SONAR 2050

THE RN's LATEST HULL-MOUNTED SONAR FOR SURFACE SHIPS

BY

C. PHIN, BSc
(Sea Systems Controllerate, Portland)
A. D. WAITE
(formerly of Admiralty Research Establishment, Portland)
K. HALL, BSc
(Ferranti-Thomson Sonar Systems Ltd)

ABSTRACT

Sonar 2050 is the latest of a generation of hull-mounted sonar. Application of modern technology has made possible considerable improvement in performance and reduction in volume and cost when compared with the earlier Sonars 2016 and 184. Further improvements are already under consideration for probable implementation in the Future Frigate.

BACKGROUND

Much of the pedigree of the RN's anti-submarine warfare (ASW) attack sonars is due to the MOD research programme undertaken in the 1960s and 1970s.

During this period the Sonar Department of the then Admiralty Underwater Weapons Establishment carried out studies into a new generation of Surface Ship Search and Attack Sonars. This major R&D programme culminated in a two-phase demonstrator programme. A BATTLE Class destroyer HMS *Matapan*—commissioned too late to see active service in the Second World War—was taken out of mothballs and converted to a Sonar Trials Vessel. The ship was extensively modified in order to mount two sonar arrays. The larger, rectangular array, mounted on a skeg extending almost half the length of the ship, was used for joint experiments with the USA. A smaller, cylindrical array was mounted in a Bow Dome and used as the demonstrator for a new Duct Sonar which became Sonar 2016, first fitted to HMS *Broadsword* in 1978 and subsequently to Type 22 and Type 42 frigates.

Sonar 2016 provides an all-round Surveillance and Attack capability based upon the use of a large bandwidth long FM pulse. Detection performance in both deep and shallow (high reverberation) environments is good, but, in certain circumstances, classification, and hence false alarm rate, presents problems. Furthermore, the reduction in target strength of target submarines makes detection in high reverberation areas increasingly difficult. Hence an improvement to Sonar 2016 was required and Industry was invited to tender for a replacement. The new sonar was designated Sonar 2050.

Sonar 2050 uses the same cylindrical array as Sonar 2016. A choice of pulse types is available to take account of different oceanographic conditions. The Computer Detection and Tracking processes are essentially derived from those used by Sonar 2016 but the manual operator classification aids of the earlier sonar have been replaced by an automatic active classifier developed by the (now) Defence Research Agency (DRA) at Portland.

During the development phase of Sonar 2050, trials were carried out in HMS *Jupiter* and HMS *Scylla*, both LEANDER Class frigates with a Sonar 2016 fit. The Sonar 2050 equipment trialled in *Scylla* was fitted in a container and located on the forecastle of the ship with cables run to the Sonar 2016 array via an escape scuttle (FIG. 1). The principle of containerization enabled trials fitting and removal from *Scylla* to be accomplished in a few hours once the deck mounting frame had been welded in place.

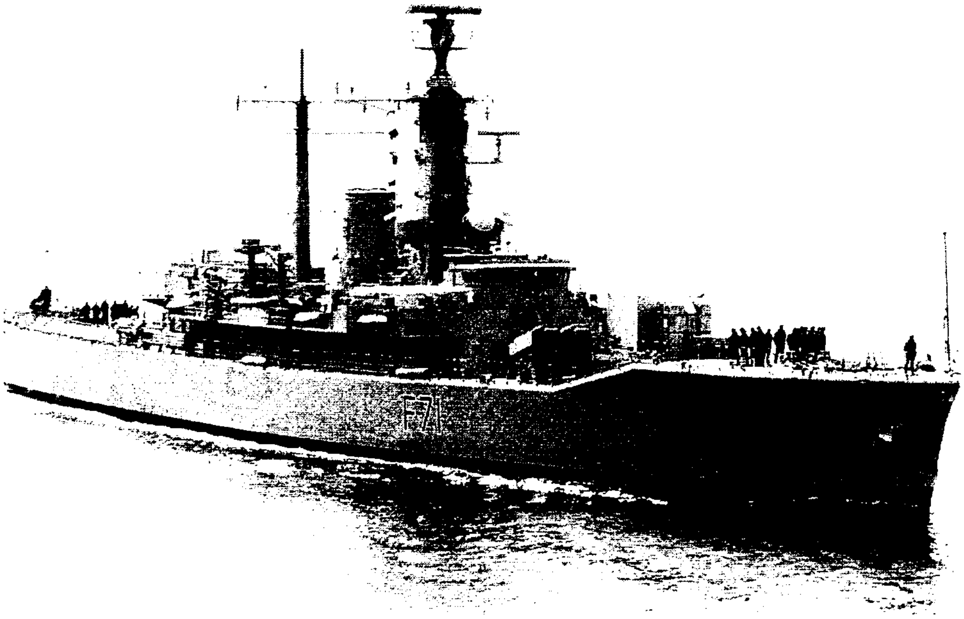

FIG. 1—HMS 'SCYLLA' WITH TRIALS CONTAINER ON THE FORECASTLE

Containerization was extended to the rest of the production programme, allowing each system to be assembled, commissioned and tested at the factory in its container and subsequently delivered to the dockyards in the container which provides a stable, protective environment for alongside storage until required for ship fit. When empty, the container is returned to the factory for re-use.

Taking advantage of early availability of the first systems and delays in the Type 23 programme, the first sonar 2050s were fitted to HMS *Brilliant* and HMS *Broadsword* at refits. Initial operating problems were overcome by adjustments to scaling parameters at various stages in the processing.

