for the pilot and the computer red is provided by the ranging system, which consists of a ranging unit long and a ranging unit short.

2. The ranging unit long fulfils the following requirements:

a. Ensures the availability of range information by locking on to the target in range and following it during the track phase.

b. By means of kinematic ranging (a probable range computed by the computer red) provides immediate lock-on to the target during noise jamming, should the target echo break through the noise level.

c. If kinematic ranging is inaccurate the computer red provides a waiting range of 35,000 feet to the unit.

d. During the track phase, provides the computer red 29·5 seconds +9000 feet-to-go circuit (subsequently referred to as the 'time-to-go' circuit) with relevant range rate information.

3. The ranging unit short provides the computer red with all range requirements, other than in para 2d above.

4. The ranging system operates in conjunction with the LFS during radar ranging and lights the 'in range' marker on the LFS when an echo is in the range brackets.

5. Basically the range lock circuit in the ranging unit long forms a closed loop (Fig 1). The positions of consecutive early and late gates produced by a gate generator are compared with the echo from a selected target. If the gates are not positioned centrally about the echo, error signals are produced. The error signal voltage is used by a velocity and range stage to adjust the timing of the early and late gates to centralise them about the echo.

Ranging Unit Long

6. The unit contains the following functional components:

a. *Gate Generator.* When the range timebase voltage from the display selector and the range marker voltage from the range stage are equal, ie at a time corresponding to the selected target range, four pulses are generated. Two of the pulses, the IF and the box-car gates, are generated simultaneously; these gates activate the receiver discriminator circuit to ensure that the receiver responds only to the echo selected by the acquisition circle during acquisition, or to the echo on to which the unit is locked during track. The IF gate also provides the ranging unit short with synthetic range information, by simulating a target echo. The remaining two pulses serve as early and late range gates used for the purpose of range lock. The range gates are generated consecutively, each having a duration of 0·75 microseconds. The overall duration of the range gates is, therefore, 1·5 microseconds which corresponds to a range bracket of 750 feet, (375 feet of radar range per gate).

b. *Discriminator*. The discriminator senses the timing of the range gates in relationship to the timing of the ungated range echo from the receiver. If the echo is not in the centre of the gates (not equally overlapped by the early and late gate) the discriminating circuits become unbalanced and provide an error signal. The polarity of the error signal is determined by the position of the echo in either the early or late gate. In the track phase, error voltages are applied via the stretching circuit and velocity stage to the range stage to control the timing of the range gates.

c. *Stretching Circuit*. This circuit converts the pulsed error signals into a DC voltage of appropriate polarity.

d. *Range Velocity Stages*. These components provide range and range rate information by generating a range marker voltage, a long range voltage and a long range rate voltage. The effects of these outputs are discussed in subsequent paragraphs.

e. *Acquisition Circle*. Long range voltage controls the position of the acquisition circle in range on the B-scope.

f. *Sweep Generator*. This generator applies a fluctuating voltage to the range stage and marker unit on entering the track phase or in the event of range lock being lost. The effect is to sweep the range gates ± 2500 feet about their instantaneous position; this causes the acquisition circle to sweep, if angle-lock is not present. When the track phase is established the sweep should compensate for inaccuracies of acquisition, eg when the total 1·5 microsecond duration of the range gates may not enclose the 1·0 microsecond duration of the echo. The sweep generator becomes ineffective when range lock occurs.

g. *Natural Frequency Switching Circuit*. This circuit provides the velocity stage with a longer memory, in order to counteract the effects of temporary echo fading. It is effective 4 seconds after range lock occurs.

h. *Noise Balancing Circuit*. The function of this circuit is to prevent lock-on to the wrong signal. A sample of receiver noise is compared with the echo in the range gates. If, after ten such comparisons, the amplitude of the echo is above the noise level, the 'signal in gate' signal is generated and range lock occurs.

