The Type 901 guidance radar.

The Type 901 radar project started during the second world war as part of the projected 'Long Range System 1' (LRS1) gunnery control system. LRS1 was never completed but the radar was utilised for the Seaslug missile project. Operating between 9·0GHz and 9·8GHz, it first tracked an aircraft as early as November 1946. At that stage the system looked very different to the tapered drum of the operational system; instead it consisted of two offset feed dishes on a wartime 2pdr pom-pom mounting. One dish was for the tracking beam and the other dish was for the gathering/guiding beams. By mid 1951 experimental missiles were riding a stationary beam, and by the end of that year they were riding a jitter-free moving beam. By the spring of 1952 missiles had been gathered at 'a relatively high elevation' and had successfully ridden a beam in the presence of jitter.

Later trials confirmed the tracking and guidance beams had a 0·8° semi cone angle (at 6db) with a 13° control cone although it was felt that a 5° cone would be better. Minimum elevation was 2° with a smooth sea surface and 1·5° with waves of 6" RMS or more, and sea reflections would be reduced with a 5° gathering deflection. This upward gathering deflection was, in fact, subsequently adopted; further improvements to the aerial system reduced the minimum elevations to 1·25° for a smooth sea and 0·75° for 6" waves.

In 1960-61 exercises were carried out to establish the tracking discrimination of the type 901 radar. These proved that the radar required a separation of 20 minutes of arc (0·33°) between two targets to be able to track either of them without jitter; this was half the predicted value, and was later reduced to 18 minutes of arc. The radar could similarly fully discriminate between targets with a range separation of only 75 yards.

Initially the Type 901's acquisition process was manual as the target tracking cone was much narrower than either the Type 992 or 278 radars fitted to the County Class destroyers. The Missile Officer (MD) points to a target on the Target Indication Unit (TIU) display. The TIU operator switches from 'standby' to 'slew' and uses his joystick to put a marker strobe onto the echo. When the echo is strobed he switches to 'track' and reports 'tracking' and switches to auto-track when ready. Once tracking has started the Missile Control Officer pushes his start search button and the search pattern starts. The TS operators (Aimer and Rangetaker) observe their displays; when an echo is seen the Aimer switches to 'Hand' and then takes control of the Type 901 and repositions it so it is looking at the target. When the target re-appears the Rangetaker moves his range strobe to align with the echo; both operators select 'auto range' and 'auto aim', target acquisition is complete.

This procedure, which is clearly based on earlier anti-aircraft gunnery techniques, took about 20 to 30 seconds. Since writing this I have been contacted by a former Aimer who stated that with practice the teams could achieve acquisition within 15-20 seconds.

The Type 901 radar has three separate radar transmitters which require to be triggered in a definite sequence and at intervals related to the instantaneous position of the conical scan. The sequence of pulses is referred to as the "502 pulse pattern". The gathering antenna's spinner (which is referred to as the "master spinner" drives a disc, the circumference of which carries 25 equally spaced narrow strips of mu-metal. A fixed magnet and pick-up coil are mounted near the periphery of the disc, and this arrangement is referred to as the "magnetic trigger initiator" and produces 25 initiating pulses per revolution of the conical scan -ie at a fixed repetition rate of (25x4000)/60 =1667 pulses per second. One of these pulses is arranged to occur exactly at "top dead centre" of the conical scan, and is made a double pulse so that it can be identified.

The pulse generator uses this to generate two pulses from the gathering antenna with a separation of 2, 4 or 6 microseconds followed by an equally spaced pair from the guidance antenna, the complete group of four pulses being sinusoidally time modulated at a frequency of 66 2/3 Hertz with a maximum time excursion of ·75 microseconds. This is "pulse position modulation" analogous to phase modulation in ordinary communication practice. It results in the "instantaneous repetition rate" of the gathering-guiding pulse group varying in accordance with the position of the conical scan; in this way information is transmitted to the missile which, in effect, enables the position of the conical scan to be reproduced in the missile resolving system.

The Seaslug system was required to be operable in a wide range of climatic environments; this included Arctic conditions with the risk of ice forming on the surface of the Type 901 radar, which would severely affect its performance. Direct electric heating of the of the face of the radame was considered and rejected, as was indirect hot-air heating; the latter would have a peak (ten minute) load of 200kW! In the end a far more ingenious solution was selected, using the latent heat of fusion. Many chemical reactions are exothermic, and one is the dissolving of ammonia gas into water. The gas is piped to the periphery of the radome and then through micro channels between the main surface and a porous top layer through which the ammonia could readily percolate. On contact with the ice it would start to dissolve and liberate heat. Tests on a model in an icing chamber showed that the ice on the radome started to melt after 25 seconds, and within five seconds of this the ice slid off in a single sheet.

There was a fear that when the de-icing operations ceased, water would travel back into the channels as the residual ammonia dissolved and might later freeze. To prevent this, warm dry air was blown into the system for a few minutes after de-icing operations to ensure no ammonia was left in the channels, and there was also a thermostatically controlled electric heating element around the periphery of the radome.

For low angle firings (below 7·5°) the gathering aerial remained at 7·5° in order to prevent sea reflections from interfering with the gathering process. In order to allow the missile to gather to a line below the gathering beam's datum, the missile was made to ignore some of the pulses occuring in the lower half of the scan cycle.

Pulse modulation.

Each guidance group consists of 5 pulses and the gathering group consists of 3 pulses; they both have a 38 µS duration.

