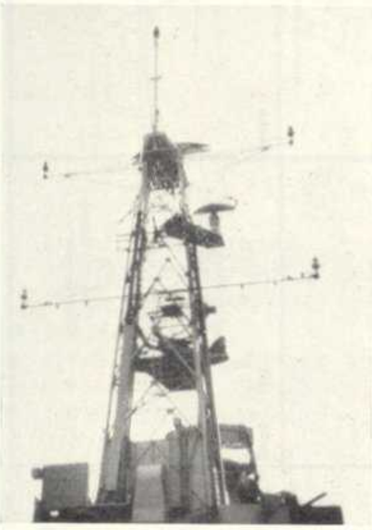
RADAR IN THE ROYAL NAVY

By Peter Hodges



Above top: *The Type 274 radar can be seen by anyone making a trip to the Tower of London as this is mounted on HMS* Belfast *which is moored close by as a floating museum.* **Above bottom:** *The fore mast from aft. Radars are 293 cheese on platform, 974 navigation cheese on offset platform and 278 height finder centrally below. Although none of these installations are operational today they serve as a useful guide for anyone wanting to model the radar carried by British warships since 1945.*

Guns, torpedoes, missiles, boats and so on are all familiar items of equipment to ship modellers, and most enthusiasts know all about them. Much less familiar—sometimes barely visible—are the radar aerials and their attendant displays and systems. With modellers very much in mind, Peter Hodges here tells the story of naval radar and describes and illustrates the principal Royal Navy systems.

AS EARLY AS 1935, the British government was considering the problem of defence against air attack from the continent of Europe, where increasing numbers of bomber aircraft were being built. It would be impractical to provide 'round the clock' fighter patrols over our vulnerable coastline, but if some 'early warning' system could be evolved, our fighter squadrons could remain grounded until an attack developed, and only then be committed to action. In this way, not only would precious combat engine-hours be saved, but also equally precious fuel, all brought to the United Kingdom by sea.

At about this time, Mr Watson Watt (later Sir Robert Watson Watt) was conducting experiments using electromagnetic beams to determine the height of the Gonosphere, and it seemed likely that these principles could be used to detect aircraft. Certainly, it had been noticed that the presence of aeroplanes near the television apparatus of the day often caused a 'double image' effect, and this was thought to be some sort of reflection from the 'planes themselves.

The outcome of all these deliberations was the chain of radar stations on the South Coast which played such a vital part in the Battle of Britain.

The potentialities of this Radio Direction Finding—or 'RDF' as it was then called—were immediately apparent to the Royal Navy, but a shipboard installation presented many problems. The new equipment would have to be squeezed into ships where space was already at a premium; and the designers had to take into account other special factors, such as field of view and aerial shape—remembering always the inevitable top-weight penalties. However, the nettle was firmly grasped by HM Signal School, although much preliminary and time-consuming work was required on the design of the thermionic valves to suit a ship environment.

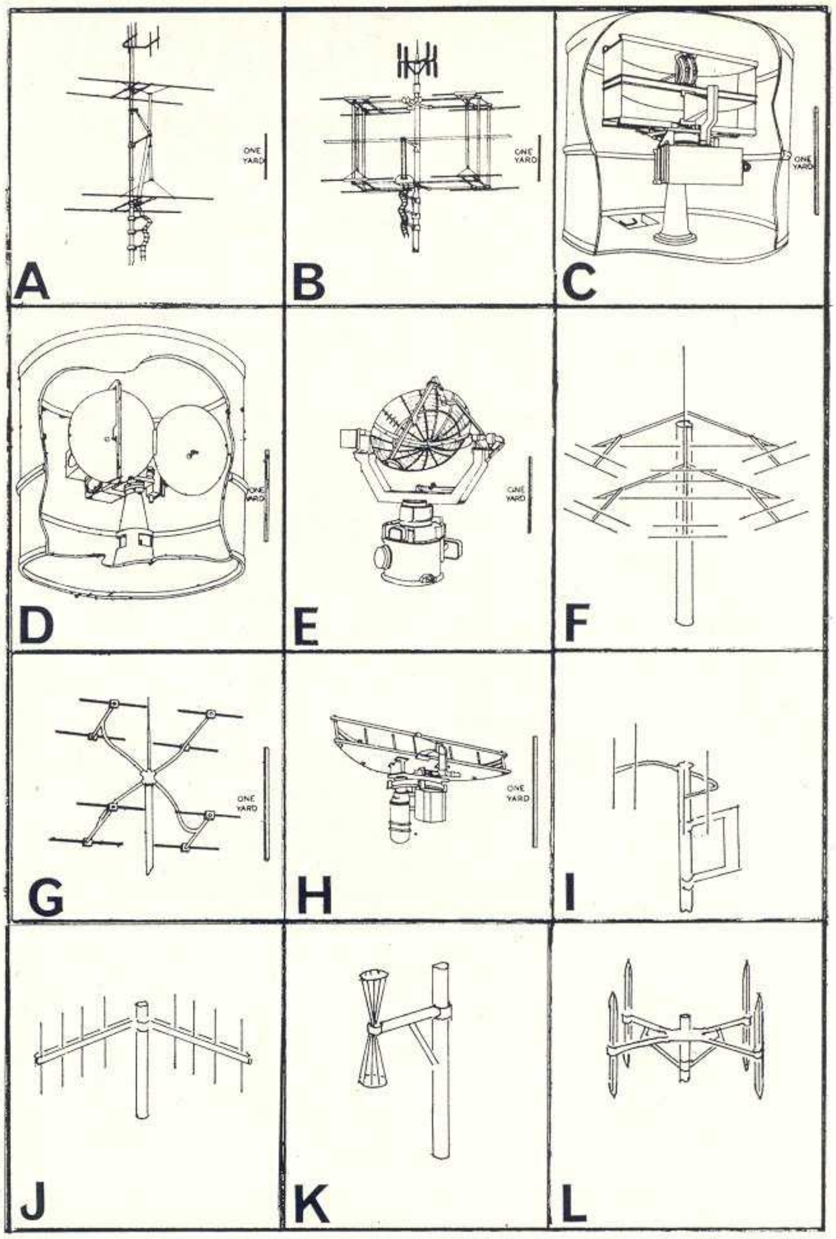
Development: air warning sets for large ships

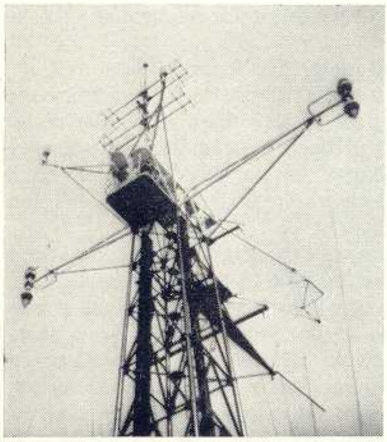
TYPE 79

Naturally enough, protection was first sought for the larger and more important units of the Fleet, which were in any case best suited to take extra equipment and top weight. The first sea-going set was known as Type 79 and was already at sea in 1939 in the battleship *Rodney* and the cruiser *Sheffield*, with a further 30-odd sets on order. In passing, it is interesting to note that the Germans also had radar at sea at this time. The pocket battleship *Graf Spee* had a large aerial on the forward face of her main armament Aloft Control Tower—presumably an elementary gunnery set.