Ranging Unit Short

7. The output of this unit is effective within the range limits 80,000 feet down to about 1000 feet. By means of a servo system the unit controls the range shaft of the computer red, which provides all the range and range rate requirements of the computer red, other than that for the 'time-to-go' circuit. At target ranges in excess of 80,000 feet the unit's outputs are fixed at their maximum values. The unit also provides relay switching functions when radar ranging is selected; the relays do not contribute to the operational aspects of the ranging functions. The unit contains the following components:

a. *Timebase Generator*. The generator synchronises the timebase with the transmissions and synchronises the timing of the range gates.

b. *Gate Generator*. This produces the range gates and controls their duration.

c. *Phase Splitter*. This component splits the range gate output from the gate generator into a positive and negative value, which are the range gates.

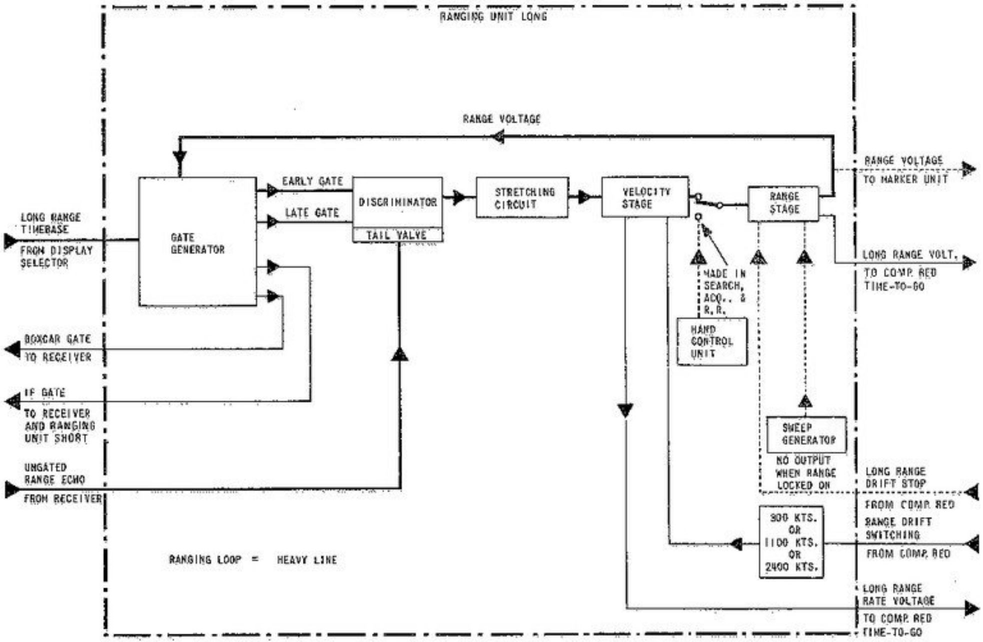
d. *Discriminator*. The discriminator provides error pulses which are the difference between the range in use and the actual range of the target. The error signals occur when the range gates and the range of the target echo (IF gate) are not coincident.

e. *Stretching Circuit*. The circuit converts the error signals into DC voltages used to null the error and align the range gates with the target's actual range (IF gate).

f. *Radar Ranging Switching Relays*. When the LFS/CRT switch is set to LFS, relays operate which issue the roll axis lock signal to the scanner and provide an earth path for programme selector switching. Associated relays controlled by the MAS complete the switching of the programme selector and both ranging units into the radar ranging mode.