These pulses are time modulated according to the formula: T+m(sin wt) where T is the mean time interval between pulses, for a spinner speed of 4000 rpm and 24 pulses per scan cycle this is equal to 625 µS.

m is the modulation depth and is 3% of the mean time interval, ie 18·75 µS.

wt is the angle turned through by the spinner flare...and may be shown to equal 72 µS.

The tracking pulse is similar but a form of random pulse modulation is called for to prevent the enemy using a deception pulse type countermeasure system. The depth of this is limited to +/- 12·5 µS about the mean position of the tracking pulse.

Data table.

Tracking radar	901 (Mk1)	901M (Mk2)
Peak power	600 kW	600 kW
Pulse duration	0.33 µS	0.33µS
PRF	1666 2/3 Hz	
Frequency	9600 MHz	9600 MHz
Aerial aperture (diameter)	9 feet	9 feet
Aerial gain	40 dB	40 dB
Beam width (half power one way)	0.8°	0.8°
Conical scan angle (vertex of cone)	40' of arc	40' of arc
Conical scan frequency	66 2/3 Hz	66 2/3 Hz
Range display	0-60,000 yards	0-80,000 yards
Guiding radar		
Peak power	50 kW	50 kW
Frequency	9485 MHz	9485 MHz

Other details as for tracking radar.

Gathering radar		
Peak power	50 kW	50kW
Frequency	As for Guiding radar	As for Guiding radar
Conical scan angle	7°	7°
Control cone	18°	18°

Searching.

Since the target information from ADA or from other sources is unlikely to be sufficiently accurate to ensure that the narrow tracking beam is pointed directly at the target at the start of acquisition, it is necessary for radar Type 901M to search about the indicated position of the target.

Selection of search patterns. ADA selects and starts the search pattern appropriate to the expected accuracy of the source of information upon which the target information fed to the Type 901M radar is based. The type of search and the end of each pattern is indicated on the display cabinet in the TS. The search continues until the target is acquired or the system is reset.

If, during searching, the source of target information is changed, the search pattern is changed automatically. If an X search is in progress the change is made immediately, otherwise the chage awaits the end of a pattern. If necessary, the search can be enlarged by pressing a push on the TSO's cabinet.

Search patterns. The type of search pattern is designated by quoting the number of degrees of bearing and angle of sight covered by the pattern. All patterns are superimposed on TI (or standby) bearing and angle of sight and include the normal conical scan. The basic search pattern is produced by movement of the BAU, larger patterns are made by moving the director in addition to the BAU.

The various search patterns are described below together with the circumstances in which they are used.

a) Pattern 2·2. The basic pattern traced out by BAU movement; it takes one second to complete. It consists of a circular scan with a radial beam displacement of 45 minutes of arc covering a volume with a conical angle of 2°. This pattern is used when bearing is obtained from radar Type 992P and angle of sight from radar 278M under good conditions.

b) Pattern 2·4. This pattern is made by the BAU basic pattern with additional sinusoidal angle of sight movement of the director. It takes 3 seconds to complete and covers 2° of bearing and 4° of angle of sight. It is used when bearing is obtained from radar Type 992P and angle of sight from radar Type 278M.

c) Pattern 2·6. Formed in much the same way as pattern 2·4, but 6° of angle of sight are covered in 5 seconds. This pattern is used when bearing is obtained from radar Type 992P and angle of sight is based upon the TIDE link and range from local radar.

d) Pattern 2·X. This consists of the basic pattern combined with a downward sweep of the director. The maximum angle of sight is determined by ADA. The time taken for each pattern varies with the maximum angle of sight, but a 50° sweep takes 38 seconds. This pattern is used when bearing is obtained from radar Type 992P but only approximate and range information is available from TIDE.

e) Pattern 4·2. As for pattern 2.4 but with the director moving sinusoidally in bearing. It is used when the bearing is obtained from radar type 965P and angle of sight from radar Type 278M under good conditions.

f) Pattern 4·4. This pattern is produced by the basic pattern and simultaneous sinusoidal motions applied to director bearing and angle of sight to complete a pattern in 5·5 seconds. It is used when bearing is obtained from radar Type 965P and angle of sight from radar Type 278M.

g) Pattern 4·6. For this pattern the director moves sinusoidally in angle of sight and makes a step in bearing at the peak of each angle of sight sweep. The pattern, which takes 5 seconds to complete, is used when bearing is obtained from radar Type 965P and angle of sight from TIDE.

h) Pattern 4·X. The director moves sinusoidally in bearing and sweeps downward in angle of sight. The maximum angle of sight is determined ADA. The time taken for each pattern varies with the maximum angle of sight but a 50° sweep takes 75 seconds. This pattern is used when bearing is taken from radar Type 965P but only approximate height and range information is available.

Emergency search patterns.

The following search patterns are selected by positioning the emergency switch on the TSO's cabinet when emergency control is in use.

a) For AA engagements the search comprises two 4·X patterns side by side, the maximum angle of sight being set by the angle of sight handwheel on the TSO's cabinet.

b) For surface engagements the 4·2 search pattern is used, the search being made around 1° angle of sight set by the TSO's handwheel.

Sources:

ADM 220/196, /342, /355, /549, /957, /960, /1925, /1996, /2062, /2345, /2353 & AVIA 6/18743.
The National Archives, Kew, TW9 4DU.