RADAR TYPE 996

BY

LIEUTENANT-COMMANDER N. BAILEY, R.N. (RET.)
(Naval Marketing Executive, Siemens Plessey Radar)

ABSTRACT

Radar Type 996 is entering R.N. service in two variants to provide new standards of surveillance and target indication performance to Vertical Launch Seawolf and Sea Dart in four ship classes. The advanced technology features of the radar system and its operation are described in outline.

Introduction

Radar Type 996 is at present entering service in a wide range of ship classes to provide high performance surveillance and target indication radar data to vertical launch Seawolf (GWS 26 MOD 1) and Sea Dart (GWS 30). This article examines the origins of 996 and describes the salient features of the radar system, within the usual constraints, to assist those naval engineers taking up appointments in ships so fitted.

Origins of 996

During the 1950s and 1960s a variety of E/F band surveillance and target indication radars were developed for Royal Navy service which, by the 1970s, had rationalized into two distinct types: 993/994 for gun direction in frigates, and 992 for surface-to-air missile system direction in larger ships fitted with Seà Slug or Sea Dart. To provide a long-range detection capability the B band Type 965, in various antenna configurations, was widely installed. It was recognized also in the 1970s that both Type 992 and Type 965 would need replacing in the 1980s by more modern radar systems capable of matching the performance needs of improved Sea Dart GWS 31 and sustaining this performance in the face of severe jamming. The combined Surveillance and Target Indication (STIR) programme allocated Type 1030 for identification started life in the early 1970s as a D band dual antenna system, changing to the E/F band before being cancelled in 1981. This left the ships of the Fleet without any adequate replacement radar system to provide the vital target indication input to Sea Dart.

Those readers with long memories may recall that Sea Dart originally had the Anglo-Dutch jointly developed Type 988 powerful radar system to give the required performance before the United Kingdom withdrew from that project. In contrast the original Seawolf system GWS 25 MOD 0, designed for installation in the Type 22 frigates and retrofitting to the Batch III LEANDER frigates, included in the development programme the dual surveillance and target indication radars Type 967 in D band and Type 968 in E/F band. GWS 25 MOD 0 with these two surveillance radars successfully entered service in 1978 in H.M.S. *Broadsword* and demonstrated its kill capability in 1982 during Operation Corporate.

Many lessons were learned and re-learned during Operation Corporate. From the radar manufactuerer's point of view the need for assured detection and timely, accurate target indication under all man-made or natural environmental conditions, at the front-end of modern naval point defence or area defence weapon systems was underscored. Political determination to rectify major deficiencies re-invigorated the programme to replace Type 992 with a cost-effective modern radar using a new procurement method. In the meantime the longer range Type 965 was already being replaced by the D band Type 1022. Late in 1982 the Procurement Executive issued to industry an Invitation-to-Tender, together with the Cardinal Point Specification (CPS) for the new Surveillance and Target Indication radar designated Type 996. Four international companies responded to the tender and the production contract was awarded to Plessey Radar in 1984.