MODES OF OPERATION AND PERFORMANCE

Active Modes

The design of an active sonar has in the past been governed by the need to compromise between performance under reverberation-limited and noise-limited situations. However, due to technology advances which allowed greater processing capability within the space available for a sonar, it has been possible to design into 2050 an optimized performance in both conditions, compensating in some measure for the reducing target strength of submarines.

Sonar 2050 uses the same bandwidth FM pulse as Sonar 2016 but a CW pulse has been introduced to exploit submarine Doppler and so improve performance in very high reverberation areas. Long and short FM pulses of identical bandwidths and long and short CW pulses may be transmitted. Combinations of these pulses give a choice of five active operating modes for different oceanographic conditions.

Active Detection Range

Detection range may be either *noise*- or *reverberation*-limited. It is necessary to determine the predominant background for a given environment and tactical situation in order to select the appropriate mode of operation.

If the sonar is noise-limited the allowable Propagation Loss before the echo signal becomes lost in the background is given by:

$$2PL = \left[SL + DI + 10\log T - \left\{ \begin{array}{c} 10\log WT \\ \textit{or} \\ 10\log W_r/W_s \end{array} \right\} - RD \right] + TS - BN.$$

where PL = Propagation Loss (dB)
SL = Source Level (dB)
T = Pulse Length (seconds)
W = System Bandwidth (Hz)
W_s = Pulse Bandwidth (Hz)
W_r = Replica Bandwidth (Hz)
DI = Receive Directivity Index (dB)
RD = Recognition Differential (dB)
TS = Target Strength (dB)
BN = Background Noise (dB)

The term 10 log WT is a term to cover mismatch. For an optimum matched filter processor, W = 1/T and hence 10 log WT = 0. A replica correlator system is effectively a matched filter processor and for equal pulse and replica bandwidths the corresponding mismatch term 10 log W_r/W_s is also zero.

The bracketed expression is the Detection Potential (DP) of the sonar and includes all the relevant equipment parameters.

The value obtained for PL is then used with propagation models to determine detection ranges. A simple propagation model assumes spherical spreading and absorption:

$$PL = 20\log R + \alpha R\, 10^{-3}$$

where R is in yards and α is the absorption coefficient which varies with frequency. α is in units of dB/kyd and at 2050 frequency is approximately unity. Note that 2 PL is proportional to DP and typically, using this equation, an increase in DP of 5dB will increase the detection range by about 15%.

If the sonar is reverberation-limited, and assuming that both target and reverberation share the same propagation path, the limiting range is given by:

$$10\log R = [10\log 1/T_r\,\theta_h] - RD + TS - 44 - SB.$$

The bracketed expression is the Reverberation Index of the sonar and includes the equipment parameters determining the performance of the sonar against a reverberation background. T_r is the Resolved Pulse Length and θ_h is the horizontal receive beamwidth, factors which determine the insonified surface and hence the magnitude of the reverberation against which a target echo is to be detected. SB is the Reverberation Back Scattering Strength and is dependent upon the sea bottom or surface as appropriate to the environment. (For surface duct sonars the dominant reverberation in shallow water originates from the bottom and, in deep water, surface reverberation can be a problem.)

Note that + 5 dB in Reverberation Index trebles the reverberation detection range, in sharp contrast to the 15% or so increase in range for +5 dB in Detection Potential when noise-limited.

The dramatic change in performance as the sonar changes from being noise limited to reverberation limited can be understood by comparing the relevant expressions:

when Noise Limited DP $\propto$ 40 log R or 10 log R^4

when Reverberation Limited RI $\propto$ 10 log R.

Thus DP (embracing the equipment parameters which determine the noise-limited range) varies as the fourth power of the range whereas RI (embracing the equipment parameters which determine the reverberation-limited range) varies directly with range.

The dilemma of the Active Sonar designer thus becomes evident. Any attempt to improve the noise-limited range—for example by decreasing the frequency of operation—may reduce the Reverberation Index, in this case by increasing the horizontal beamwidth, θ_h, given the same array size, and hence result in the required range being limited by reverberation.

Signal Processing Considerations

The technology available during the design of the earlier Sonar 2016 meant that the replica correlators, used for the detection of the FM pulse, could only handle a limited dynamic range signal and hence front end Automatic Gain Control (AGC) amplifiers were used to limit the dynamic range of the signal entering the correlators.

The gain clearly has to change fast enough to follow the decay of the returned signal. Unfortunately, this means that the gain changes significantly over the length of the pulse and the resultant amplitude and phase distortion produces an undesirable spreading of target echoes in bearing (phase). The performance against reverberation, which we have seen to be crucially dependent upon the horizontal receive beamwidth (a factor determining the Reverberation Index of a sonar), is thus not fully achieved because the target echo spreads into more bearing cells than its physical size subtends (except at short ranges).

Sonar 2050, however, is designed to be a fully linear system with wide dynamic range correlators and no AGC. The target echo therefore only occupies the bearing cells subtended by its physical size (perhaps plus one for quantization). The effective value for θ_h is thus significantly smaller than the value for Sonar 2016 and the detection ranges in reverberant backgrounds are greatly increased (halving θ_h increases RI by 3dB and hence doubles the reverberation-limited range).

Passive Mode

Sonar 2050 provides a passive mode simultaneously with the active or it can be passive only.

Passive processing is provided using the same beamforming as the active and occupying a wide frequency band below the active transmissions. The small aperture of the array at these frequencies and the self-noise of a moving surface platform prohibits the detection of all but the noisiest of submarines, but surface vessels are detected and tracked at significant ranges providing a useful covert capability during radar silence operations. The primary function of the passive mode is for self-protection against torpedoes.

EQUIPMENT OVERVIEW

A typical Sonar 2050 layout is shown in FIG. 2.