The Gunnery Branch of the RN itself quickly realised the enormous advantages of radar for gunnery ranging, because its only instrument was the optical rangefinder. Obviously, the range-taker manning it needed to see the target and there were therefore severe limitations in its use at night, in bad visibility, or against aircraft in cloud.

A *79B and 279B, with co-axial IFF 'pitchfork'*
B *281B, with co-axial IFF 'candelabra'*
C *271 within 'lantern'*
D *273 within 'lantern'*
E *277*
F *286M*
G *286P and 291*
H *293*
I *241 IFF 'pitchfork' with stabilising wind-vane*
J *242 IFF (fixed)*
K *242 IFF and 253 IFF (fixed)*
L *243 IFF 'candelabra'*





Above: *A view of the main mast on HMS* Belfast *with the post-war 960 warning radar aerial. Note its design compared with 281 in drawing B at right. Also of interest are the U/VHF radio aerials suspended from the lattice work either side of the mast.*

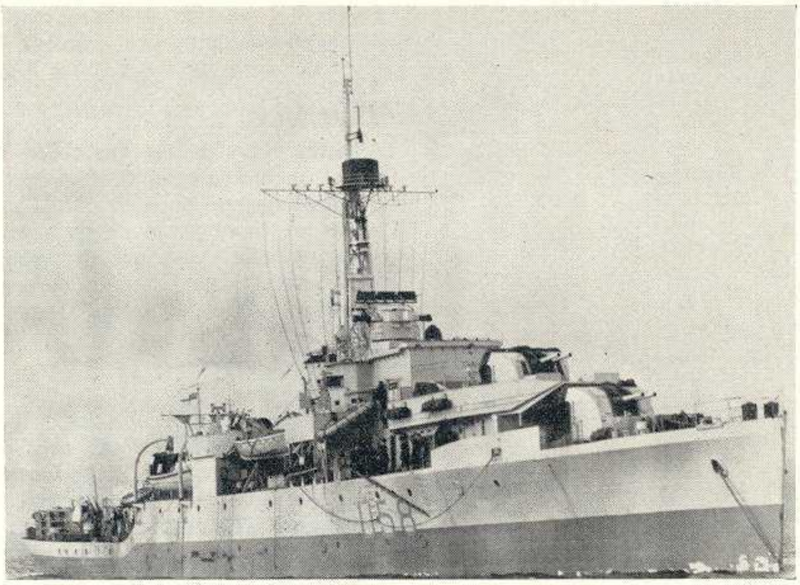
TYPE 279

The next development was a modified form of Type 79, known as Type 279, which had a ranging panel incorporated so that gunnery ranges could be transmitted from it. But there were now clashing requirements, for by allocating the radar to a specific gunnery target and holding it on one bearing, its function as an all-round early warning device ceased. It was quite evident that separate gunnery radars were required, and when they had been developed, 279 reverted to its proper function as an early warning set.

TYPE 281

Meanwhile, the general cry was for a better set with greater range and improved bearing accuracy and Type 281 soon followed 279. The new set could detect an enemy battleship at 12 miles, or an aircraft flying at

Above top: Newcastle *after her post-war modernisation. The 6 inch DCT has 274 and both 277 and 293 are carried on the lattice foremast. Notice the Mark 6 director with its 275 'nacelles' and the 960 aerial on the mainmast.* **Above bottom:** *The fixed 'pigtrough' aerials of Radar type 284 are clearly visible on the 8 inch DCT in this view of the cruiser* Berwick. **Right:** *A wartime shot of the sloop* Hart, *with 285 on the R/F director, 272, the IFF 'pitchfork' above it, and 291 at the masthead. Notice also the tall TBS radio aerial.*



16,000 ft as far as 100 miles. Its enhanced 'surface' range also provided better cover against lower-flying planes.

TYPES 79B, 279B, and 281B

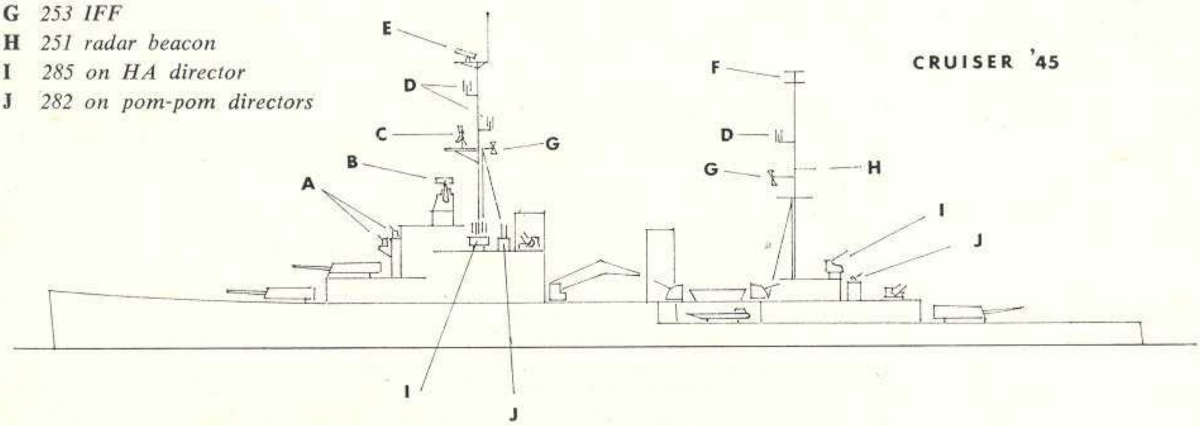
These three early sets—79, 279, and 281—all used twin aerials, one being the transmitter and the other the receiver. They were mounted on the fore and main topmasts and rotated in synchronism. This arrangement was difficult to implement in aircraft carriers where space for masts is always a problem (because of their 'Island' superstructure) so variants of all three sets were produced. They were distinguished by a letter 'B' as a suffix to the basic number, indicating that a single aerial fulfilled the duties of both receiver and transmitter. Other large ships took advantage of this and sometimes had two quite independent sets, but it was impossible to tell from their appearance whether, for example, a vessel had one Type 79 or two Type 79Bs. This is of little consequence to the model maker, of course, and all the aerials discussed so far were very similar in construction.