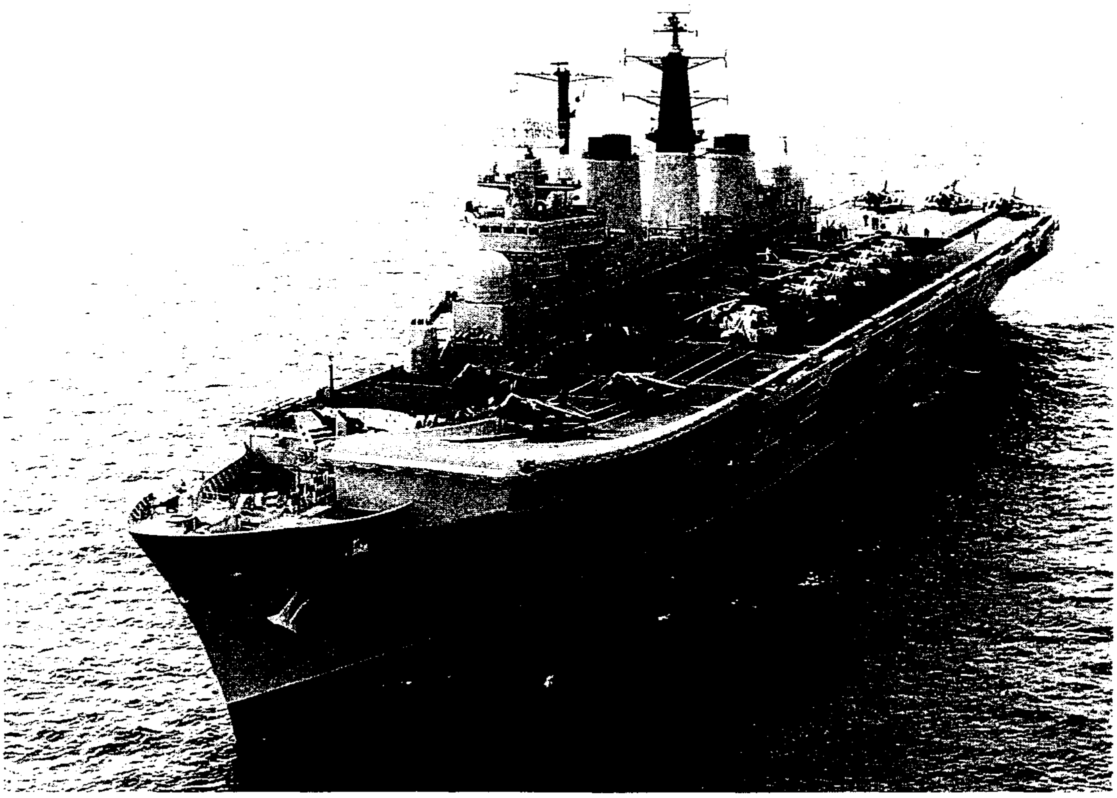

FIG. 1—H.M.S. 'INVINCIBLE' RECENTLY FITTED WITH RADAR TYPE 996(2)

996 Operational Requirements

The operational requirements for Type 996 defined in the CPS were novel and very demanding. The principal challenge was to design a single high performance radar system capable of providing surveillance and target indication data to two very different missile systems—Seawolf and Sea Dart—as well as providing the key inputs to many other functions such as gun direction, aircraft control and picture compilation. Originally, Type 996 was to be fitted on build to the new Type 23 Class of frigates and retrofitted to the Type 42 destroyers, Type 21 frigates and the INVINCIBLE Class light aircraft carriers (FIG. 1). Subsequently, it was decided there was insufficient hull life in the Type 21s to justify a major equipment change. In their place was added the new FORT VICTORIA Class of AORs to be fitted with GWS 26 vertical launch Seawolf.

The radar performance demanded was assessed against a wide variety of targets, including: sea-skimming and high diving missiles of very low radar cross section; long range maritime patrol and fighter attack aircraft; and a variety of surface ships. This performance had to be maintained in the most severe clutter environment, principally land, sea and rain clutter. In parallel very comprehensive anti-jamming features had to be provided. For the first time in many years, the target indication radar was required to provide three-dimensional information to the weapon systems to reduce the overall weapon system reaction time by limiting the search area for the fire control radars Type 909 and 911. The overall weapon system reaction time needed to be minimized by increasing the data rate to twice that of Type 992 and by providing automatic track formation within the radar system direct to the weapon system without the need for manual track confirmation from the command system.