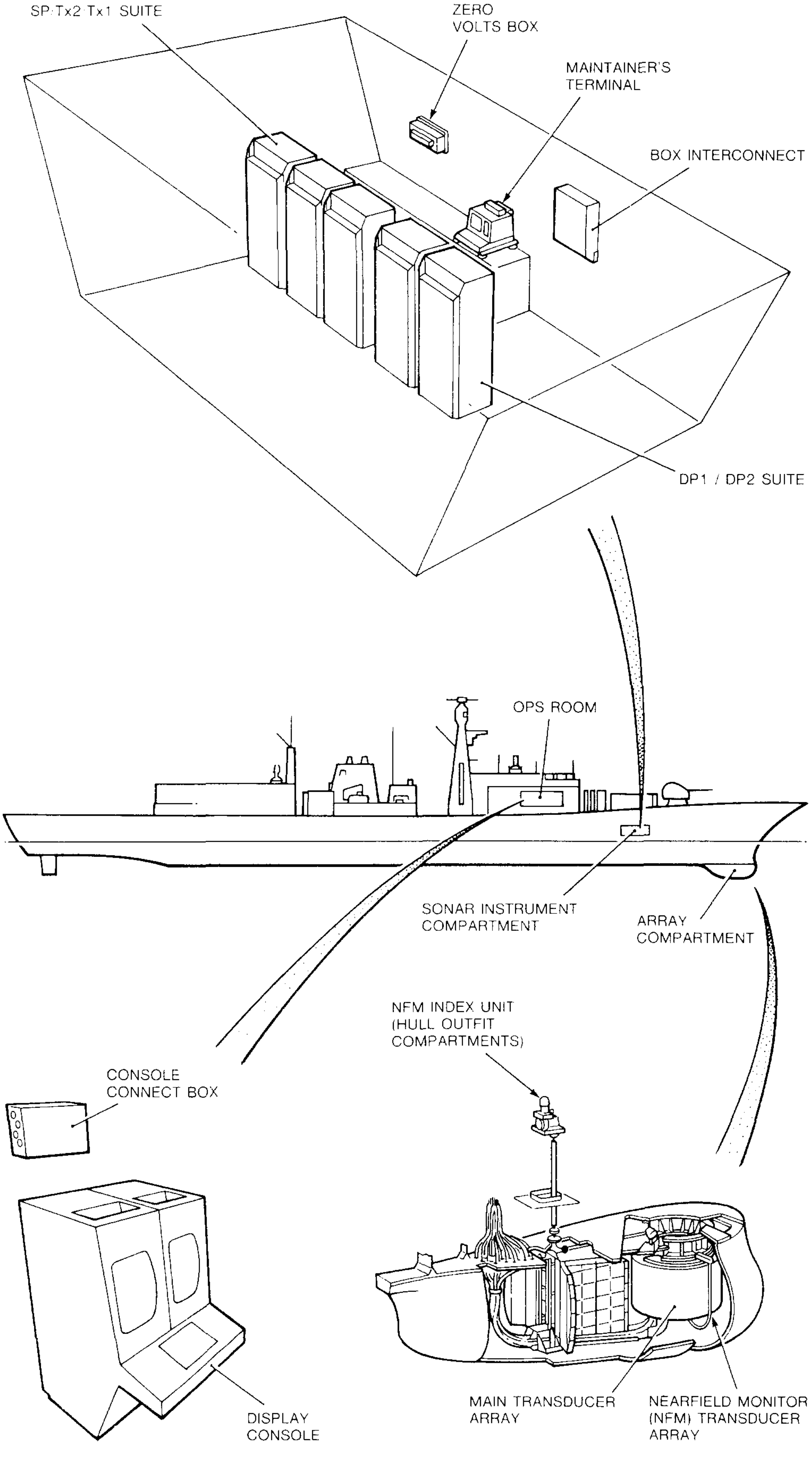

FIG. 2—TYPICAL INSTALLATION OF SONAR 2050

The Array

The array is common to both Sonars 2016 and 2050. A major constraint in its design was the requirement to back-fit the array in LEANDER Class frigates and similar ships then fitted with Sonar 184M. This limited the diameter of the cylindrical array and, although the dome had to be increased in size, its depth below the keel could not be increased because of docking problems.

Given the size of the array, a balance between noise-limited and reverberation-limited performance is achieved by choosing suitable active frequencies. For good performance in high reverberation backgrounds the horizontal receive beamwidth—a factor in determining the insonified surface and hence the magnitude of the background reverberation against which a target echo is to be detected—should be kept small, and this requirement limits the lowest usable frequency.

The array is assembled from 64 staves—each stave containing 12 transducers connected as 4 'quaves' ('quave' = QUarter stAVE) of 3 elements each. The transducers, either singly or in quaves, are broadly tuned by the inductance of autotransformers which match the input admittances of 32 groups of 8 quaves to 32 transmitters.

In the transmit mode all the quaves in a ring are fed simultaneously, resulting in an omni-directional horizontal transmission. Phase delays are introduced between rings, however, in order to achieve vertical beamwidth.

In the receive mode each stave is formed into vertical beams which can be steered to depressions of either zero, 3.5 or 7 degrees. The resultant stave outputs are then used in the horizontal beamforming process.

A number of co-directional beam pairs are formed. Twenty staves are used to form each pair of 'half beams'. Each half beam uses 10 staves, amplitude weighted to reduce the side lobes and phased to a plane. The arrangement is shown in FIG. 3. The fine bearing θ of a target is found by measuring the phase difference ϕ between the two co-directional half beams.

$$\phi = \frac{2\pi f d}{c}\theta \text{ (for small values of } \theta)$$

where d is the distance between weighted phase centres of the two groups of 10 staves.