Combined warning sets

There was soon a call for a radar set for destroyers and small ships generally, but at first no set with an aerial system compatible with a small-ship fit, in terms of size and top weight, was available.

By chance, the crew of a 'Walrus' amphibian on the slipway at Lee-on-

- **A** *283 on barrage directors*
- **B** *274 (stabilised) on DCT*
- **C** *277 surface warning*
- **D** *243 IFF*
- **E** *293 combined warning/gun direction*
- **F** *79B or 281B air warning*
- **G** *253 IFF*
- **H** *251 radar beacon*
- **I** *285 on HA director*
- **J** *282 on pom-pom directors*



Solent noticed that its own small air-to-surface radar could detect the passage of shipping in the Solent. This led to the transfer of numbers of these sets from the RAF to the RN, where they formed a useful stop-gap.

TYPE 286M

In the Navy the set was called Type 286M and had a fixed 'bedstead' aerial on the fore topmast, facing forward. It could only give cover to about 60 degrees on each side of the bow and in any case the ship had to be swung to obtain even an approximate target bearing. Its range and accuracy were weak, and altogether it was unpopular because it imposed such severe tactical limitations on the ship carrying it. Even as large a reflective surface as a capital ship could not be detected beyond about seven miles.

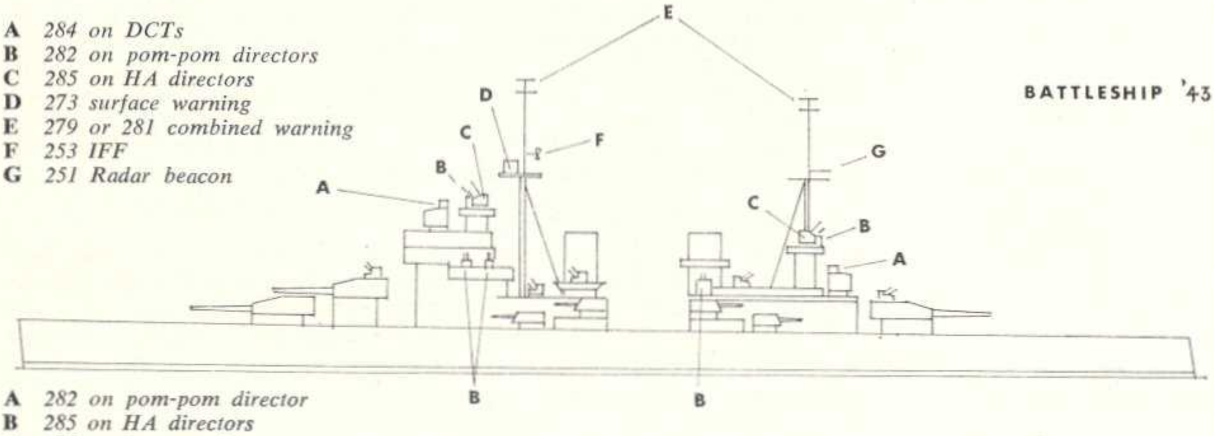
TYPE 286P

To improve the capabilities of Type 286M, the aerial was redesigned to rotate and so give the much needed all-round sweep. In this form, the set was called Type 286P. It had been hoped that its range could also be improved, but despite the endeavours of the scientists ashore this did not materialise. The problems of the Type 286 series really stemmed from the fact that the basic set had not been designed in the first instance for warship installation, and suffered accordingly.

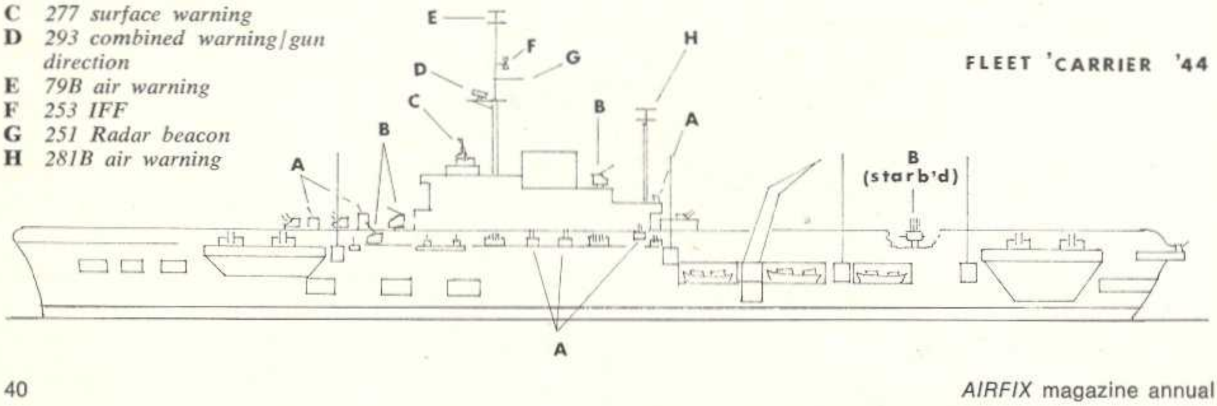
TYPE 291

Mindful of this, the backroom boys had already undertaken the research and development necessary to produce an adequate ship-borne radar. Their efforts resulted in the very successful Type 291. This could give accurate surface ranges up to ten miles with air cover out to 50 miles for high-flying aircraft. It was widely fitted in destroyers and small ships from about 1942—43 onwards, and survived into the 1950s.

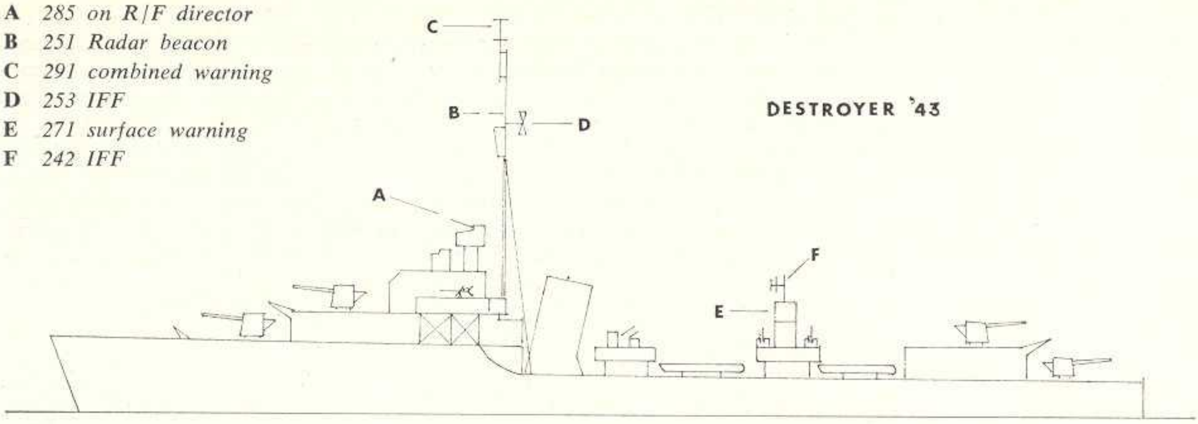
A *284 on DCTs*
B *282 on pom-pom directors*
C *285 on HA directors*
D *273 surface warning*
E *279 or 281 combined warning*
F *253 IFF*
G *251 Radar beacon*

