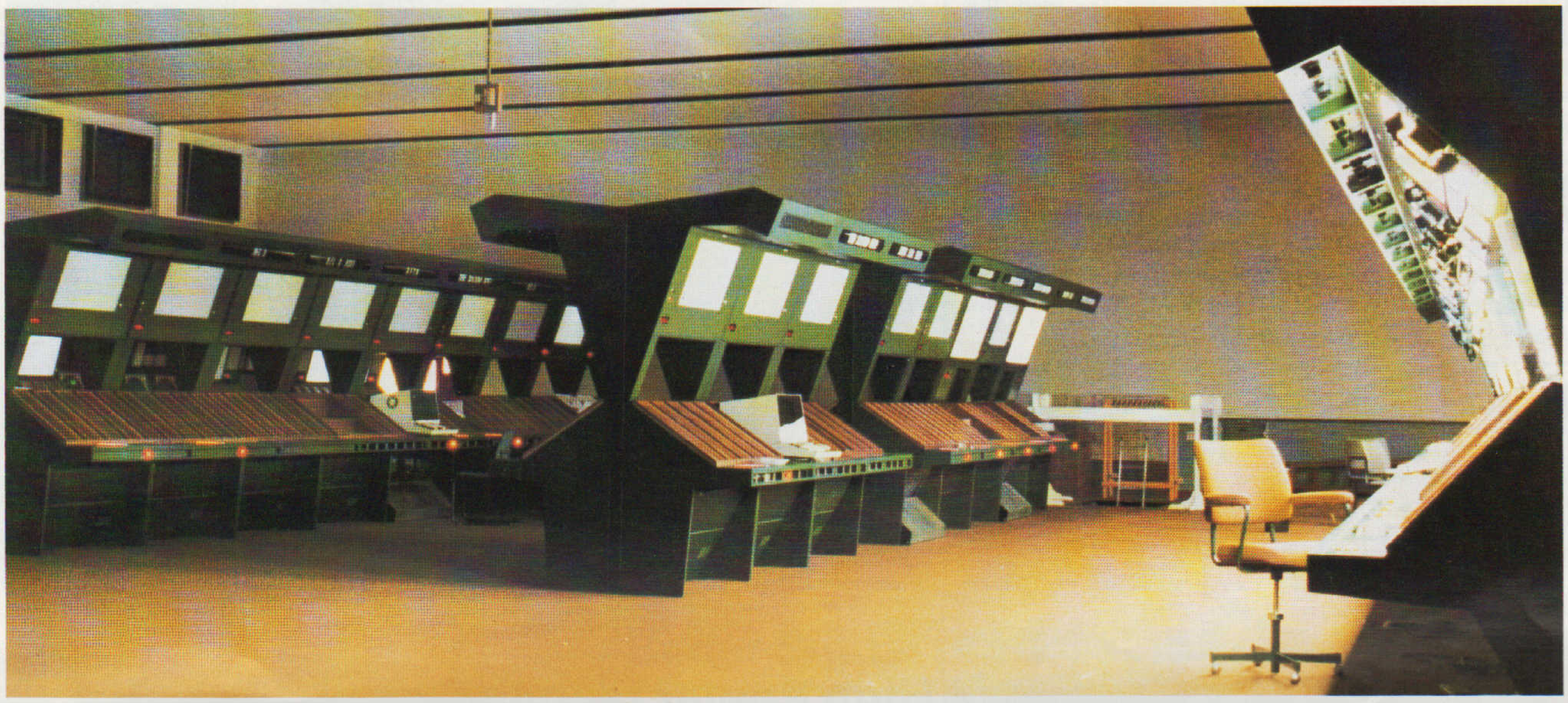
Radar Systems International

MARCONI

No. 22



When in operation, this air traffic control complex will be manned by 27 controllers.

New advanced ATC Systems for Scotland

Marconi Radar Systems Limited has installed a massive system for the new Scottish Air Traffic Control Centre at Prestwick. It incorporates the world's most advanced ATC radar data processing system, based on the Locus 16 data processor, which can monitor all aircraft in 2 million cubic miles of airspace above Scotland, Northern England and the North Sea.

One of the first systems in the world to use synthetic 'clutter-free' radar information exclusively, it provides an automated radar data presentation which makes the control of aircraft in the Scottish terminal areas simple and extremely efficient. The controlled air space includes those areas around the rapidly expanding airports at Glasgow and Edinburgh, also the upper, middle and lower airspace in the Scottish Flight Information Region.