Inboard Processing

The structure and processing techniques adopted for Sonar 2050 were solidly based on those implemented in Sonars 2016 and 2020, deriving from the original work done at ARE, Portland. The principal advances in the 2050 implementation were the use of digital techniques from as early in the processing chain as possible, compared to the analogue circuitry of the previous generation of sonars, and the employment of multiple, distributed processors. The latter feature encompassed the use of embedded microprocessors within all stages of signal processing, and data processing based on a multiple M700 linked Eurobus architecture.

Although Sonar 2050 made use of the original 2016 array, the availability of extensive processing power, especially within the signal processing section, allowed full electronic stabilization against the effects of ship's motion to be incorporated, replacing the earlier 2016 attempts at mechanical array roll stabilization.

The array elements act as both acoustic transmit transducers and receive hydrophones, and analogue signals to or from the array elements are coupled through Transmit/Receive (T/R) Switches, as shown in the overall structure diagram of FIG. 4. The T/R Switches incorporate preamplifiers and pass received signals to the Preconditioner which performs further amplification, basic filtering, and analogue-to-digital conversion. All processing from this point onwards is fully digital, with the first stage being a Beamformer. This produces a single set of stabilized half-beams which are common to all subsequent processing stages. The time-domain beamforming techniques employed here, like many of the processing structures and algorithms used in later stages, are based on original work pioneered by Dr T. E. Curtis at ARE, Portland.

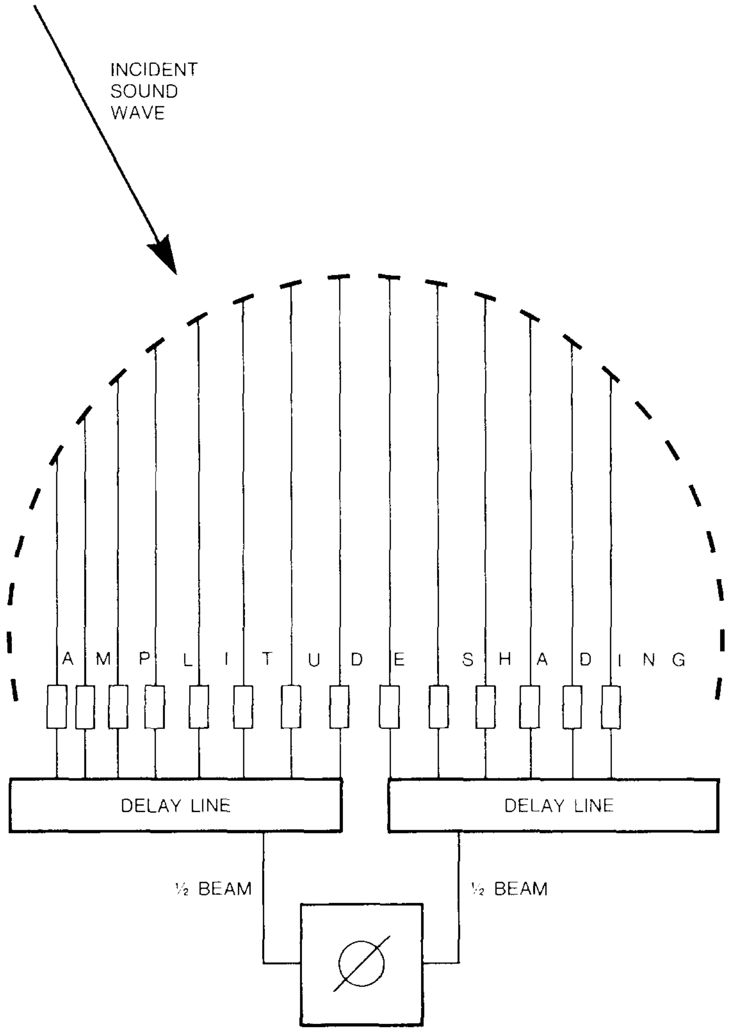

FIG. 3—ARRAY CONFIGURATION

Following beamforming, the beam time-samples are reduced to the appropriate complex-baseband form within each signal-processing subsystem and filtered to the frequency band of interest using digital, finite-impulse-response (FIR) filters. The 2050 Sonar contains three SP subsystems, FM Active, CW Active, and Passive.

The FM Active Processor determines the accurate range and bearing of a contact. It does this by utilizing a linear-period frequency-modulated (LPFM) transmit pulse and then correlating the returning echoes within each beam against a replica of the transmitted signal. The replica correlation process produces a sharp peak in its output when the received signal matches the transmit replica, and the measured delay allows a contact range to be