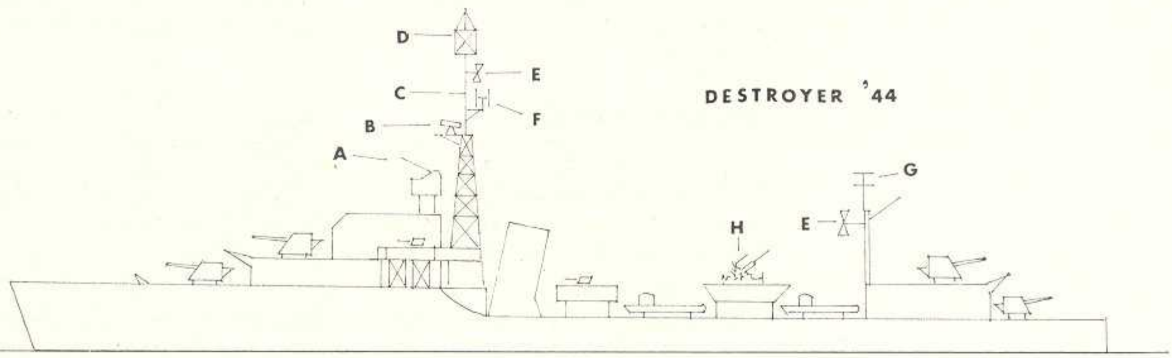


A *282 on pom-pom director*
B *285 on HA directors*
C *277 surface warning*
D *293 combined warning/gun direction*
E *79B air warning*
F *253 IFF*
G *251 Radar beacon*
H *281B air warning*



A *285 on R/F director*
B *251 Radar beacon*
C *291 combined warning*
D *253 IFF*
E *271 surface warning*
F *242 IFF*





A *285 on D/P R/F director*
B *293 combined warning/gun direction*
C *251 Radar beacon*
D *H/F D/F aerial*
E *253 IFF*
F *242 IFF*
G *291 combined warning*
H *282 on twin Bofors Mk IV (Hazemeyer)*

Surface warning sets

Once the U-boat 'wolf-pack' tactics became established, whereby they shadowed convoys during daylight hours and made attacks on the surface at night (to say nothing of their habit of mustering their forces by radio when they surfaced), there was an increasingly urgent need for an efficient surface warning set for escorts. A U-boat on the surface escaped the probing beam of the Asdic and its low silhouette made it extremely difficult to detect visually. At night, therefore, it was virtually immune from detection.

Such a set was rapidly designed, to the great credit of those concerned, and was one of the major contributors to final victory. It was later discovered that this set was far in advance of anything that the enemy had, and the techniques involved were immediately passed to our American allies.

TYPE 271

The aerial for this outstanding set was contained in the now-familiar 'lantern', and the combination of short wave-length and high power output made it very efficient, even in such small vessels as corvettes. Its environment was then as low-set as could be imagined, yet a major surface unit could still be detected at about 12 miles and a surfaced U-boat at about three miles. The beam-width was of the order of five degrees, giving it a 'searchlight' form which greatly aided the bearing accuracy of the set as a whole.

The aerial and its associated 'office' were prefabricated in one piece, forming an integrated equipment. This was done to keep the length of the feeder cable (between the set and its aerial) to a minimum, for long cable-runs seriously dissipated the power output.

Type 271 was produced at very short notice, and was fitted in large numbers of Fleet and Escort destroyers as well as in smaller ships.

TYPE 272

A development of Type 271 was Type 272 which enabled the aerial and set to be separated by up to 40 feet, and the former could then be placed higher in those ships which could tolerate the top weight. The higher siting of the aerial much improved the range capabilities of the radar. The operator now trained the aerial (within its protective 'lantern') remotely, rather than directly as was the case with 271. In neither instance was a power training facility provided, but this at least allowed the operator to hold the aerial on any particular bearing when a suspicious echo appeared. The lanterns of 271 and 272 were almost identical, but while 271 invariably had an enclosed radar office immediately below it, 272 was mounted either on a special pylon, or sometimes on a platform on the foremast.

TYPE 273

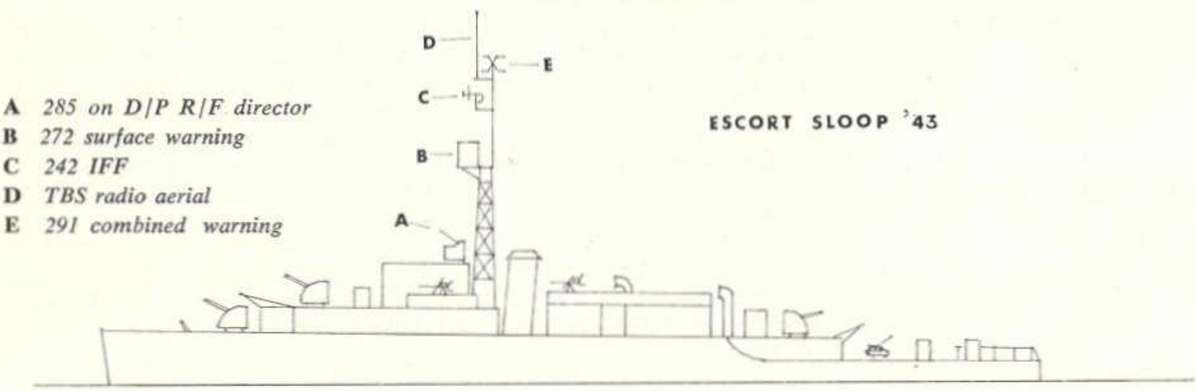
Type 273 was an even more powerful variant, designed for capital ships and cruisers. Again, its aerial was housed in a lantern, mounted high on the main superstructure. So equipped, a battleship could detect a U-boat on the surface at over seven miles, and an opposing capital ship up to 20 miles away.