Radar sites linked by simple telephone connections

The Prestwick air traffic control centre will be linked via standard telephone cables to radar sites located in Scotland, Northern Ireland and Northern England. At the sites, most of which have Marconi primary radar, both the primary and secondary radar will be processed by plot extractor units to provide aircraft position, height and identity on all detected aircraft tracks, in the form of digital messages. These will then be fed to Prestwick, where four Locus 16's process the incoming radar messages and route the information through a narrow band data highway to twenty-nine Locus 16 display suites.

A typical display position

Each display suite holds its own operational and diagnostic programs and drives a 16in display. At Prestwick, the displays will have 28 levels of brilliance to suit the ambient light conditions of the control room, and a high enough 'refresh' rate to eliminate flicker.

By means of a radar head selection switch panel a controller will have access to radar information relevant to the sector he is controlling.

Reliability

Earlier ATC systems have been built around large centralized computing complexes in which a hardware failure may cause a complete system failure.

By contrast, the system at Prestwick is based on the concept of 'Distribute Data Processing'. All Locus 16 processors operate quite independently of each other, and failure in one will not affect the others. Additionally, any of the two types of processor can do the work of any of the others of its type, thus affording a high degree of overall reliability.

In 1973, the CAA, in a pilot scheme, adopted the Marconi CMM (Computerized Modular Monitoring) to control remotely the on-route radar at Raith Hill from its old control centre at Gails.

Radar Systems have supplied a simple control and monitoring system (based on the Marconi CMM system) for the new Scottish Air Traffic Control Centre at a cost of about £180,000.

The computer-based control and monitoring system gathers system status information from the CAA equipment at Prestwick and from en-route radar stations at Stornoway and Lowther. The same network remotely controls CAA equipment at the out-stations.

Marconi CMM is a versatile control and monitoring system which can be built up from a range of hardware and software packages to meet the control, management and maintenance requirements of almost any electronic or electro-mechanical equipment.

The system at Prestwick represents a great step forward in the supervision of radar in the exercise of air traffic control, and contributes to the safety of air travel.

RADAR RESEARCH '78

Marconi Research Laboratories at Great Baddow, near Chelmsford, is the research establishment for the GEC-Marconi Electronics group, one of the largest electronics manufacturers in Europe. Main laboratories specialize in radar, communication, antennas, industrial systems, theoretical sciences, and microcircuitry, with a number of groups concentrating on applied physics, process instrumentation, metrology, magnetic materials, materials application and mechanical engineering.

Research is supported by comprehensive computer facilities including a powerful centre for real-time applications, computer aided design, system proving and software assessment. These laboratories are among the world's foremost research organizations and carry out research work sponsored by government agencies and organizations such as the European Space Agency, The Ministry of Defence and member companies of GEC-Marconi Electronics. The research laboratories work in close association with the development departments of these companies and also maintain close contact with the Hirst Research Centre, the research facility for the whole of the GEC organization.

Radar Research

Radar research evolves new design methods and advanced techniques to counter the developing threats to defence and to provide faster, longer range strike power.

Within the Radar Research organization, the laboratory structure provides teams of specialists who can operate within individual projects with provision for cross fertilization of ideas from a wide range of work.

Close contact is maintained with external customers such as MoD and with the Systems Companies to define new requirements or examine the feasibility of meeting them. The performance and application potential of new technology and devices is constantly evaluated and hardware appropriate to a requirement, including consideration of cost and reliability, is defined.

Experimental study of 'grey areas' where past experience is incomplete often reveals new approaches, the parameters of which are evaluated by theoretical performance assessment, including computer modelling. Prototype bread board models of special systems are constructed before development for production.

Apart from large, well-equipped workshops for development models, access is available to specialized equipment in all GEC-Marconi factories, including machines, production of glassware, printed circuit boards, thin and thick film and hybrid circuits.

The facilities include mechanical engineering laboratories and design offices staffed by personnel with many years experience in special design problems of a research nature, and a very comprehensive Library service for the loan of books, journals and proceedings plus abstracting and bibliography services.

A Quality Management Department oversees all Contracts with approval up to Defence Standard 05-21, including functions such as standardization, test, inspection and metrology. Access is available to the Chelmsford Computer Centre IBM370 by batch or terminal mode with an extensive library of CAD packages, with access to the Real-Time Computer Centre (MYRIADS) for on-line data processing.

Mechanical Engineering

Analysis and design work not only covers the design of radar structures and similar mechanical and electrical designs, but a wide range of projects requiring specialist skills in electro-mechanical and hydraulic applications.