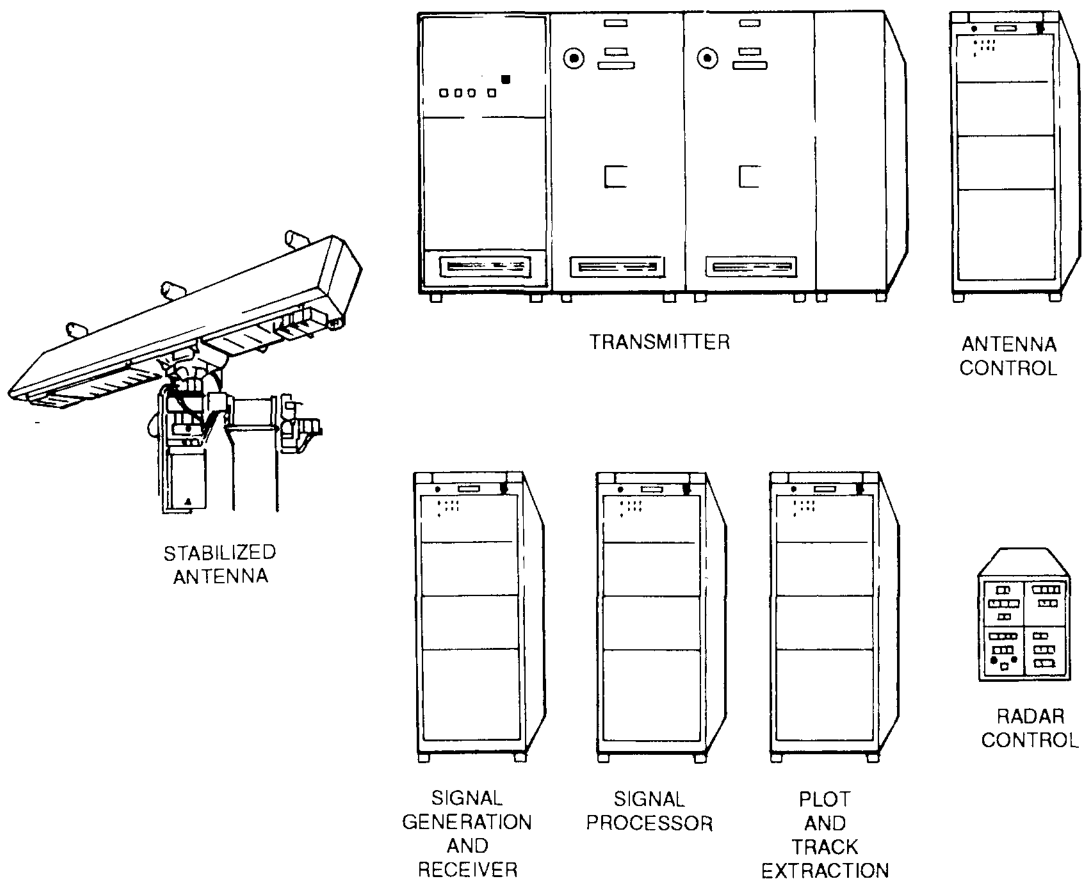

FIG. 2—RADAR TYPE 996 SYSTEM OUTLINE

In addition, the radar system designers were faced with the challenge of meeting the severe ship-fitting constraints imposed by retrofitting Type 996 in the place of existing Type 992 installations. The Type 42 Sea Dart destroyer, in particular, has limited available above-decks weight. Plessey Radar offered a range of radar system configurations employing different technologies. The configuration selected for production was assessed to be the best at meeting the criteria of providing the required performance with an inherent design flexibility capable to matching the two principal R.N. surface-to-air weapon systems and their future enhancements, together with low development risk and delivery within the required timescales.

996 System Elements

The system outline of Radar Type 996 is shown in FIG. 2. Two system variants are currently entering service, 996(1) associated with Seawolf GSW 26 MOD 1, and 996(2) associated with Sea Dart GWS 30. Within each Radar system certain elements are separately distinguished by Outfit identifiers as in TABLE I.

TABLE I—*Outfit identifiers*

Outfit	*System Element*
ADQ	Antenna Sub-system
AMO	IFF Antenna
LFA(1)	Plot and Track Extractor Sub-system

Antenna Sub-System Outfit

The most striking visual feature of Radar Type 996 is the new E/F band Antenna. Outfit ADQ comprises the Antenna and its associated Stabilizer shown in FIG. 2 which is controlled by the Antenna Control cabinet, located in the 996 Radar Office. The antenna is a multiple-beam planar array comprising a vertical stack of stripline distribution networks fed through a waveguide assembly from the rear of the array. The antenna is 4 m wide and rotates at 30 rev/min. It has been designed to operate to full efficiency in the very hot funnel gas environment to be found at the top of the mast, particularly in the Type 42 destroyers, and its distinctive trapezoidal shape minimizes the wind resistance and radar echoing area (FIG. 3). Three sidelobe cancellation auxiliary antennas shown mounted on the top add to the unique profile of this advanced-technology antenna. The ship's maintenance team will quickly discover one of ADQ's most significant features, that is the marked increase of active electronic components at the masthead which are controlled from the below decks equipment. Only the use of active electronics at the masthead can ensure the radar system meets the required performance within acceptable limits of antenna aperature size and weight. These active components include:

- Beam steering electronics, including high power phase shifters.
- Low noise amplification receiver front end electronics, together with receiver protectors.
- Beam switching electronics.
- BITE self-monitoring sub-system controlled from the Antenna Control cabinet.