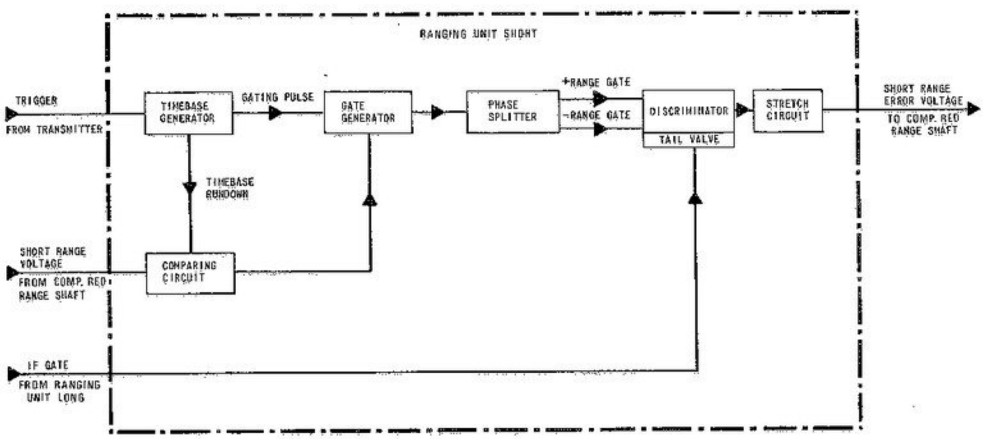
Normal Ranging

8. *Search and Acquisition*. In these modes the velocity stage is isolated from the range stage and the hand control unit is connected to control the



1—3—4 Fig 1 Ranging Loop — Simplified

W.S.M.14
3-4-1



1—3—4 Fig 2 Short Range Voltage Control — Simplified

W.S.M.15
3-4-2

output of the range stage. The range marker voltage is directed to the range marker unit, where it positions the acquisition marker in range; the range marker voltage also positions the range gates at target range. The remaining outputs of the ranging unit long are ineffective at this stage.

9. *Track.*

a. Immediately the track phase is selected, the hand control unit no longer controls range voltages or the acquisition circle. Prior to receiving the 'signal in gate', the velocity stage moves the range gates in at a closing speed of 2400 knots whilst the sweep generator sweeps them ± 2500 feet about their instantaneous position as they close.

b. When the 'signal in gate' is received, range lock occurs. The stretching circuit now automatically controls the position of the early and late gates to centralise them about the echo.

c. The rate of opening or closing of the gates in range is a measure of target opening or closing speed. Closing speed as well as range information is necessary for the calculation of 'time-to-go' information, $\frac{R}{\dot{R}}$. The velocity stage produces a voltage (the long range rate voltage) which represents target closing speed and this and the range voltage are passed to the computer red but are inhibited for 4 seconds after range-lock occurs. The delay of 4 seconds is necessary to allow the velocity stage to settle, otherwise false information could be generated. The long range rate voltage is also used by the computer red to position the time circle range-rate gap when the B-scope COMPUTER switch is set to position 1, 2 or 3.

d. At the conclusion of the 4 second delay period, normal ranging takes place, the ranging unit long supplying the computer red with information, the *time-to-go circuit* and the ranging unit short supplying it with other range information. If temporary fading of an echo occurs which causes loss of range lock, a 5 second memory circuit comes into operation. This ensures that the range gates continue to move at the last known range rate, at the moment of loss of range-lock. A ± 2500 feet sweep is superimposed immediately range lock is lost. If the echo is restored within 5 seconds the equipment returns to normal ranging, otherwise the gates sweep in to zero range, unless kinematic ranging is available (see paras 11 and 12 in this Chapter).

10. *Reject In and Reject Out.* When the reject lever is used, relays break the range-lock and the range stage drives the range gates inwards or outwards as appropriate. Drift inwards is at approximately 10,000 knots and drift outwards approximately 7600 knots; sweep is not applied. When the range gates encounter a signal, range lock occurs automatically. If no signal is present, the range gates commence to sweep inwards, as described at para 9 a, when the reject lever is released.

Kinematic Ranging

11. Kinematic ranging is continuously computed by the computer red during the track phase, but is only applied to the range stage when the angle-locked-on signal is present and the range-locked-on signal is absent. Under these conditions when kinematic range is inaccurate the gates will drift in at 2400 knots towards the waiting range, but if kinematic ranging is accurate the marker will immediately indicate the computed range.