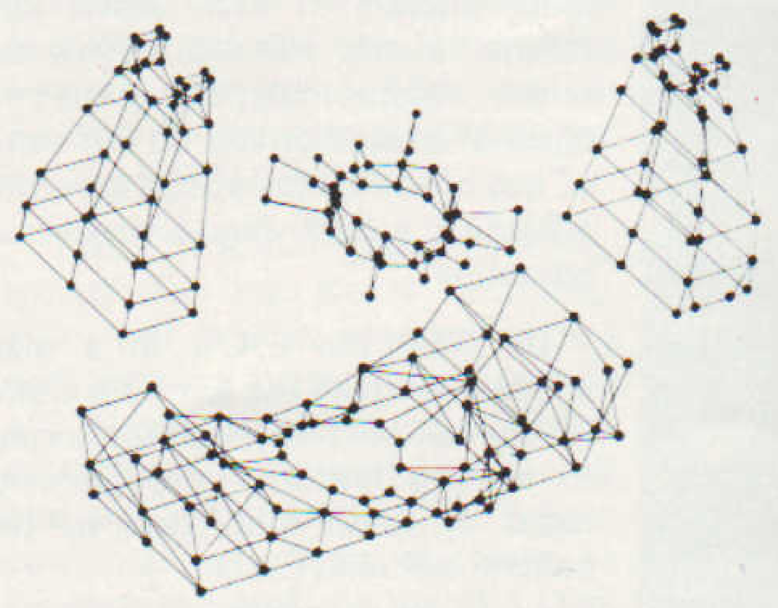
Typical of these projects is the design of a number of special-to-type stabilized platforms, control systems, optical shaft encoders, etc.

Among the more demanding projects undertaken has been the development of the mechanical aspects of the squintless feed described in 'New Antenna Concepts'. Work in this field has progressed continuously, resulting in the successful machining from solid of extremely complex shapes possessing a high order of accuracy.

The engineers provide a consultancy and advisory service covering environmental conditions such as wind, icing, thermal limits and vibration, facilities exist for mechanical testing and vibrating, together with access to wind tunnel facilities for environmental testing to appropriate Ministry standards.

Finite element programs are studied and developed, and computer programs and graphics are employed in thermal, static and dynamic stress analysis to evolve optimum design parameters for the more critical structures.

Part stress diagram, below, is part of the design procedure prior to the construction of the Y frame for a new naval radar, right, undergoing vibration testing.



Studies and Computer Simulation

Investigatory studies into many facets of current radar technology are a continuing part of the Laboratories work.

These studies are engendered by interest in, or requests from many sources, sometimes from a government agency or from commercial or academic sources.

Once an initial study has proved sufficiently promising both technically and commercially, true research and development is initiated with the object of achieving a satisfactory prototype, device, or system. System proving and testing is greatly facilitated by the use of the digital computer.

Mathematical models are constructed which contain the essential processes of the system and these are then validated and updated using hypothetical and initial practical trials data. By this means the product performance can be optimized for many changing, and sometimes conflicting, parameters. The models can also predict the outcome of proposed practical trials to ensure that the trial is capable of demonstrating the results required.

This technique is much more cost effective than the complex and protracted trials which often keep expensive equipment and associated personnel in use for long periods. For example, an entire modelling, validation, optimization and prediction exercise has been mounted for less than the cost of one major practical trial.

These processes are particularly valuable when developing new airfield control and airborne radars or naval weapons systems. In these cases, antenna performance characteristics and other system parameters such as power handling capability and achievable pointing accuracy are important parameters in a design specification.

Post development studies are also carried out when improved or new product specifications evolve from an existing product or from new ideas. Long term survival in the international electronics industry can only be ensured by constant study, innovation and design.

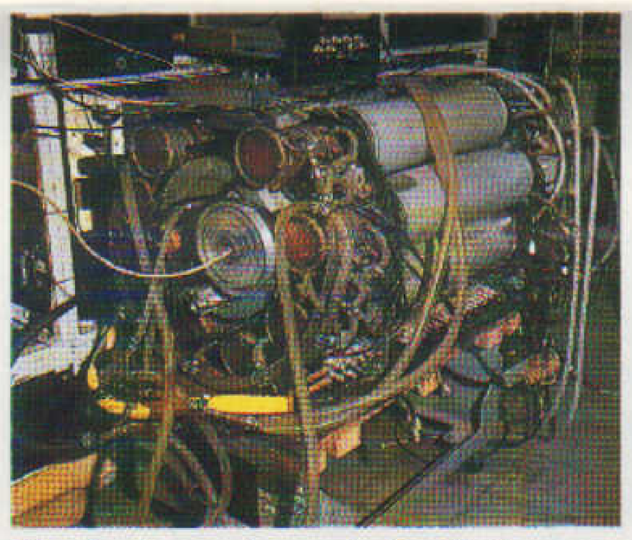
H.M.S. Penelope was the first vessel to be fitted with the Marconi GWS25 tracking and guidance system. The design studies from which this system evolved were carried out at Radar Research, Great Baddow. This guidance system has proved itself capable of detection tracking and destroying a 4.5 inch shell in flight.