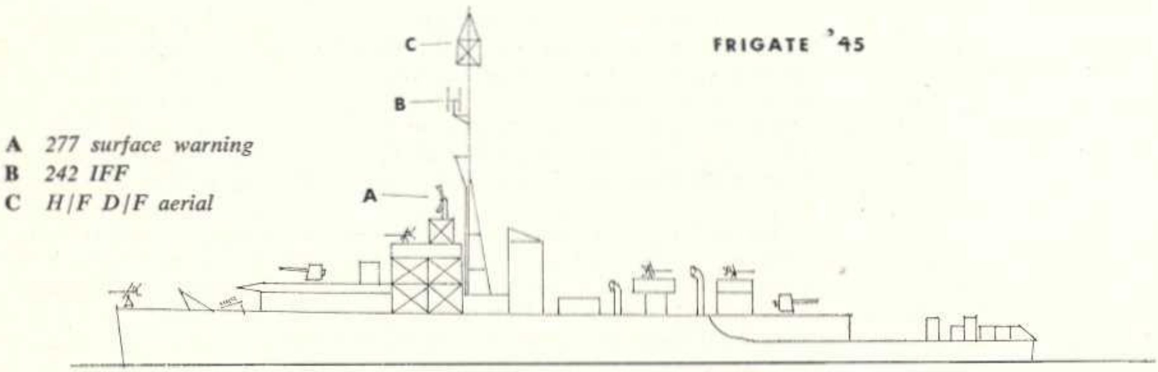
Gunnery radars

These were a natural development which released the original warning radars from their subsidiary task of providing gunnery ranges. The aerials associated with the sets were carried on the director or DCT, but an exception was the aerial array fitted directly to the Bofors Mk IV (Hazemeyer) mounting, which was 'self-contained' in the fire control sense.

TYPES 284 AND 285

Although the electronics of the first two gunnery sets were identical, their aerials were very different. For the control of surface fire in capital ships and cruisers Type 284 was used, its 'pig-trough'-shaped aerial being





Above top: *The battleship* Revenge *has 285 on both HACS directors, 273 in the mainmast 'lantern' and the double 79 or 279 aerials at each masthead.* **Above bottom:** *Close-up of the two HACS directors on the* Revenge.

fixed rigidly on to the appropriate DCT. Other than for corrections to allow for 'roll', the line-of-sight to a surface target was roughly horizontal, so there was no need for any elevation movement on the aerial itself. On the other hand, in High Angle Control System Directors and on the Dual Purpose Rangefinder Directors of small ships, it was necessary to elevate the aerial by some sort of take-off linkage coupled to the master sight drive. These small directors required a much lighter array, so a special aerial was designed—the familiar 'fish-bones'—when the set was called Type 285. It also had a small 'pig-trough' from which five, and later six, struts projected. The bearing accuracy of the set was reasonable, but its elevation accuracy was less good, so that while it could always be relied upon to range within a few yards, it could not be used to determine Angle of Sight and had to be 'aimed' at the target. It follows that it could not, therefore, be used in any form of 'Radar Lock-On' system.

TYPES 282 AND 283

Similar, but smaller, 'two-stick' aerials were developed for the Barrage Director (283), the Pom-pom Director (282), and the 'Hazemeyer' Bofors (282). The maximum range of these smaller sets was much less than that of their big brothers, but then they were only for use at close ranges. Type 284 was effective to a range of about 14 miles, while the lighter 285 could range on a large surface vessel at 10 miles or an aircraft at eight miles.

Later developments: combined warning sets

TYPE 293

This radar was originally intended to be a replacement for both 271 and 291 in small ships, but to give overall vertical cover between the horizontal and 70 degrees, its 'cheese' aerial was tipped upwards. This somewhat diminished its surface detection capabilities, but it was an excellent set for target indication purposes which became its principal function. It was this radar which put the individual gunnery radars on to selected targets and its aerial on a platform on the foremast became a familiar sight for many years.

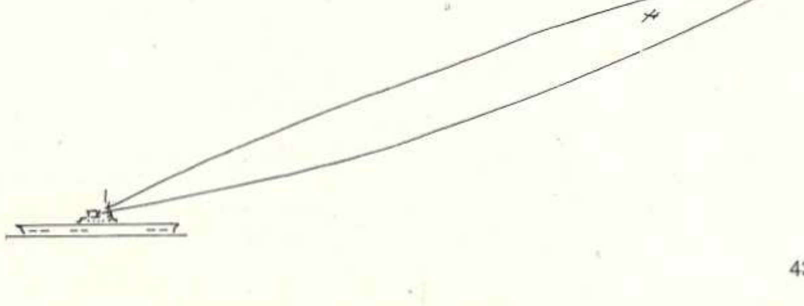
TYPE 276

Another 'cheese'-shaped aerial of similar dimensions was linked to a set known as Type 276. It seems to have been interchangeable with 293, and occupied the same position.

TYPES 980 AND 981

In an attempt to overcome the difficulties of providing a truly combined warning set, Type 980 was developed for large ships. This had a double aerial, the lower part cheese-shaped to give surface cover and the upper part capable of independent movement in elevation. This upper aerial was particularly valuable as a height-finder but the mechanics of the array were complex and eventually the aerials were separated.

Height-finding was a very important element in the control of air defence, for by knowing the bearing, the range, *and* the height of an incoming raid, our fighters could be vectored by R/T to the most advantageous position.



Right: *Typical side elevation of a height finder lobe. Range and angle of sight will be accurately measured, but bearing will be inaccurate.*

Above top: *A typical Leander class frigate,* Arethusa *has 903 on her director, 976 on the forward face of the foremast, with 993 above and the H/F D/F aerial on the topmast. The shorter mainmast carries 965 with its own co-axial IFF.* **Above bottom:** *Close-up of the superstructure on* Arethusa.

Below left: *Plan and elevation of typical combined warning lobe. T 1, a high flying target, will be detected at range R 1 as the lobe sweeps through its position. Similarly, T 2 will be detected at range R 2. Target T 3, on the other hand, is a low flier and will not appear on the radar screen until it comes into the lobe. Target heights in all cases will be unknown.* **Below right:** *The narrow 'pencil' beam of a surface warning set, with good bearing accuracy.*

Surface warning

TYPE 277

An entirely new set, Type 277, was designed to replace the earlier 271/272/273 lanterns. Its aerial took the form of a paraboidal 'dish' which rotated continuously in power and could also elevate. The elevation drive permitted stabilisation in the vertical plane, but although in theory it could be used as a height-finder, when so employed the rotation had to be stopped on the required bearing. Again, one sees the problems which arise as soon as one set is used for other than its designed function. As a surface set, however, Type 277 was most efficient, with a bonus of being able to detect aircraft up to 5,000 feet out to nearly 20 miles.