12. A waiting range voltage, representing 35,000 feet, is supplied from the computer red in place of kinematic range and the 'time-to-go' circuit is isolated to prevent the premature issue of firing brackets whenever:

a. The sightline rate tends to zero or scanner elevation angle reduces to less than $\pm 2°$; if either occurs, it is assumed that kinematic range is inaccurate. As a further precaution against the premature issue of the firing brackets the Launch Warning, Fire and Breakaway signals are inhibited until kinematic range becomes accurate.

b. With GW selected on the MAS, range-lock is lost after Launch Warning has been given. Waiting range is applied even if accurate kinematic range is available, and the system operates on memory of the last known range rate: this is done to prevent inhibition of the attack should kinematic range inaccuracies develop at this late stage.

c. With GW selected on the MAS and launch warning computed on kinematic range correct values, the ranging circuits will not switch to memory.

Loss of Range-Lock

13. The response of the ranging system to loss of range-lock depends upon whether the angle-locked-on signal from the receiver is present or not. The angle-locked-on signal becomes available when the scanner is locked on and gain control voltage falls to a low level due to very strong signals being received,

Table 1 — Range-Lock Signal Conditions

	Loss within 4 seconds of lock-on
Angle-locked-on signal absent	Signal-in-gate and range-locked-on signals cease and the ranging unit long reverts to the pre-lock on state, ie the stretching circuit is disconnected from the discriminator, 2400 knot voltage is applied to the velocity stage and the range gates drift in at this rate towards zero range. Sweep voltage is applied to the gates, the tracking strobe and the acquisition circle.
Angle-locked-on signal present	As above, except that the gates drift inwards at a rate of 2400 knots when kinematic ranging is inaccurate and the long range drift stop is applied to the range stage to stop the gates at waiting (35,000 feet) range. When kinematic range is accurate the gates immediately jump to indicate the computed range continuously and thus obtain the computed rate of 2400 knots when KR is inaccurate and the long range drift stop is applied to the range stage to stop the gates at waiting (35,000 feet) range. When kinematic range is accurate the gates immediately jump to indicate the computed range continuously and thus obtain the computed rate.
	Loss at any time subsequent to first 4 seconds of lock-on
Angle-locked-on signal absent	The sweep generator is immediately connected to the range stage and the 5 second memory initiated. After 5 seconds the acquisition circle drifts in at a rate of 2400 knots.
Angle-locked-on signal present	As above except that the long range drift stop circuit is part completed to provide computed range or waiting range to be displayed.
	Loss continues after 5 second rundown
Angle-locked-on signal absent	Reverts to the pre-lock on condition.
Angle-locked-on signal present	If accurate, kinematic range is applied to the range stage, if inaccurate waiting range is applied in lieu.

Note 1: When the angle-locked-on signal is present and range is not locked on the kinematic range marker is displayed.

Note 2: If the acquisition circle is brought quickly from beyond 80,000 feet, the range shaft in the computer red will require time to reach its correct position and may readily overshoot and oscillate before settling down. In extremes (lock regained at very close range) the range shaft may take several seconds to settle and during the course of its oscillations may initiate as many as three firing bracket sequences.

a condition which occurs when high powered jamming is taking place. This condition is kinematic range available and is indicated by the acquisition circle changing to a short horizontal line. The ranging system behaves as indicated in Table 1, depending upon when the signal is lost.

Radar Ranging

14. With LFS selected at the LFS/CRT switch, relays are operated which feed the roll axis lock signal to the scanner, prepare the 'in range' circuit between the ranging units and the LFS for 'in range' signals and supply the programme selector with relevant switching signals.

15. *Radar Ranging with Missiles.* A GW selection on the MAS causes relays in the ranging unit long to isolate the velocity stage from the range stage and connect an internal voltage representing 7500 feet when the fighter is above 15,000 feet and an internal voltage representing 4500 feet when the fighter is below 14,000 feet to the range stage. The sweep generator adds a ± 2500 feet sweep at higher altitudes and a ± 1500 feet sweep at lower altitudes to the preset range voltage. The 'signal in gate' circuit produces a pulse output when a target echo enters the area of sweep, which activates the 'in range' warning on the LFS.

16. *Radar Ranging with Guns.* A GUNS selection on the MAS causes a preset range gate to be generated between 1350 feet and approximately 500 feet in range. The 'in range' warning on the LFS is activated whenever a target echo enters the gate.


CPL V WOOTON
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