WHERE ARE WE IN RADAR CROSS SECTION REDUCTION?

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ABSTRACT

The application of RCS reduction measures on major warships is proving successful, but careful attention to details in the design is required. RCS control on submarine masts poses greater problems. Developments in progress and future trends are explored in relation to overall fighting effectiveness.

Introduction

'Where are we in radar cross section reduction?': a good question for an important aspect of stealth strategy. Unfortunately we are still a long way, at least as far as major surface units are concerned, from introducing stealthy warships into the Royal Navy.

The aim of this article is not to explain the scientific principles of Radar Cross Section (RCS)—this was ably covered in an earlier article by Dr Gates[1]—rather to provide an update on where we are today in design of ships for low radar signatures, on techniques for measuring RCS and to set RCS control in the context of fighting effectiveness.

While concentrating on the surface fleet, I will include a brief review on some aspects as they apply to the submarine.

Theory

We will quickly summarize the theoretical basis for the work. Most readers will be familiar with the radar equation in the form:

$$P_r = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 R^4}$$

Where P_r is the power received
P_t is the power of the transmitter
G is the antenna gain
λ is the wavelength of the radar signal
R is the range to the target
σ is the Radar Cross Section (RCS) of the target.

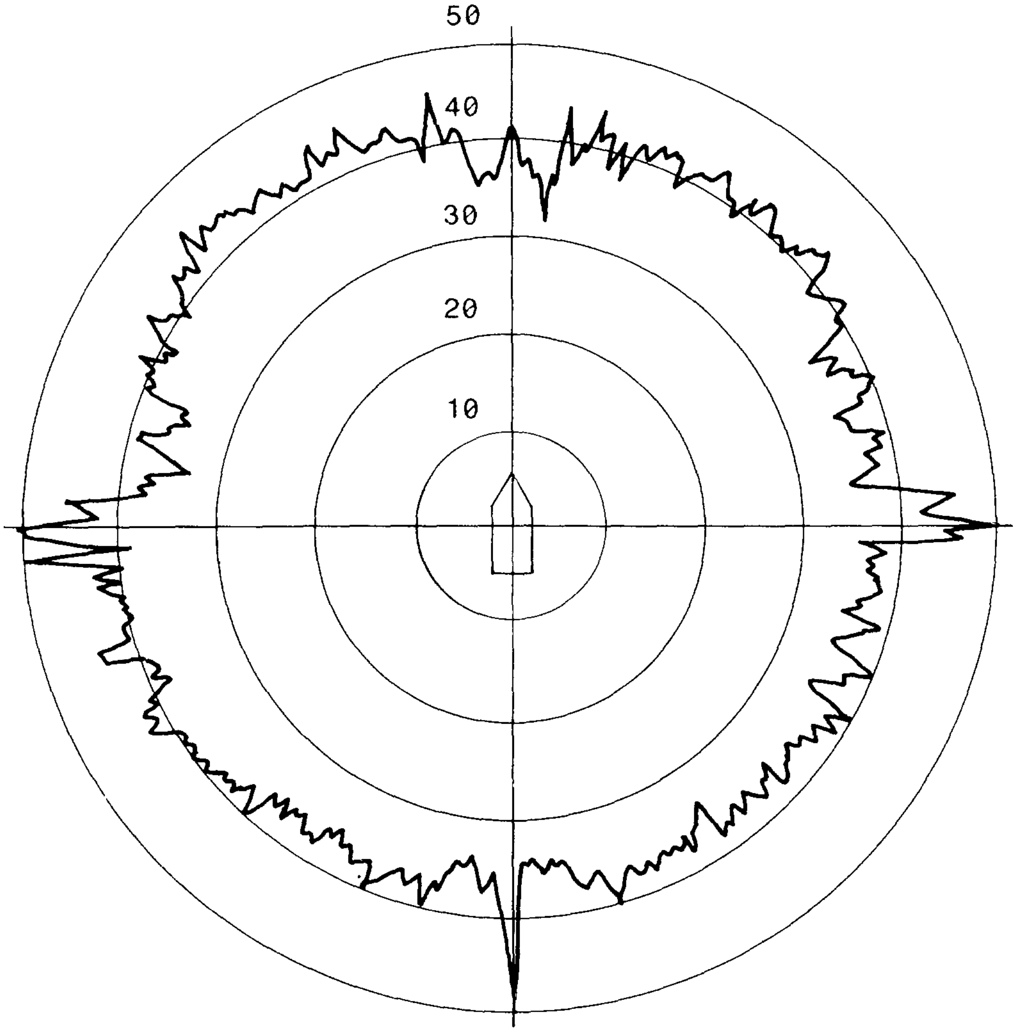
RCS is defined as the cross-sectional area of the imaginary isotropic scatterer which would return to the radar the same power as the target in its particular orientation to the radar beam.