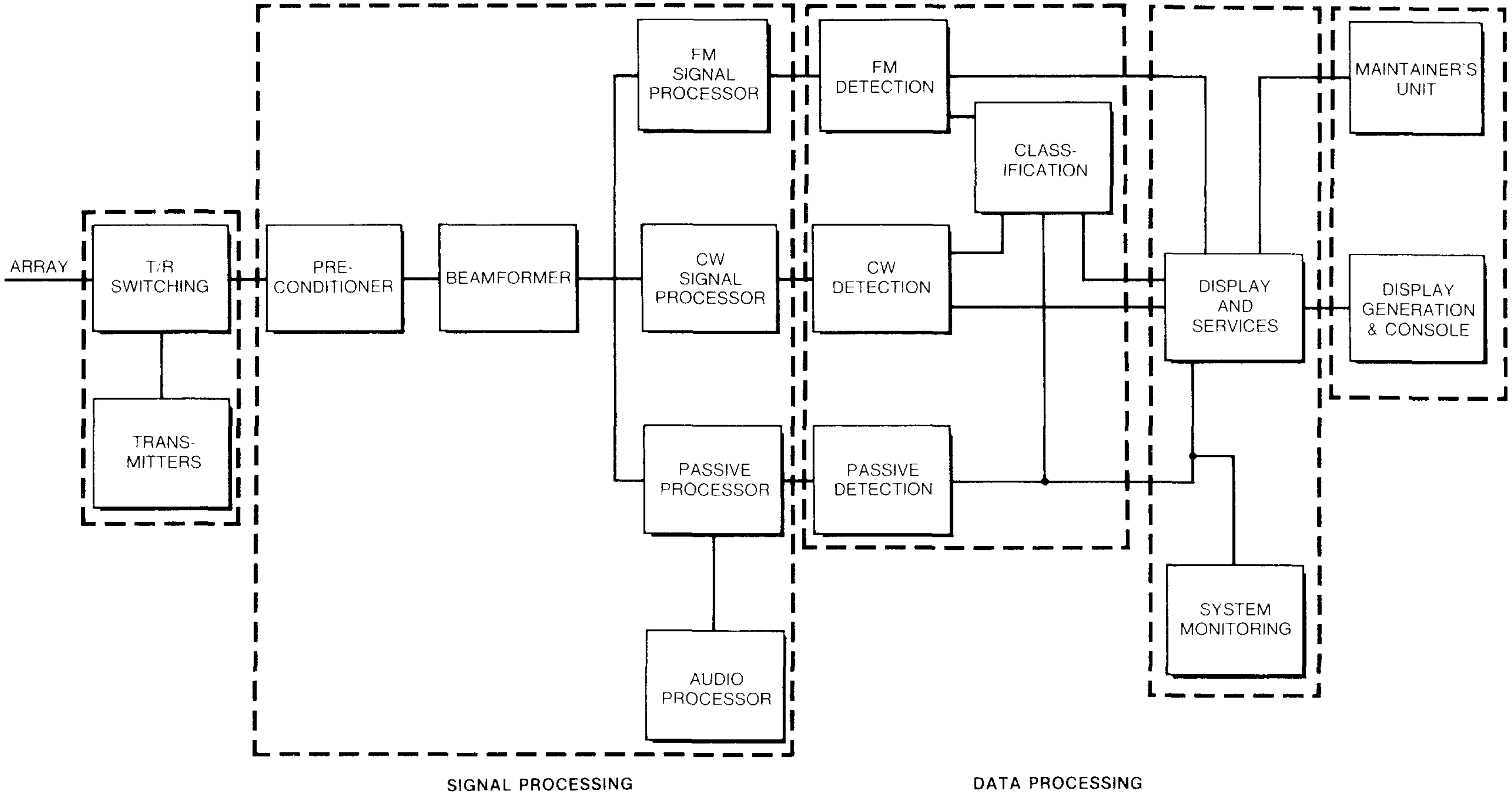

FIG. 4—SONAR 2050 OVERALL STRUCTURE

calculated. The phase difference between the correlation peaks in adjacent half-beams is used to calculate the accurate bearing of a contact within a particular beam.

The CW Active Processor is an additional feature over those provided in the previous 2016 sonar set, and determines the relative velocity of a contact by measuring the Doppler shift in frequency of the returned echoes of a transmitted pulse of constant frequency. Again, this processing is carried out for each formed beam, and full compensation is applied for the effects of own-ship's motion. The range of the contact can also be determined by measurement of time delay but here accuracy is limited by the length of the transmitted pulse and is much less precise than the FM subsystem.