High Power techniques

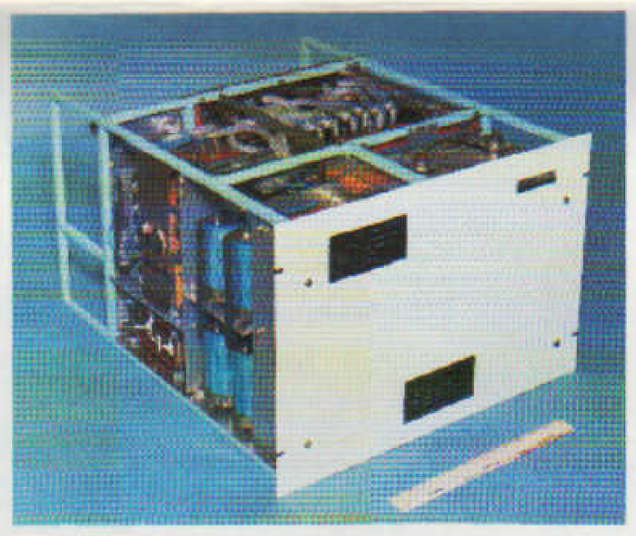
The quality of a radar transmitter waveform is vital to the efficiency, ECM resistance and clutter rejection of the system and a correctly formed transmit pulse is dependent on good modulator design.

The concentration of study and research into high power modulators and pulse forming networks is an important aspect of radar research and demands considerable theoretical and practical knowledge of high power electrical engineering at powers ranging from a few watts to many megawatts.

Research is carried out into the design of high frequency inverters and special power supplies, including specialized transformers and chokes. The laboratory has pioneered advances with inverter design, which have allowed thyristors to be replaced with high power transistors in all but the highest power levels and, combined with many other developments, will provide the radar designers with lightweight, high efficiency, reliable and fully protected units for use in aircraft, at sea and in land and land-mobile systems.



Single phase element of a high power three phase inverter. 30kW continuous.



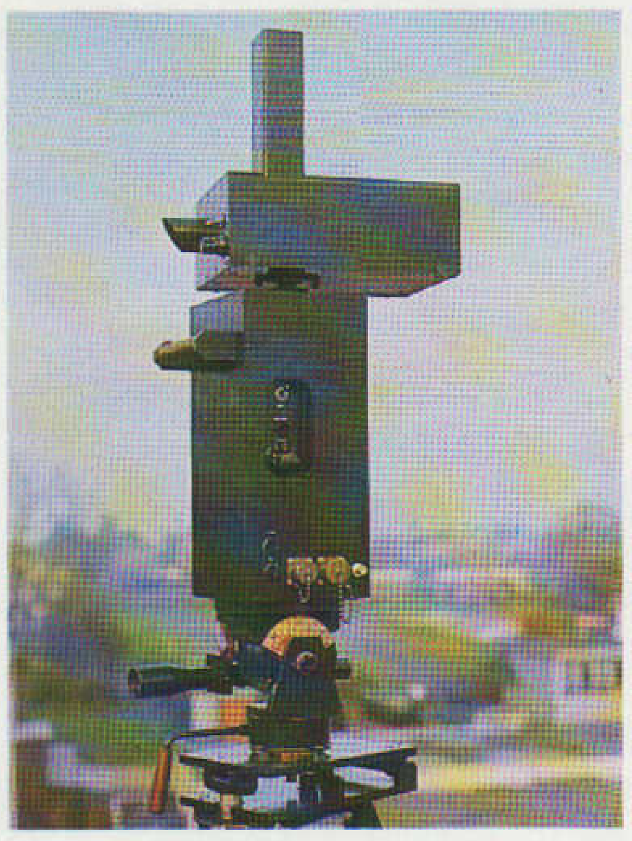
Transmitter modulator for Naval use.

Infra-red Surveillance techniques

Surveillance activity has been influenced by the growing importance of ECCM in radar design, and the operational advantages of passive infra-red technology has led to the design of equipment which can see without being seen.

Infra-red surveillance is a complementary technology to radar. Using passive infra-red techniques, very small temperature differences may be detected with sufficient definition to form a very useful visible thermal image. The information forming the thermal pictures includes unwanted signals known as clutter. While sufficient signal energy is available to detect targets, the paramount requirement is the removal of this clutter. Signal processing techniques developed for radar are extensively used to remove unwanted clutter and increase the usefulness of infra-red surveillance equipment by improving image definition.