RCS depends on properties of the target—its size, shape and orientation, and the nature of its surface and the properties of the radar system—its wavelength, polarization and whether it is monostatic or bistatic.

Although we can define the RCS of simple shapes in terms of their geometry in relation to the wavelength and position of the radar, a warship is a complex target composed of many flat plates, corners, cylinders, spheres and other less easily categorized shapes. The higher the frequency of the radar, the more significant become smaller and smaller items of detail and the more and more difficult the task of defining the ship as a collection of simple shapes.

A corollary of this view of the ship as a collection of scattering sources is that the radar returns from these scatterers will arrive at the radar receiving antenna with a complex wavefront. This gives rise to the phenomenon of 'glint', where the apparent centre of the target is removed from the physical centre, and may even be outside the target altogether.

The geometry of the ship presented to the radar will depend on the relative position of the radar (e.g. shipborne or airborne) and the relative attitude of the ship (heading, list, heel, roll). Data on the RCS of a ship is often presented in the form of a polar plot as shown in FIG. 1.



AVERAGE (Sectors) : 39.5dBsm

AVERAGE (Total circle) : 40.3dBsm

SECTOR AVERAGES (dBsm)

002.5° to 085.0° : 39.7

095.0° to 177.5° : 37.3

182.5° to 265.0° : 39.2

275.0° to 357.5° 41.0

FIG. 1—TYPICAL RCS POLAR PLOT

Note that these data relate to a particular frequency, polarization and look-down angle from the radar. The RCS is conveniently shown on a logarithmic scale in dB relative to 1 square metre.

Both the incident and reflected waves may be subject to reflection from the sea surface, known as multi-path effects. Theory predicts a maximum multi-path enhancement of 12 dB for a point source. For a distributed target like a ship the maximum enhancement seen in practice on a smooth sea is about 7 dB, falling off rapidly as sea state increases.

We note then that any consideration of ship RCS must be related to the frequencies and polarizations of interest and specified look-down angles, and that measurements of real ships afloat on the sea must make allowance for multi-path effects for comparison with target levels.

FIG. 1 shows the large broadside flashes of a typical warship. While a figure can be assigned to the ship's RCS as the average of the 360° plot, we often exclude the broadside flashes and quote a sector average figure or an average over 90% of azimuth angles.

In the Sea Systems Controllerate (SSC) we need to consider RCS in relation to the operational need for stealth when the perceived threat is from search radars and to improve the fighting effectiveness of the ship against tracking radars and missile seeker radars.

Search Radars

In stealth strategy the design aim is to reduce the RCS of the ship so that it will not be detected by the threat radar at a certain range. The design principle adopted is to reduce the average RCS of the ship when viewed at low angles of elevation on any azimuth angle at the asssumed frequency and polarization of the threat radar. Ground-based and shipborne search radars tend to operate in the E/F bands to achieve maximum range performance, while airborne search radars, where space and weight are at a premium, may be at I/J band. A secondary design aim is that, if the ship is detected, classification should be as difficult as possible.

Although the search radar is unlikely to see the ship from all angles as in FIG. 1 (unless she is steaming in circles), a high resolution radar could well capture a profile of the ship as shown in FIG. 2. This shows the importance of reducing highspots in the RCS signature. This type of profile is captured most easily from head-on or stern-on , when range resolution has its greatest effect.

When the ship is broadside to the radar the effect of ship motion (roll) is to induce Doppler shift in the reflected signal. This can also be used to show up highspots and lead to classification (FIG. 3).

Tracking Radars and Missile Seeker Radars

These aspects are dealt with together as the problems in RCS terms are very similar. Once the ship has been detected and is engaged by an enemy RCS needs to be considered in the context of softkill and hardkill effectiveness. Whether countermeasures are deployed for distraction or seduction they can only have a reasonable chance of success if they are returning a signal to the threat radar more convincing than the return from the ship. This is not just a matter of making chaff rounds bigger, since modern radar technology, or rather the signal processing power associated with it, is increasingly able to discriminate between the wanted and spurious signatures.

The probability of softkill effectiveness needs to be balanced in the combat system decision-making with the option of deploying hardkill measures. These in turn depend on the performance of the ship's own radars and its RCS. Thus the RCS must be considered in the context of the total combat system design.

The ship's own radars present a particular problem, in that they are often in the same band as the threat radar, and their antennas pointing at the threat radar can produce a relatively high RCS.