IFF Antenna Outfit

The IFF Antenna Outfit AMO has been separately identified to give ship installation flexibility. The INVINCIBLE Class CVS and the Type 42 destroyers already have on-mounted IFF antennas associated with Aerial Outfit AZV forming part of Radar Type 1022. However, the Type 23 Class frigates only have one medium range surveillance radar—Radar Type 996—and therefore Outfit ADQ has to accommodate the addition of the IFF antenna. In the future it is expected that it will be replaced by a combined IFF and NIS antenna.

FIG. 3—RADAR TYPE 996 ANTENNA SUB-SYSTEM OUTFIT ADQ INSTALLED IN H.M.S. 'CARDIFF'

Antenna Stabilizer

The Antenna Stabilizer is a two-axis pitch over roll stabilizer designed to operate between the limits, roll $\pm 20°$ and pitch $\pm 8°$. The masthead weight limit of approximately 1000 kg faced the designers with the severe challenge of reducing the stabilizer-antenna weight ratio significantly below the normal 2:1 relationship. By employing high strength forged aluminium alloy, a ratio of 1:1 has been achieved. The stabilizer incorporates a high capacity rotating joint with a 60 way slipring for data and power in addition to the waveguide and co-axial channels.

Antenna Control Cabinet

The Antenna Control Cabinet contains the control, monitoring and interlock circuits necessary to ensure safe operation of the masthead equipment. The cabinet also contains the solid state power amplifiers which replace the amplidynes of earlier systems.

Transmitter

The Transmitter comprises a three-bay cabinet (FIG. 4), with the addition of a half bay to accommodate the vertically mounted high power TWT. The left-hand bay houses the Control and Status Indication unit, together with the Invertor power supplies. Also housed are the heat exchanger and circulator pump for the ship's chilled water primary circuit transfer to the de-ionised water secondary circuit. The centre bay contains the four Invertor power units feeding the EHT transformer. The right-hand full bay contains the EHT capacitors and voltage dividers, the Body Stabilizer and the Grid