Gunnery radars

TYPE 274

Capital ships and cruisers with DCTs had their earlier Type 284 replaced by the large 'cheese' aerial of radar Type 274. Again, there was no requirement to elevate the array, but it was later mounted in trunnion arms, to allow a stabilisation movement, so that it was unaffected by any ship movement along the Line of Sight to the target. The power follow-up of the stabilisation drive derived from a master gyroscope in the DCT itself which was also coupled to the director sights and the (now) secondary rangefinder.

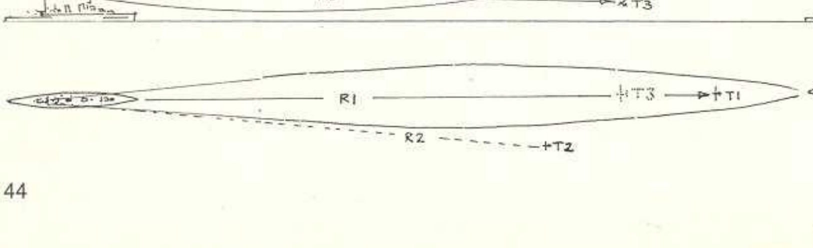
TYPE 275

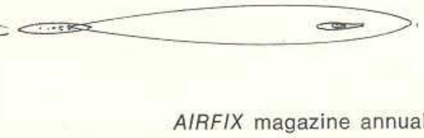
The greatest drawback of Type 285 lay in its inability accurately to measure angle of sight and, because of this, it could not be used for 'blind' follow. Its successor, Type 275, was accurate in both planes, and with this set full 'blind follow' against unseen targets was possible. The twin aerials resembled very large 'headlamps' and were set on each side of the HA/LA director. One aerial was the transmitter, the other the receiver, and both elevated in coincidence with the stabilised director sights. Type 275 arrived almost too late for World War 2 but later became the standard gunnery radar and is still in service in a few post-war ships.

Other radars :

Interrogator, friend or foe

An immediate problem arose when the first coastal warning radars came into service. The radar operators had no means of telling whether echoes were from enemy aircraft, or from our own planes, perhaps returning





Above: *Rather unusually for a cruiser, HMS* Belfast *retained her after DCT. It, like its counterpart on the forward mast, had the stabilised 274 aerial in trunnions. This is just visible at the upper left-hand side of this picture.*

from a raid or for refuelling. To overcome this, the IFF set was evolved, entailing the fitting of a device in every Allied aircraft, so that when our radar 'looked' at it a characteristic shape of echo would appear on the radar display.

In order that the Interrogator 'looked' in the correct direction, its aerial had either to form part of the main radar aerial array, or had a quite independent rotatable system. Radars Type 271/272/273, for example, had a dipole IFF aerial projecting through the top of the lantern. Type 281 had a dipole aerial (similar in design to that of Type 291) attached to, and rotating with, the main array. The independent IFF aerial was a later development that trained automatically on to the bearing of a target picked up on the main warning set. It looked rather like a candelabra, and had its own platform, usually on the after side of the foremast.

Another Interrogator was used to establish friendly ships. Its aerials were fixed and resembled a pair of wire-mesh cones set vertically, point to point, carried on short struts projecting from the foremast.

Radar beacons

Yet another device was known as the radar beacon, which might be described as IFF in reverse; that is to say, it indicated friendly ships to Allied aircraft. Large warships carried it as a matter of course, but it was only fitted to a proportion of the smaller vessels. A typical selected ship might be that of the Senior Officer of an Atlantic Escort Group, on whom Coastal Command anti-submarine aircraft could 'home'. Like the ship-to-ship Interrogator, the radar beacon had a small fixed aerial, somewhere fairly high on the foremast.

Aerial characteristics

The radar transmissions from an aerial form a three-dimensional shape in the sky called a 'lobe', whose proportions are determined by several factors, which include the design of the aerial itself and the power output of the set. The aerials of the earliest sets were of the dipole type, rather like those of household television sets. In these, the 'poles' were set at a designed distance apart, the rearmost acting as a reflector for the other. This had the effect of directing the lobe along one axis, at the same time increasing the power of the transmission.

However, the most efficient form of 'reflector' is of paraboidal shape, like a car headlamp, and can be made to produce a probing cigar-shaped lobe, giving a high degree of positional accuracy at relatively short ranges. Most modern gunnery radars are of this type, and have characteristic 'dish' aerials.

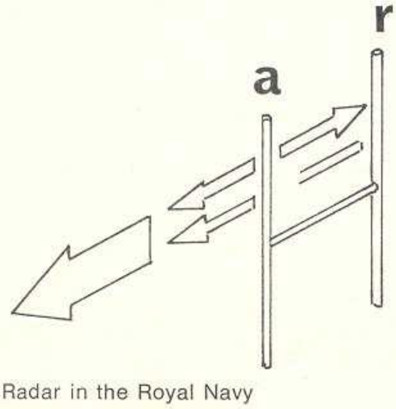
The requirements of an air warning radar are to establish the range and bearing of a target as far away as possible and then to ascertain whether or not it is approaching. To achieve this, the lobe shape is modified so that it is of narrow width but of considerable depth and this gives high bearing accuracy.

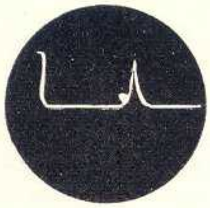
One might imagine that a tall, narrow aerial would give this lobe shape, but in fact the contrary is the case, and it is produced by the 'cheese' design. This shape is, of course, simply a slice from a paraboidal contour and as we have seen the aerials of both 293 and 274 radars were like this. The 'fishbone' or 'Yagi' arrays, to give them their proper name, also developed the narrow-deep lobe. From the sketch on page 44 it will be seen that the range and the bearing of the two targets can be established but not their height and this is why radar 'lock-on' could not be achieved in the Type 285 system (see page 43).

In height-finding radars the exact converse applies. Now, the aerial is tall and narrow, or comparatively so, and its lobe is very shallow in depth but is of great width.