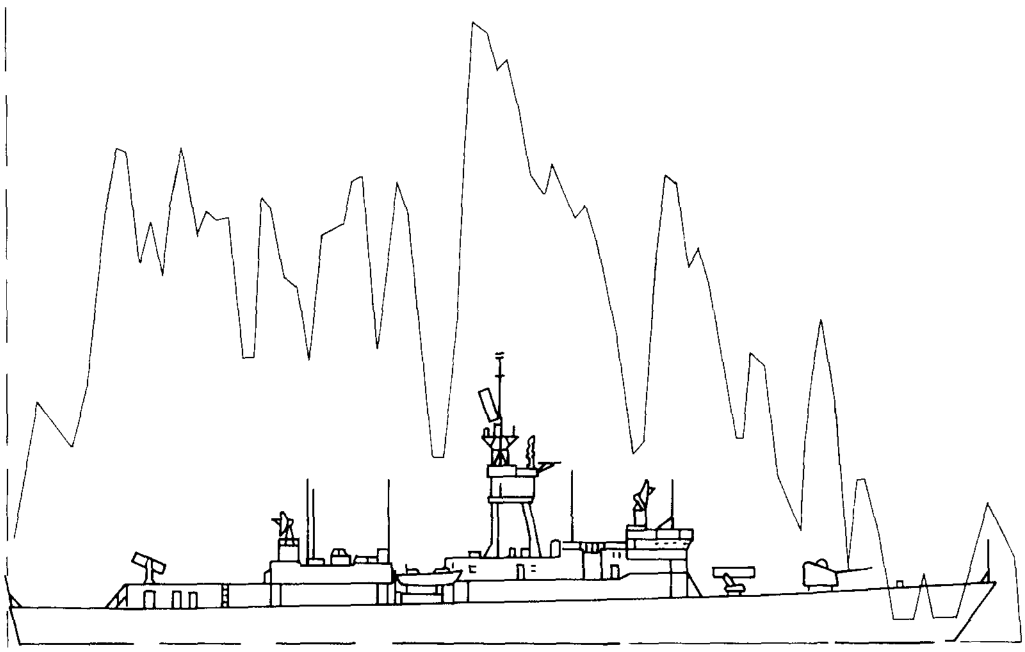


FIG. 2—TYPICAL RCS PROFILE

Measurement of RCS

The staff of Director Combat Systems/Submarines manage contracts with industry to undertake measurement and analysis of ship RCS. There are two formats for these trials. The first, known as a ground-based trial, involves the ship steaming in a circular course some 7 to 9 km from a clifftop site, producing a lookdown angle of about 0·4°. The ship will normally perform port and starboard turns in case there is asymmetry in the RCS, and may be asked to induce roll or rotate her radar antennas to produce additional data if time allows.

Alternatively an airborne trial is arranged, with the ship steaming on a straight course at a steady 10 to 12 knots while the aircraft is flown in circles around the ship. Apart from reducing the constraints on ship operations, this has the added advantage that by varying the height of the aircraft various look-down angles can be covered.

Modern measurement radars can produce high resolution plots of RCS (fractions of a metre) which allows the analyst to identify individual scattering mechanisms on the ship.

Reports are published showing polar plots of RCS in the different frequency bands and polarizations, identifying the major scatterers and the angles over which they are visible to the radar.

Measurements are performed on new construction, post-refit and pre-deployment ships in accordance with the relevant DCI. Information from the measurement reports is used by a variety of authorities. For the platform manager they provide evidence of compliance (or otherwise) with target levels; the ship's operations staff use the polar plots to assess the course to steer when facing a threat situation, and SSC and FOSF staff are able to assess the effectiveness of RCS reduction measures. The reports also form a useful database for DRA's applied research work.