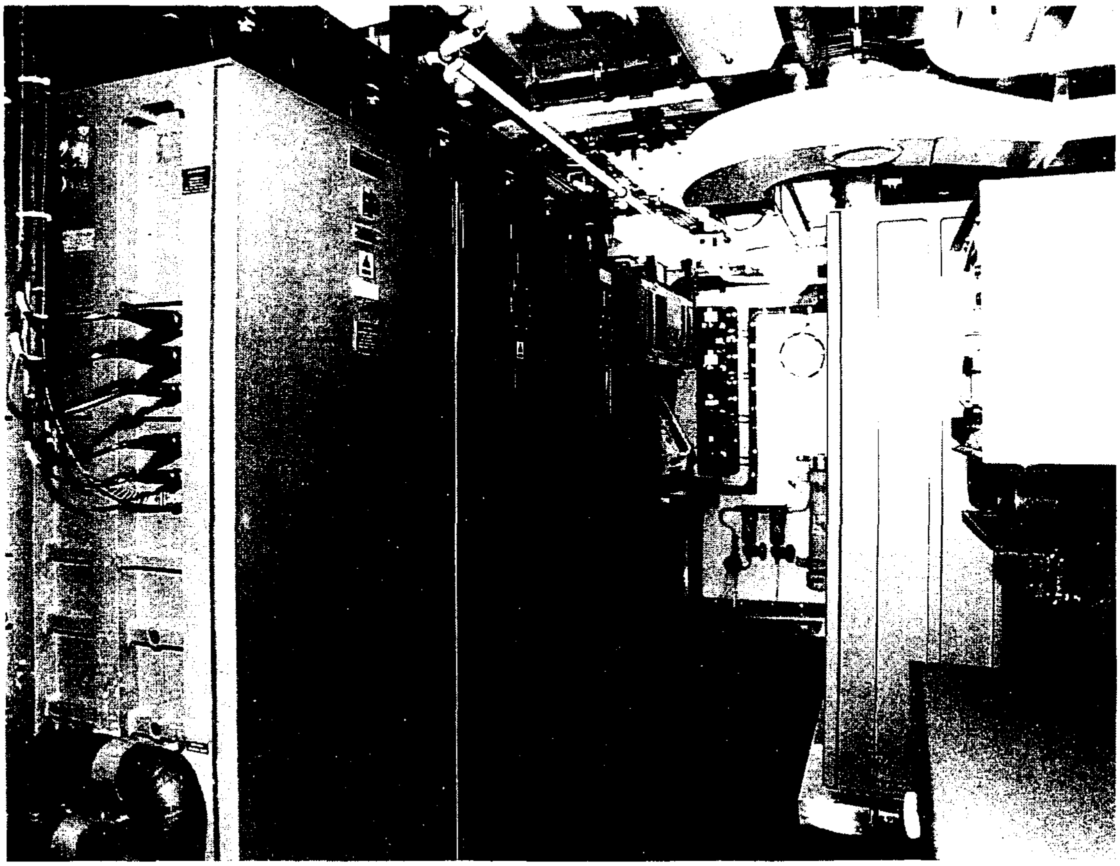

FIG. 4—RADAR TYPE 996 OFFICE EQUIPMENT

Modulator. The high power grid-modulated pulse TWT, mounted on the side of transmitter cabinet for easy access, enables full output power to be achieved instantaneously on application of the modulation signal. Similarly, radar silence can be achieved instantaneously by inhibiting the modulation pulse. The system MTI performance requires highly stable RF inputs to achieve the significant improvement factor due to the transmitter alone. In addition, low distortion ensures good pulse compression is achieved with low range time sidelobes. The transmitter operates at voltages up to 50KV and is water-cooled. The EHT components are generally air-insulated except for resin encapsulation used in vital areas. This has resulted in a compact transmitter of high output capacity but with good access for maintenance.

Signal Generation and Receiver (SGR) Cabinet

The SGR Cabinet comprises a swing frame receptacle containing four card frames. Further line replaceable units can be plugged in to the rear of the cabinet. The agile frequency source and master clock are housed in the SGR cabinet, together with local control and BITE facilities associated with signal generation. On the signal reception side, the SGR cabinet houses the following receiver functions:

- 2 main receivers.
- 3 auxiliary channel receivers.
- 1 jamming assessment receiver.

Their outputs are down-converted and passed to the Sidelobe Cancellation System. After further processing received signals are passed to the Signal Processing Cabinet.

Signal Processing (SPC) Cabinet

The SPC Cabinet comprises a swing frame receptacle and houses the MTI system, the video alignment sub-system and the video output sub-system linked to the ship's data distribution and display systems. Up to seven MTI and seven normal log video outputs can be provided. Other functions carried out in the SPC cabinet include ship's head marker, display triggers and azimuth turning data. Blanking pulses are provided for the ESM system and pre-triggers for IFF when co-ordinated with Type 996, together with jamming strobe outputs.

Plot and Track Extractor Cabinet, Outfit LFA(1)

Outfit LFA(1) is a single-bay cabinet divided into three sections. The top frame contains the height extraction video processing function. Outputs from this frame are passed to the Plot Extractor housed in the centre frame. This comprises a series of microprocessors which correlate the partial plots to form single plot declarations. The completed plots are then passed to the lower half of the cabinet which houses the Ferranti Computer Systems Track Extractor. This unit comprises a series of Argus M700 computers tasked with the formation of valid air and surface tracks without manual intervention, and the maintenance of tracks already initiated. Links to the Command System enable operator specification of certain key parameters such as auto-initiation areas, velocity thresholds and Veto areas. For the Type 23 frigate system the track extractor formats the track data for passing over the Combat System Highway defined by DEF STAN 00-19.