The lobe shapes can easily be demonstrated with an oriental fan. Flap it up and down and one has the height-finder; flap it from side to side and

Below: *Dipole principles. The reflector (r) helps to give the lobe direction and also strengthens the transmission. Without a reflector, the lobe becomes symmetrical about the aerial, but this is useful in such devices as Radar Beacons.*





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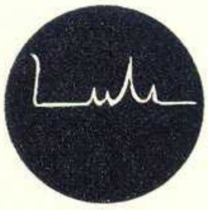

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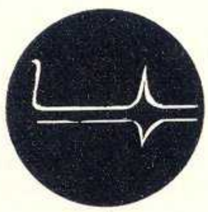

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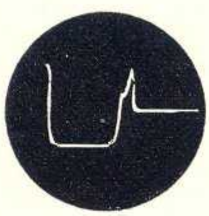


e

Above: *Five different types of radar displays*

a: Target echo 'strobed'

b: Echo and IFF return

c: Main echo with smaller target echoes

d: Echo with inverted ranging 'pip'

e: 'Stepped' trace

one has the air warning radar. Close the fan and one has the pencil beam of the modern gunnery tracking set. In passing it is worth mentioning that a radar specifically for surface cover can also have a lobe approaching the pencil-beam shape—like the 'lantern' sets, for example—because surface targets have virtually no height. But attempting to use, say, Type 277 for height-finding proved unsatisfactory, for as well as losing the all-round cover when the aerial rotation was stopped, it was extremely difficult to pick up, and hold, a high flying aircraft in the narrow beam.

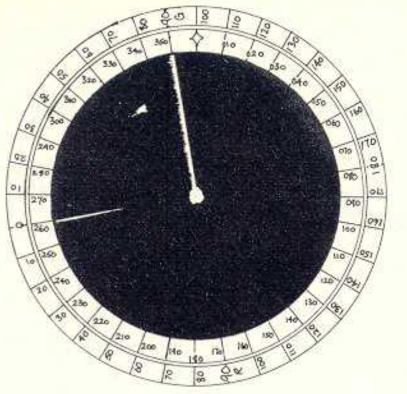
Radar displays

To establish range from a radar set, a display called an 'A' scan was used. The radar 'picture' appeared as a horizontal line of green light across the width of the screen. Often there were two screens side by side, one a 'coarse' tube whose width represented the maximum range of the set, and the other a 'fine' tube, for accurate ranging. Conventionally, the left-hand edge of the line of animated 'grass' was zero range and the right-hand edge maximum range. Echoes, showing the presence of targets in the lobe, appeared as 'blips' on the trace and it was the shape of these echoes which were distinctively changed by the IFF transponder in a friendly aircraft. Superimposed on the trace was a brightened spot called the strobe which could be traversed by the operator's ranging handwheel and in 'strobing the echo' the range of the target was measured. The same drive was geared to electrical transmitters which fed the range information to repeaters, fire control predictors and so on. They thus received accurate and continuous ranges and also a measure of the rate at which the range was changing. This 'range-rate' helped to establish the target speed—a vital quantity in the complex mathematical formulae of the fire control prediction problem.

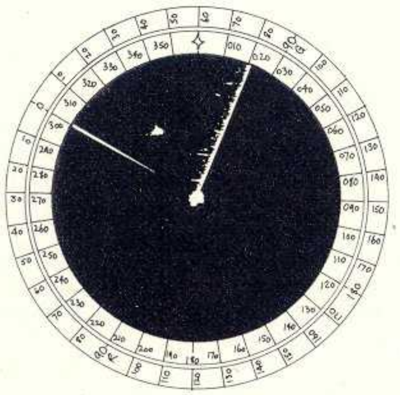
The other type of display was the Plan Position Indicator, or PPI, associated with the warning sets. A line of light, rotating like the spoke of a wheel, represented the radar beam, and echoes showed up as smudges of light as it passed through their bearing. The cathode ray tube was treated with a fluorescent substance which gave persistence to the echo after the line of light had passed through it. Whenever the radar beam passed through the bow of the ship the aerial triggered a separate line of light to give an indication of ship's head and, since the PPI had a compass ring around its circumference, it was possible to see one's own course. A second ring, which moved as the ship altered course, translated the compass bearing of a target to 'relative bearing' with respect to 'own ship'. In Fig **a** it can be seen that ship's course—as shown by the 'ship's head' mark—is 260 degrees; that 'Target Compass Bearing' is 330 degrees; and that the 'Relative Bearing' is 'Green, 70 degrees'. In Fig **b**, we have altered course to 300 degrees, the Target Compass Bearing has not altered, but the Relative Bearing ring has revolved in sympathy with the ship and the Relative Bearing of the target is now 'Green, 30 degrees'.

By this means the warning radar could indicate the bearing of targets to the weapon systems, whose directors would train to the appropriate Relative Bearing. Because the centre of the PPI represented 'own ship', it follows that the range of the echo could also be found. It was usual for the scale of the radar 'picture' to be adjustable so that the diameter might represent, say, 20, 10, or 5 miles. It goes without saying that land echoes appeared almost like a chart, making the display invaluable for 'Blind Pilotage' in confined waters. It was also an enormous aid to station-keeping in convoy at night.

Nowadays almost all ships, merchantmen and men-o'-war, have a 'navigation set' specially for this purpose, with its own 'cheese' aerial. Key channel-marking buoys have radar reflectors fitted to them and one can see a scale picture of a fairway on a PPI display. With so many aids to navigation, the spate of collisions and groundings in the English Channel in 1971 become all the more incomprehensible.



a



b

Above: *PPI presentation, described in text.*

Post-war naval radars

Type 960, another masthead dipole array, succeeded the earlier warning sets in large vessels and remained in service until fairly recently. With a need for even earlier warning in the missile age, very powerful sets indeed have been developed. Type 984 has an enormous single nacelle and was designed for aircraft carriers. Readers familiar with the Airfix *Victorious* will remember this vast unit. It is also carried by *Hermes* and *Eagle,* but is too large and heavy for smaller ships. Much more common is the 'bedstead' of Type 965, fitted in the 'Leanders', the 'Tribals' and the first of the Guided Missile Destroyers, as well as in *Blake*. The later Guided Missile Destroyers have a double-bedstead—as had the Air Direction 'Battles'—and *Ark Royal* has two.

A combined warning set called 993 is the successor to the original target indication 'cheeses' and most ships have this for gunnery direction. It has an odd-shaped aerial, but Type 974 and its variants—the 'navigation' sets—have retained the 'cheese' shape.

In general, British radar aerials have a neat appearance and in this respect contrast sharply with the large and clearly parabolic shapes common in the United States Navy and in continental ships. The design of some of the most modern aerials has reverted to the protective 'lantern' idea, in that they are contained within large mast-head spheres, often linked to complex computers and, not surprisingly, are referred to as 'crystal balls'!

Only a few of the older post-war frigates still retain Type 275 as a gunnery set; and with the passing of the battleship and cruiser the big DCT for their main armament has also disappeared—and with it Type 274. Only HMS *Belfast* remains so fitted.