Microprocessor and integrated circuit technology increases the quantity and complexity of the processing equipment which can be contained in a small package. This not only improves the directional accuracy and fine detail detected passively by infra-red technology, but makes it possible to design smaller, lighter portable equipment which could change the tactical applications of night surveillance and detection.



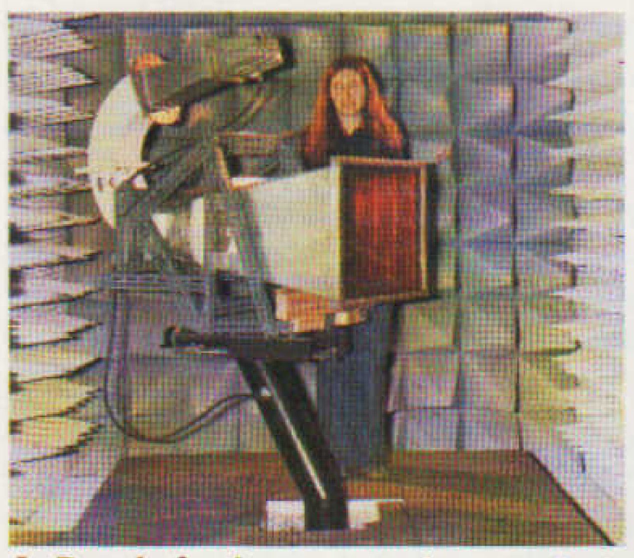
Experimental equipment for determining the thermal characteristics of targets and clutter.

RADAR RESEARCH '78

New Antenna Concepts

Designs formulated in Research cover civil and military applications for use on land, sea or on aircraft for h.f., v.h.f., microwave and millimetric microwave systems.

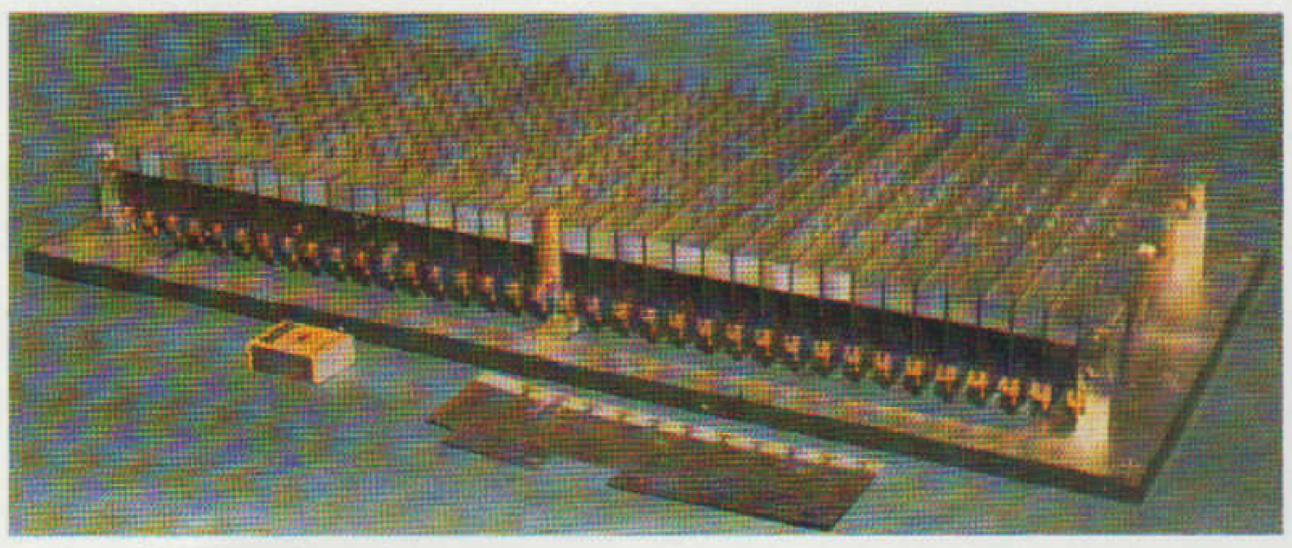
These antennas range in size from very small (less than 1 metre diameter) to very large (greater than 20 metres) and are used for air traffic control and military radars of all types and include scanning and squintless antennas, shaped beam antennas, very low sidelobe antennas, reflector antennas and phased arrays.



L-Band feed on test in anechoic chamber.

Whether designs are required for quantity production or single items for highly specialized applications, the capability and experience of the laboratories is combined in research, design, mechanical evolution and testing at a high technical level.