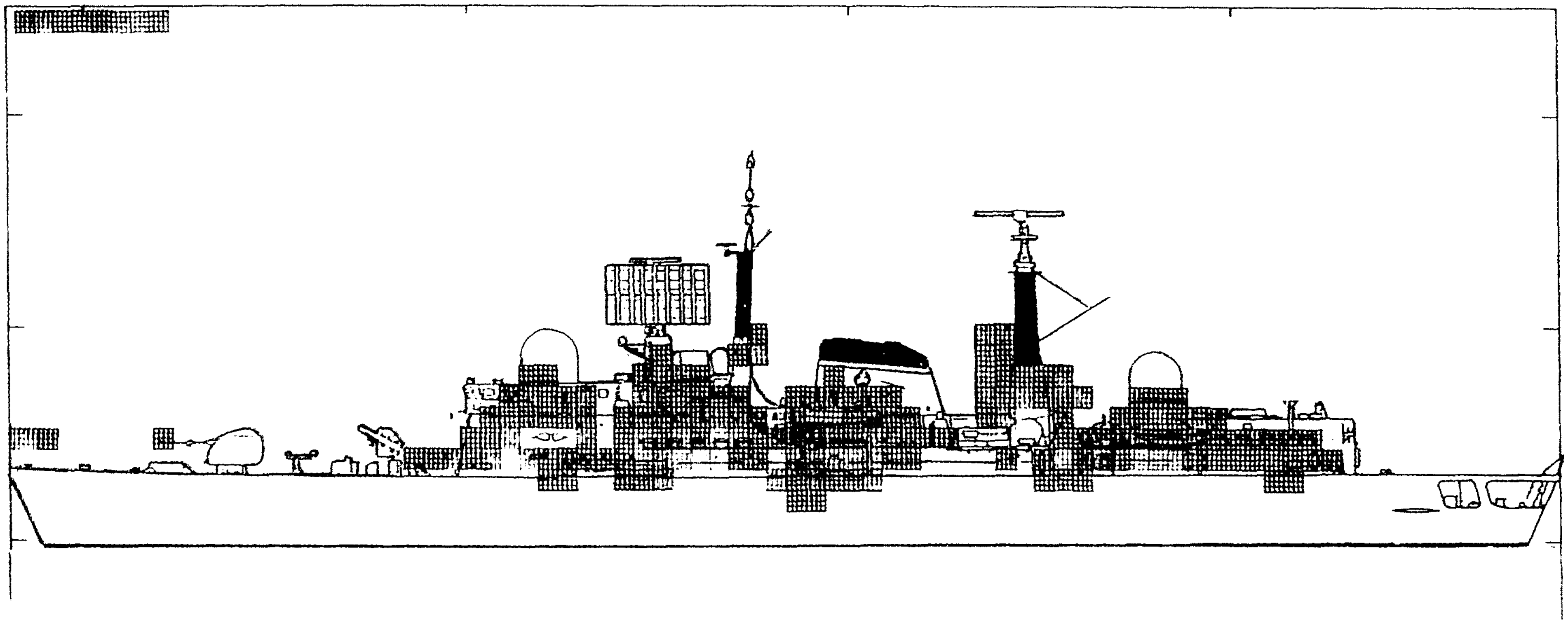


FIG. 3—TYPICAL DOPPLER-PROCESSED RCS PLOT SHOWING EFFECT OF SHIP ROLLING

Policy

A comprehensive committee structure has evolved in the MOD to establish policy for the control of ship and submarine signatures, including RCS, the final group being chaired by ACDS OR(Sea). RCS policy may appear in the relevant platform Staff Target or Staff Requirement or be supplementary to it.

The committees also agree the policy for routine ranging of signatures to ensure compliance with the endorsed levels.

RCS Reduction

Responsibility in the SSC for advice to projects on signature reduction rests with ADNA/SR with advice from DCS/SM and DRA. Guidance by ADNA/SR on the design of hull, superstructure and above deck mounted equipment is published in NES 809 Part I. Part II of the NES, published by DCS/SM, covers guidance on the design of antennas.

In common with other navies, shaping of the superstructure is used to reduce RCS. It is important that the design rules are carried through to the weapons systems, as it is often the weapons equipment mounted topside which causes large RCS returns. NES 809 Part II describes how antenna systems can be designed to reduce RCS.

Most of our major warships have now been subject to RCS reduction measures. The latest ships, the Type 23s, have been shaped in accordance with the design rules, and measurements have shown this to be very effective. Older ships have been treated wih Radar Absorbent Material (RAM) to reduce highspots in the radar signature.

The prediction of RCS during Feasibility, Project Definition and Design has been aided by making scale models (generally 1/100 or 1/200 scale) for testing on the MOD laser range at Locking. Development work is now in hand to produce computer software to predict RCS from ship designs input in CAD format on magnetic media, which it is hoped will greatly simplify this part of the design process.

Submarines

With the submarine, the problem is mainly one of avoiding detection by search radar when a mast or masts are exposed. This could comprise any combination of periscopes, ESM, radar or communications masts or snorts, depending on the type of submarine and the mission.

Although we now have several years' experience of covering masthead equipment in RAM, measurements have shown that reductions in RCS are difficult to achieve. A series of trials is under way to study the causes of the radar returns.

Future Development

Like most other areas in defence there is a continuing need to keep RCS reduction abreast of developments in technology available to a potential enemy. This seems likely to involve wider frequency bands and significant increases in signal processing power, particularly in the capabilities of missile homing heads. A clear definition of the RN's future operational environment is required to ensure proper direction of development activity.

Shaping the steel warship has taken us so far down the path of RCS reduction, but future progress may have to await the development of new materials.

Acknowledgements

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References

1. Gates, P. J.: Radar Cross Section of Warships; *Journal of Naval Engineering*, vol. 29, no. 1, June 1985, pp. 105–119.