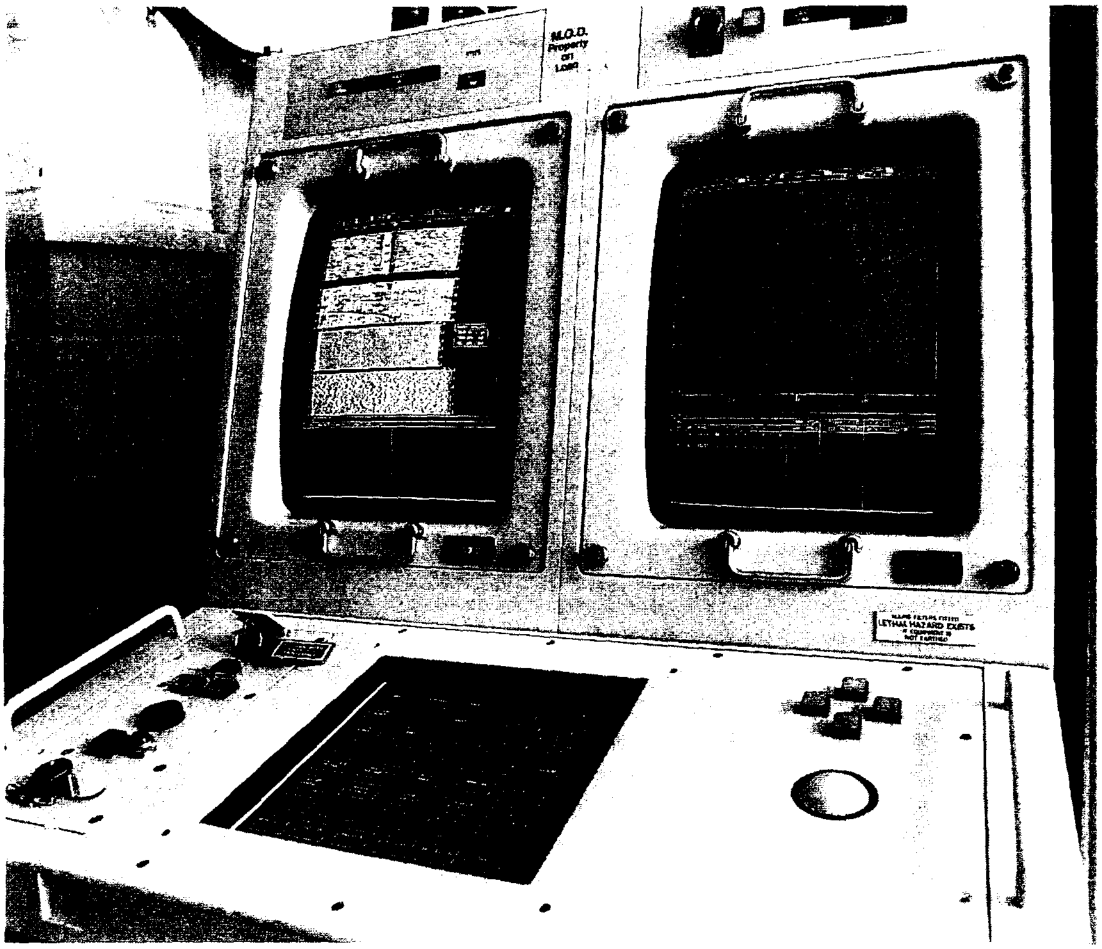

FIG. 5—SONAR 2050 OPERATOR CONSOLE

The Passive Processor provides data on contacts detected solely through their own emitted noise. The original broadband function installed in 2050 is similar to that in 2016 where cross-correlation between adjacent half-beams over relatively long periods is used to recover signals that are normally concealed by other sea noises. Only bearing information is available, of course, since there is no way to measure the signal transit time from the noise source to the array. The Passive Processor can be used separately or in combination with either or both of the Active Processors, although steps have to be taken in the latter case to reduce the disruption caused to the long-term Passive correlation processing by the periods of active transmission from the array.

Each of the SP subsystems utilizes a similar set of hardware modules and they are generally structured as a data pipeline with point-to-point links between processing modules and a number of embedded microprocessors to handle control and monitoring aspects. The processing modules all use the same general-purpose Digital Signal Processor PEC which is programmed (using PROM) for each specific application. The algorithms employed are essentially the same as those originated by ARE, Portland for use in Sonar 2016.

Outputs from the three SP subsystems are combined into a common data stream for transmission to Data Processing. The latter is again, notionally, divided into three subsystems (FM, CW and Passive) for the purposes of contact detection and classification, followed by stages of picture processing and preparation of the data for display. Data processing also encompasses overall system control and monitoring, and interfaces to other ship systems.

The processing power requirements for 2050 DP were considerable, and far in excess of the single Ferranti 1600B computer used on 2016, so a distributed, multiprocessor architecture was adopted, following its original development at Ferranti, Cheadle Heath, as part of Sonar 2054. This architecture uses 25 M700 computers in a network of 7 Eurobuses. Communication is handled by a combination of inter-Eurobus parallel links and 1553B serial connections. The algorithms employed are a combination of those developed by ARE and others proprietary to Ferranti, with the implementation being done in CORAL in a MASCOT environment.

Display of the processed results is accomplished using high-resolution, raster-scan displays with two 17 inch diagonal screens being available to the operator. Screens are mounted side by side, and operator interaction is via a touch overlay on a large plasma panel, mounted in a desk unit below and in front of the screens, and a tracker ball with fine-positioning keys (FIG. 5).

Signal Conditioning

Although the bulk of Sonar 2050 is digital, there were some analogue design problems to be solved during development. The first problem was that of the limited space available to process the 256 analogue channels received from the array. The solution adopted was to design and implement a thick-film hybrid module to handle all amplification and filtering functions for a single channel. Each hybrid module consists of a ceramic substrate on which are printed the required pattern of conductors and resistors, using conductive inks in a silk-screen process. The substrate is fired to turn the ink patterns into actual conductors and resistors; then active components such as transistors and operational amplifiers, generally as bare silicon chips, are added and connected into the circuit with fine wire bonds. The complete assembly is enclosed in a hermetically-sealed metal can.

The second problem in the analogue design was to accommodate the different dynamic ranges in signal strength required by the Active and Passive functions. The ideal solution would have been to provide completely separate analogue (and digital) channels for Active and Passive, but this was precluded by space and cost constraints. The compromise adopted was to split the input signal within the hybrid module circuitry into two frequency bands, covering Active frequencies in the higher band and Passive frequencies in the lower, and apply different levels of gain to each band as required by the operating conditions. The two parts of the signal are then recombined to form a single output from the hybrid module. Gain for each band, and for the module overall, is controlled automatically within the 2050 system and is set by digital control inputs to the hybrid modules.

Sixteen hybrid modules are accommodated on a standard double Eurocard PEC in two groups of eight, with the outputs of each group multiplexed into an analogue-to-digital converter (ADC), and a total of 16 PECs are used to handle the 256 analogue channels from the array. Eight-bit digital outputs from the ADCs are multiplexed in turn to provide a single output data stream from the Preconditioner to the Beamformer. The Beamformer performs all of its processing using only this 8-bit data but, for later stages of processing, the data is supplemented by a 3-bit exponent representing the gain setting applied to the Active or Passive signals as appropriate, allowing computation to be carried out in a block-floating-point format.

Digital Signal Processing

At the time that 2050 was in the development stage, general-purpose digital signal processing devices were beginning to appear on the market. These were generally very limited devices mostly aimed at telecommunications and not powerful enough to meet the requirement. Sonar processing is characterized by the need to process a large number of continuous data channels in parallel, applying a number of relatively simple algorithms sequentially to each data channel, and is thus unlike any other form of computation. The DSP devices available then (and even now) are usually intended to handle only a single data channel, and lack the general data handling facilities.