Large squintless feed elements over 5 metres long are machined to a high order of accuracy from solid billets of light alloys, including magnesium for low inertia, in a complete array with individual elements. A squintless feed is a microwave waveguide network which allows a series of horns to be fed in a prescribed phase and amplitude over a wide frequency band. This enables a linear feed to be made with a non-squinting beam and low sidelobes suitable for frequency diversity operation.



X-band Radar phased array.

Microwave and Millimetric research and engineering

Rotating joints capable of passing many separate r.f. channels using waveguide or co-axial line through the rotational axis of a rotating radar head is a specialist activity and multi-channel rotating joints have been designed for most radars produced in the last fifteen years. Recently, 'round-the-mast' rotating joints have been designed which can be stacked to form multi-channel assemblies. A seven-channel joint and a five-channel joint with two additional water channels are being designed at present.

5 channel rotating joint with 4 'around the mast' channels.

Motorized waveguide switches which have been developed include special high speed versions to very stringent reliability specifications.

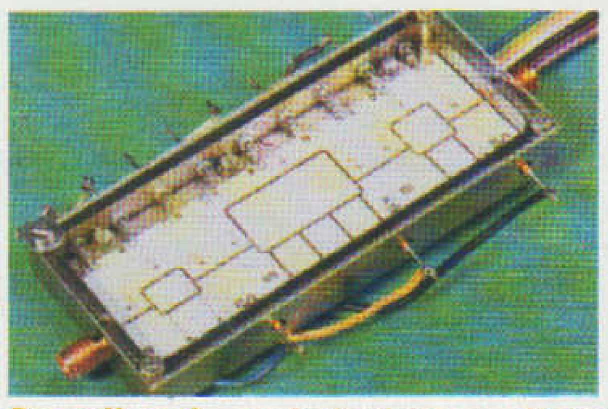
Filters engineered by the group include 'MOP' filters for absorbing spurious power emission from high power radar transmitters, both for harmonic interference suppression and for protection of systems against out-of-band transmission line resonances. Work also includes the design of high power bandpass/bandstop filters for channel allocation or receiver protection and passive networks to combine two or more transmitter outputs into one antenna including wideband channels in frequency agile systems.

Other specialized work includes stripline and microstrip components for low power intergrated circuits and the use of P.I.N. diodes for r.f. switches, attenuators and phase shifters. Research into the use of these devices for electronic beam forming (phased arrays) is being carried out, also similar work such as special phase and amplitude control circuits using co-axial line.

Ground work has been undertaken to realize practical hardware at frequencies up to 110GHz for possible future radar applications.

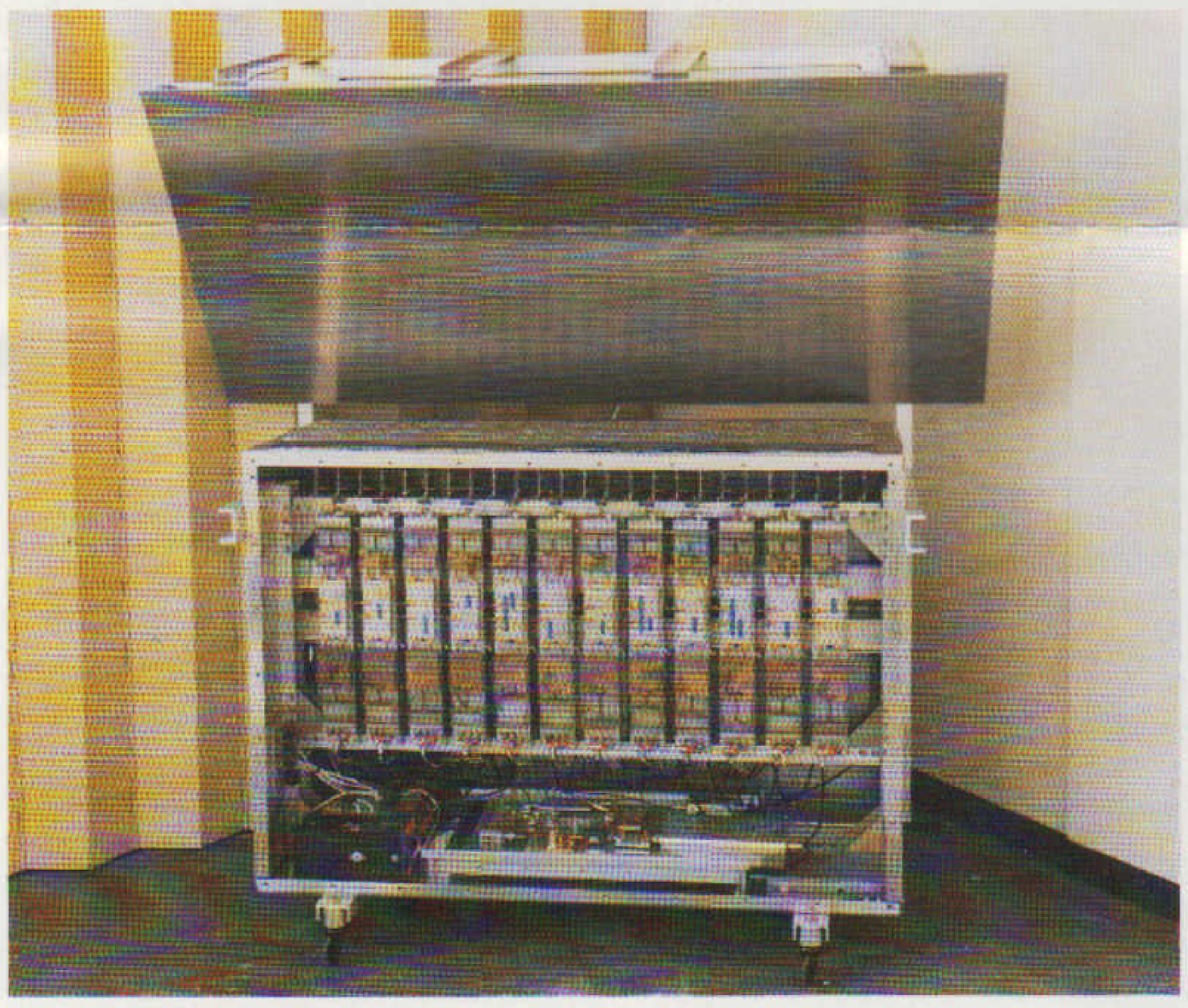
R.F. absorbers have been designed ranging from low power high precision loads for r.f. test gear through to 'calorimetric' load systems capable of accurately measuring the power output from high power transmitters.