Radar Control Unit

The Radar Control Unit is located in the Operations Room to enable the Command System operators to control and monitor the system performance using the comprehensive radar control facilities. Five VCS style modules make up the complete control system.

996 System in Operation

Signal Generation

The transmission cycle (FIG. 5) starts in the SGR cabinet where a SAW expander initiates a non-linear FM coded pulse which is up-converted to produce a frequency coded pulse output. There are a considerable number of selectable frequency channels spread across a wide bandwidth. Specific pulse patterns are generated using varying groups of pulses of different pulse length and PRF optimized to the operational requirements of three specified modes.

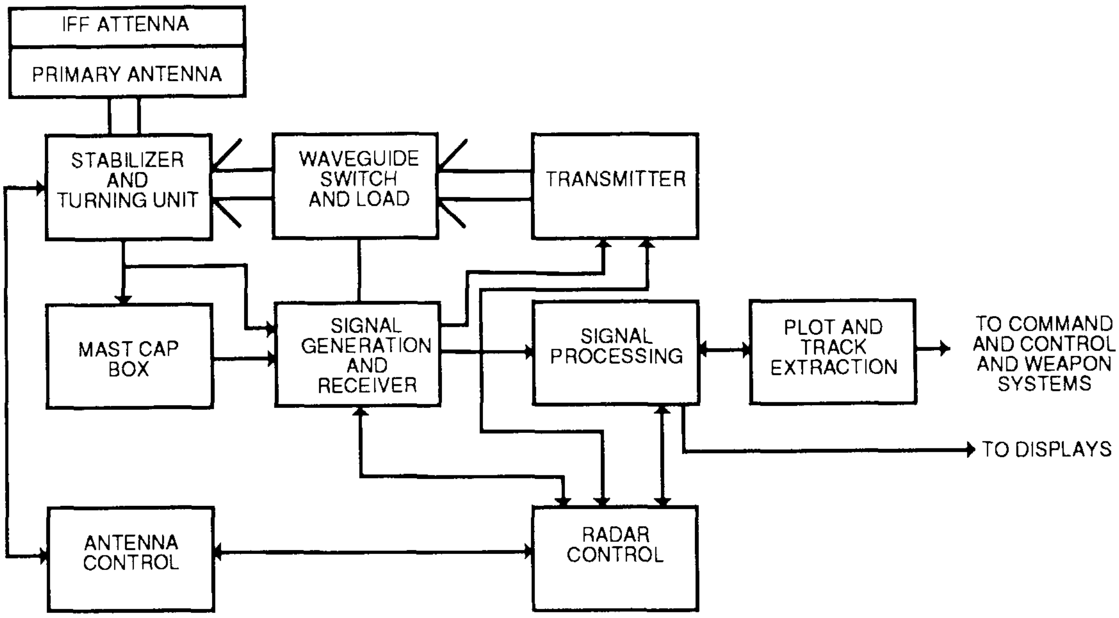

FIG. 5—RADAR TYPE 996 SYSTEM FLOW DIAGRAM

Operating Modes

Type 996 has three operating modes which are operator selectable as follows:

- *Normal Mode* provides both target indication to the weapon systems and medium range air and surface picture compilation data.
- *Missile Mode* concentrates the detection performance to enhance the weapon system kill probability while still providing picture compilation data.
- *Long Range Mode* providing extended range detection for maritime aircraft control purposes and long range air picture compilation.

In addition, there are Frequency Management Modes which control the number and range of channels selected for frequency agility operation.

Transmission

Following generation of the pulses and mixing to the transmission frequency, the pulses are amplified to high power in the Transmitter and fed through the rotating joint to the waveguide power divider network. The divided power passes through elevation beam steering phase shifters via three port circulators to provide isolation between the transmit and receive paths to the vertical stack of stripline distribution networks. The beam is transmitted in preset elevation positions to provide gapless cover from the sea surface to the required high angle, in synchronism with the selected pulse train. This enables the available RF energy to be radiated into free space distributed so as to achieve the optimum performance required for the prevailing clutter conditions and detection demands. It is the capability of precise radiated power management that gives Type 996 the flexibility to match a wide range of operational requirements and different weapon systems.