Prior to development of 2050, Ferranti, Cheadle Heath, had taken the decision to develop a piece of digital-signal-processing hardware which would handle efficiently the majority of sonar algorithms and processes. Where this was not possible—generally where the data throughput required was too great—specialized, single-purpose PECs would be designed, thus minimizing the number of PEC types in a given system and, hence, the through-life cost.

The general-purpose PEC developed was based on the concepts produced by Dr Curtis at ARE, Portland and was (perhaps unimaginatively) entitled the Digital Signal Processor, or DSP. Eighteen DSPs were used within the signal processing part of 2050 to carry out a variety of functions. Within the Passive subsystem the DSP carries out auto- and cross-correlation as part of the broadband function, and Discrete Fourier Transforms for narrowband spectral analysis. The latter function is also performed within the CW Active subsystem for Doppler extraction. In the FM Active subsystem DSPs perform the extraction of fine bearing for contacts, and in all subsystems DSPs are used in the latter stages to normalize results, remove trends, and to format the computed data for transmission to Data Processing.

The DSP is based around a 16 × 16 Multiplier-Accumulator (MAC) device, complemented by an AMD Am29116 16-bit bipolar microprocessor, input and output stores, and a number of AMD bit-slice devices to handle the complex data addressing schemes required by sonar processing algorithms in the most efficient manner. The DSP functions are controlled by 80-bit wide microcode instructions held in PROM on the card, and specific to the functions to be carried out by that DSP. There is space for several program functions to be accommodated in each DSP such that the number of distinct PEC types in the system is minimized.

The DSP was designed to operate on a 200 ns processing cycle. This may not appear fast by today's standards but the architecture of the card is such that several operations can take place at the same time. Each 80-bit wide microcode instruction gives individual control over all of the DSP's functions. The MAC, the Am29116 processor, and the address generators all produce results within a single cycle and all operate in parallel, so that the DSP can perform a 1024 × 1024 complex DFT, including all data input and output, within 13 ms. Subsequent versions of the DSP were enhanced to double this performance.

To support the DSP PEC a VAX-based assembler and simulator were written so that microcode could be easily generated and tested and, using a hardware emulator which was also built, programs could be executed and debugged at full speed. Finally, an in-circuit emulator was developed that allowed the debugging of programs executing within the target system.

Although the DSP card is versatile enough to carry out all sonar signal processing functions, in some areas too many would have been required to make it a cost-effective solution. In these cases special dedicated PECs were designed to carry out a specific function in the most efficient way.

These specific functions included the Beamformer, digital bandshifting and filtering, and replica correlation within the FM Active Processor. The Beamformer task is very processor-intensive and requires the manipulation in real time of complicated data addressing schemes. The replica correlation process requires even more processing power since the received signal in each beam has to be correlated against a replica of the complete transmitted waveform each time a new beam sample is received. The Replica Correlator PEC developed contains a replica store, data stores, and four MACs running at 8 MHz for processing. Sixteen of these cards were required to process all the beams under control of a sequencer PEC which distributed data such that every processor cycle could be usefully employed.

Even where specific hardware was employed, use was made of DSPs to support it in all cases, generally recalculating processing coefficients as necessary to provide compensation for the motions of own ship. For the FM Active Processor these functions included computation of the required replicas for each beam.

Data Processing

The data processing function is supplied by application program software which is initially delivered to the systems on magnetic tape then stored on Winchester Disk. These programs develop the information available at the output of the signal processing function in order to present it in a reduced, meaningful and usable form to the 2050 operator and to other units of the combat system.

The functions carried out by the data processing software are:

- Active FM Display Processing
- Active CW Display Processing
- Passive Broadband Display Processing
- FM and CW Auto Detection
- Automatic Contact Following
- Simple Oceanography
- Active Automatic Classification
- Target Motion Analysis
- Man Machine Interface
- Command System Interface
- Logging and Data Extraction
- Fault Monitoring
- On-board Training
- Geographical Stabilization
- Wreck Chart Store and Display

Contact data is passed to the appropriate Command System which in turn supplies targeting information to the Magazine Torpedo Launch System

(MTLS) and to the MATCH system in order to prosecute submarine targets using deck-launched or helicopter-launched torpedoes.

The data processing software, implemented in CORAL 66 language, and the MASCOT runtime operating system is mapped on to twenty-seven M700 processors connected using eight Eurobus highways and contained in two Naval Equipment Practice (NEP) cabinets.

Man Machine Interface

The functions listed in the previous section are controlled by a single Operator at the twin display console. Operator injections are handled by a Plasma Panel which is a display device with a matrix of infra-red beams set across the surface effectively acting as a touch-sensitive display. The display is under software control. Using these devices an MMI was designed in conjunction with the School of Maritime Operations, HMS *Dryad*.

The main criterion behind the MMI is to give the Operator all the information he requires in as uncomplicated a way as possible to reduce confusion and fatigue. The displays consist of four main sections. From top to bottom of the display are: two lines at the top of the displays showing status information such as range scale, Tx mode and cursor readout etc; beneath these status lines are the active, passive, self noise and oceanographic pictures; beneath these is the fault line; and the bottom area contains the tabular information such as contact and environmental totes.

To keep Operator injections to a minimum, the menu structure on the Plasma Panel consists of eight pages with only two levels of menus. Pages of keys are accessed by either using the ‘firm keys’ at the bottom of each page or by requesting a particular function which automatically displays the appropriate page to control that function. Default settings for parameters such as Tx mode, Range scale, Power, Dip, etc., are programmed into the system to obviate the need to set up parameters repetitively. The greatest benefit of the Plasma Panel is that the Operator need not remember lengthy sequences of commands to input as each key has its function written on it. Erroneous key injections are rejected and the Operator prompted accordingly.