Half section of a millimetric multiplexer.



Broadband, switched-line, digital phase shifter for L-band operation.

Among the absorptive elements and materials supplied for integration into production hardware are special materials such as a sheet absorber which is tuned to give low reflection in particular bands. This is finding a wide variety of applications, from small r.f. loads to suppression of unwanted propagation in stripline devices.



Prototype static IF beam slewing array — refer to text.

Multi-beam arrays

Conventional mechanically rotating surveillance antennas or nodding height finders can be replaced by antennas which do not physically move but provide either an electronically scanned beam which simulates a moving beam, or multiple fixed beams, or a hybrid mixture of the two. The techniques used will depend on the operational requirements; to avoid the complexity of mechanical rotation, to achieve adequate dwell time on the target (giving intergration gain and the potential for good doppler resolution) or to realise some degree of adaptivity to the operational situation.

A 3-D radar requiring multiple beams stacked in the vertical plane, all mechanically rotating in azimuth, can employ multiple feeds in the focal plane of a double curvature reflector. However, more control of the beam-shape can be achieved if the antenna consists of an array of elements each followed by individual processing. This applies more particularly if we need a large number of beams covering a wide sector, as might be required in azimuth for a bistatic configuration.

Electronic scanning and multi-beam techniques are relevant to both the transmitting and receiving function, but in an array designed for receive-only, signals may be converted to i.f. in each element, split several ways according to the number of beams required and formed into multiple beams by vector addition of the separate contributions to the total signal. Each beam shape and pointing angle is controlled by phase and amplitude weighting, built in to the beam-forming arrangement.

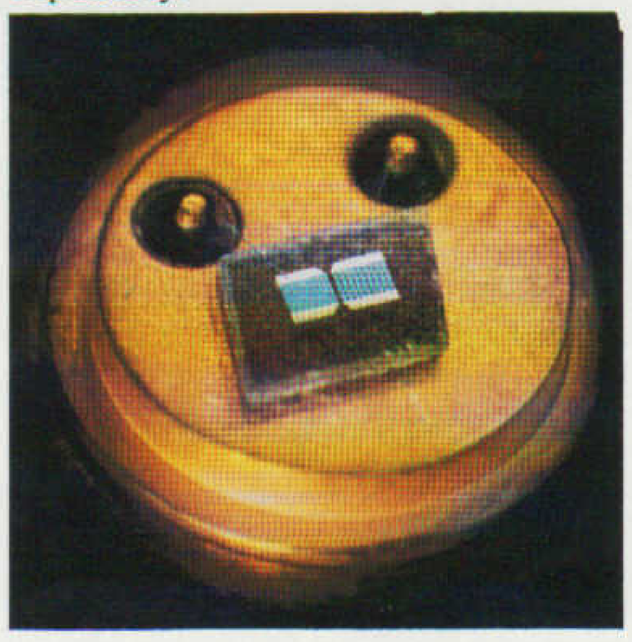
Several beam-forming techniques and antenna configurations have been built as experimental rigs and evaluated. It has been shown that the essential equality of gain and phase differential between elements across the array can be maintained through the chain of frequency changers and amplifiers.