Reception

On reception the signals are fed through receiver protectors to the low-noise amplifiers. The amplified outputs are passed to the beam former to generate the receive elevation beams. Monopulse height processing is used to extract the angle of sight information. Two main receiver channels are maintained through the system up to the point of elevation measurement in the Plot and Track Extractor. After down conversion the received signals are compressed in the SAW compressor located in the SGR cabinet before passing to the MTI Phase Sensitive Detector at the start of the signal processing chain.

Signal Processing

Signal Processing is applied to In-Phase and Quadrature MTI receive channels as well to the Normal (Non-MTI) channel. Among the various processes performed are:

- Cancellation to remove clutter interference from the wanted signals.
- Ambiguous Range Trapping to remove second trace clutter.
- Constant False Alarm Rate processing to remove the average background noise.

Different MTI pulse bursts depending on beam position are transmitted and have to be processed before integration when the two receive channels are collapsed and a detection declared. Declarations are passed to the Plot and Track Extractor for track formation.

Video Processing

The final stage in the processing chain is the realignment of the various MTI and non-MTI videos to ensure the complex receiver signals are suitable for handling by the Display system.

TABLE II—*Radar Type 996 system variants*

Radar Type	*Weapon System*	*Ship Fit*	
996(1)	Seawolf GWS 26 Mod 1	Type 23 AOR	CURRENT
996(2)	Sea Dart GWS 30	CVS Type 42	
996(3)	Sea Dart GWS 30 Seawolf GWS 26 MOD 2	Type 42 Batch 3	FUTURE
996(4)	Seawolf GWS 26 MOD 2	CVS	
996(5)	Sea Dart GWS 30	CVS	

996 Variants

Two of the variants of Radar Type 996 shown in TABLE II are entering service now. Type 996(1) with IFF AMO is being installed in the Type 23 Batch I and Batch II frigates, and in the AORs. Type 996(2) is being installed in the CVS light aircraft carriers and the Type 42 destroyers. There are no hardware differences other than the addition of the IFF sub-system in Type 996(1).

In the future, certain Type 996(2) installations in the Type 42 destroyers will be re-optimized to provide target indication to Seawolf and Sea Dart. In the CVS an additional Type 996 installation will be fitted when Seawolf GWS 26 MOD 2 is installed.

Conclusion

Radar Type 996 is entering service in increasing numbers after the successful completion of extensive trials to demonstrate the performance of the overall system and its many individual advanced features. The severe ship-fitting constraints have been met and the inherent design flexibility to meet new requirements, is now being exploited. Naval engineers, who have mastered the potential of Type 996, will find their application rewarded when they move from ship to ship and find the different system configurations performing the vital role of target indication to the air defence missile systems of the Fleet.

MAST VIBRATION

A CASE HISTORY

BY

D. WILSON, M.SC., C.ENG., M.R.I.N.A., R.C.N.C.
(Sea Systems Controllerate, Bath)

AND

R. N. SHIMMIN, B.SC.
(British Maritime Technology CORTEC Ltd)

ABSTRACT

The investigation and solution of a case of severe mast vibration in a Type 42 destroyer following the fitting of the new 996 radar is described. As well as being an illustration of a classic engineering problem, the article also draws attention to the role of a post-design warship project in providing support to the Fleet and the importance, in a climate of reducing in-house resources, of the necessary arrangements for professional engineering support from industry.

Introduction

H.M.S. *Glasgow* is a Type 42 destroyer first commissioned in 1979. During the period 1988-89 she underwent a refit (now termed a Repair Period) at Rosyth Royal Dockyard, during which several significant enhancements to her weapons systems were undertaken. One of these was the replacement of the 992 radar by the new 996 set. During the post-refit trials period in September 1989 a very high level of mainmast vibration was apparent, to the extent that damage was being caused to components of this radar, preventing setting-to-work. Initial on-site investigations into the cause were inconclusive and the Director General Surface Ships (DGSS) Type 42 warship project at Bath took on the investigation. As rapid a solution as possible was essential to minimize disruption to the ship's immediate post-refit programme and subsequent operational deployment.