The Operator has a rollerball and nudge keys to the right of the Plasma Panel which enable him to move a cursor around displays to enable areas of interest to be pointed to and selected for an operation such as display centring. The rate at which the rollerball is moved determines the velocity of the cursor. This enables coarse and fine control to be achieved from the rollerball. The nudge key allows the cursor to be moved one display picsel at a time.

Example of a Data Processing Function—Active Contact Following

Both FM and CW auto detection and contact following is implemented in 2050. The processes for CW and FM are not identical but the main FM processes described here also apply to CW to a large extent.

Contact detection and contact following contain the following processes:

- Acceptance of thresholded data from Sonar Data Stream Highway.
- Generation of clusters (potential contact detections).
- Association of clusters between transmissions (contact following).
- Update for own ship’s motion at the end of transmission (end of ping processing).
- Generation of contact table.

Data is received from Signal Processing in the form of a series range, bearing amplitudes (bins) for each time period of the transmission. These bins of data are amplitude thresholded to prevent excessive data being processed.

The clustering process takes each data packet of range/bearing bins from each time frame and determines if each bin has an adjacent bin in range or bearing with which it can be connected. This is shown diagramatically in FIG. 6. As the transmission returns are received these connected bins form clusters. Each cluster has a centre range, a centre bearing and a Weight of Evidence (WOE) associated with it. The WOE is determined from a set of Weight Tables. These tables take account of the shape and spread of a cluster and a cluster which reflects submarine-like characteristics will be given a high WOE. These Weight Tables are derived from *Matapan* trials data.

Contact following is achieved by assessing whether incoming clusters associate with existing echoes by the use of windows. The larger the window required to make the association the weaker the association. A cluster will then be either associated or unassociated with a previous echo. Unassociated clusters are attempted to be made into new contacts while associated contacts are processed for a new event on an existing contact.

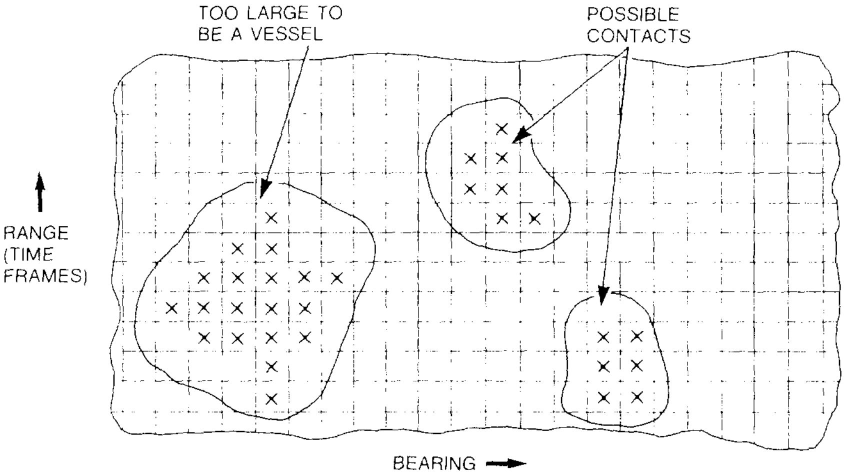

FIG. 6—ECHO CLUSTERING

At the end of the transmission the information contained on the echoes and contacts are adjusted for ship's motion. This is necessary so that associations required to be made in the next transmission are using a common reference. In addition, the contact tables are pruned of stale contacts and reordered for more efficient processing in the next transmission; window sizes are established depending upon range scale selected, and then the predicted contact positions are determined. Finally, the contact table is updated.

TECHNOLOGY CHANGE AFTER 2050 DEVELOPMENT

During the development phase of Sonar 2050 the versatility of the design allowed a number of design changes to be made and implemented within a very short (2 month) timescale and at minimal cost. This in-built flexibility will ensure that the system can be maintained at its optimum operational capability during its in-service phase.

Technology change will ensure that even greater versatility will be available to future sonars. Since the development phase of 2050, technology has moved on significantly, the principal advances having been in microprocessor technology.

The next generation of sonar equipments will probably make use of Transputers to handle most data processing functions. Current Transputers are very powerful devices operating at 20 MHz, with full facilities to perform 32-bit floating-point arithmetic. Their main advantage over other microprocessors is their built-in communications hardware in the form of high-speed (20 MHz) serial data links. Through these links each Transputer can communicate with any other Transputer without further support devices, reducing the space required for each processing unit and allowing a large amount of processing power to be packed into a small volume.

The Transputer software structure does not distinguish between a set of processes running on one Transputer or distributed across an array of the devices. This, combined with their built-in scheduler for use in multi-tasking applications, allows a system to be optimized for cost, volume and performance, and upgraded in the future without major structural changes.

Each transputer is roughly equivalent in processing power to an M700 as currently used in 2050. Eight Inmos T800 transputers can be mounted on a single processing card together with 1MByte of DRAM store. It would only take four of these cards to provide enough processing power to perform all of the data processing tasks presently carried out by two 5-shelf *cabinets* of M700s in 2050.

Similar advances in signal processing techniques being carried out at DRA will enable considerable reductions in the volume of SP hardware required for 2050 functions. It is now feasible to accomplish all beamforming on two cards and all signal processing on another two cards.

Sonar 2050 electronics which is currently housed in five cabinets could now be redesigned at minimal cost (due to availability of general purpose hardware) into two and a half cabinets with a production cost at least 30% less than the current system. It is hoped that future hull-mounted sonars will benefit from these technology advances in order to retain and improve the RN's hull-mounted sonar capability into the next century in a cost-effective, reduced volume and in a credibly supportable form.