All the old 'fishbone' arrays have vanished (although a few may be in service in ships sold abroad) and a new set called Type 262 has taken over from the close-range 'Yagi' aerials. This was first fitted in the STAAG twin Bofors and subsequently to the Close Range Blind Fire Director. The latest version of the latter is used to control certain 'Seacat' missile systems and the radar aerial is dish-shaped with full 'lock-on' facilities. Earlier applications of the CRBFD included the divided control of 'X' mounting in the 'Daring' class; the control of the twin 4 inch in the Type 15 frigates; and the control of twin and six-barrelled Bofors.

A less familiar radar was that linked to the American Mk 63 control system. This again had a dish-shaped aerial, but few were fitted in the RN. The complete set-up was fitted in *Victorious* where it controlled the USN 3 inch 50 calibre guns for which it had been originally designed, but it was also adapted for the British twin 4 inch and some of the 'Colony' class 6 inch cruisers were re-equipped with it during their final modernisation.

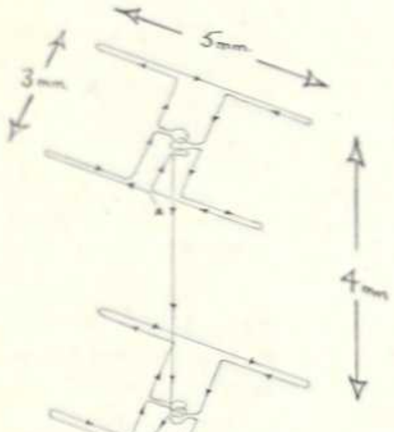
The standard gunnery radar in the British fleet today is known as Type 903. It has a large, fully stabilised dish on the right-hand side of its director, and mostly controls the modern 4.5 inch calibre gun, but also directs the 6 inch and 3 inch weapons in *Lion, Tiger* and *Blake*. A variant has been made for the latest 'Seacat' missile system.

A radar with a large nacelle, reminiscent of the 984 aerial in the carriers, is Type 901, the guidance radar for the Seaslug missile. Modellers of the Airfix *Devonshire* kit will remember that this overlooks the launcher on her quarterdeck. Another set found in the Guided Missile Destroyers is Type 278, a height finder, trunnioned like the old 277, which it closely resembles. There are other and bigger height finders in service but these are restricted in the main to aircraft carriers. They are easily recognisable because they are always mounted 'shaving-mirror' fashion.

One of the latest developments in weapon system control is the addition of a conventional television camera to the radar tracking head, providing a visual picture on special TV screens in the Operations Room below. A particularly ingenious arrangement has a 'search' radar, a 'tracker' radar and a TV camera in one unit. A conventional 'cheese' rotates constantly

KEY TO AERIAL CONSTRUCTION METHOD

A represents the basic form of the Type 79 and 279 series and B its successor, the Type 281. In both cases, the continuous wire-run starts at A and finishes at Z. The outside dimensions are correct for 1:600 scale, but can be considerably exceeded without appearing over-large. The smaller dipole aerials and the H/F D/F array can be made in the same way.



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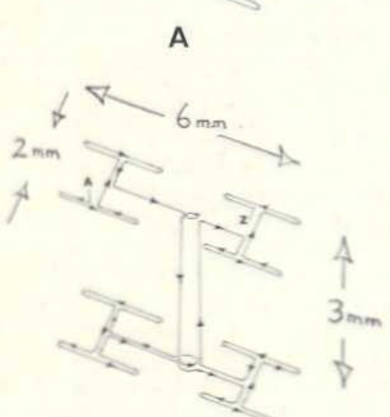

B

to provide a warning sweep; above, and co-axial with it, are the 'tracker' aerial and TV camera. When the warning radar detects a target, the tracker and TV lock on to it, while the lower aerial continues its uninterrupted sweep.

A possible drawback of this scheme is that the complicated unit cannot be protected by the spherical 'radome', unless it, too, rotates and has some kind of observatory-style shutters. However, sooner or later we will see a transparent sphere through which the TV camera can look; and when that arrives, there will be no prizes for guessing what its nickname will be. 'Crystal Ball, Mk II' perhaps?

Modelling the radar aerials

Accepting that the keen warship modeller has a fair degree of skill and patience, the level of accuracy he can achieve depends very largely on the size of the model. In the bigger scales—say 1:48—it is no more difficult to make a realistic aerial than it is to rig guardrails, but in the smaller models the task becomes increasingly difficult. Indeed, in 1:1200 it is virtually impossible, but this is far from being the case in the popular 1:600 scale of the Airfix kits.

In a number of these a useful selection of aerials is already available and most are easy to copy in scrap plastic. For the kit converter, who wishes to model, perhaps, *Suffolk* with her wartime fittings, the most likely area of difficulty will lie in making reasonable replicas of the dipole arrays of the early sets. For these fuse wire is by far the best medium provided one is prepared to compromise slightly on the exact dimensions.

Five amp wire is ideal and most households have a card containing enough for a whole model fleet somewhere near the fuse-box. The trick is to make the aerial from a continuous length of wire, doubling it back on itself where necessary. The sketches show the general idea.

Quite a good scheme is to push a needle into a flat piece of wood and 'build' the aerial around it. When complete, the aerial is slid off, dropped on to the mast and secured with a drop of cement. Choose a needle fractionally larger than the diameter of the mast and cement a tiny piece of scrap plastic to it in the appropriate position to prevent the aerial from slipping down: the scrap can always represent the drive motor.

Bending the fuse wire is best done with tweezers and their blade width forms a useful jig for dipole lengths.

Trying to produce aerials from extended plastic sprue is pretty well impossible, for although it is perfectly feasible to extend a sprue to hair thickness, the trouble is that it literally dissolves when an attempt is made to cement it. Further, unlike plastic, wire is malleable, so that, even if the final result is lop-sided, it can be eased to symmetry when in position.

The use of fuse wire can be extended to remake the 965 aerial provided as part 32 of the *Devonshire* kit. Here all one needs is a scrap of plastic of the same size as the kit part, around which the wire is wound in a continuous open coil. Leave enough 'tail' on the wire to run back to the mast, slide the coil carefully off the plastic jig, and an excellent 'open' aerial will result.

Wire can also be used to make the 'fish-bone' arrays. All they require is a tiny trough of paper, pierced with needle-point holes, through which twin 'sticks' are inserted. Make them plenty long enough and trim all at the same time with sharp scissors when their securing cement has set.

One final point about positioning aerials. The majority of modellers probably complete their ship kit in the full hull condition and in this case everything can be in the 'harbour stowed' position. If, however, the ship is worked into a dummy sea environment it is quite in order to set the aerials at random bearings (except, of course, the twin arrays of the early sets, mentioned above). For 'action' conditions, don't forget to train the appropriate director or DCT on to the same bearing as the armament. This is an error which many make, including maritime artists.