Radar Signal processing

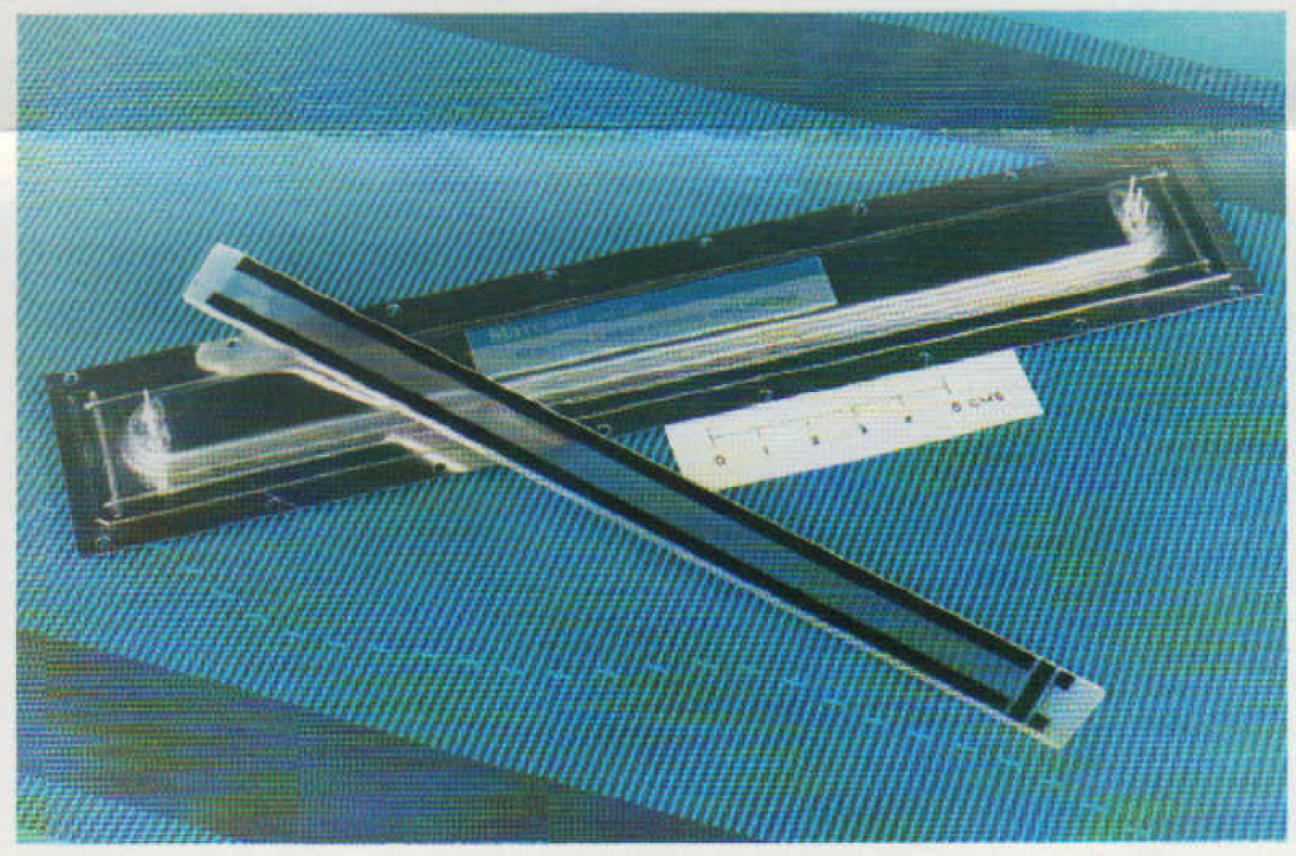
Radar echoes returned from targets must be separated from spurious echoes returned from rain, sea or ground in order to extract information such as position, speed, heading, height and size. The separation, selection and extraction of this informatin is carried out by the radar signal processor.

The last decade has seen an ever increasing growth in the use of complex digital circuits. In particular, as the speed of microprocessors has improved, we can expect to see in the future widespread use of multiprocessor hardware programmed to do the tasks which up to now have required expensive dedicated hardware. Recently, a resurgence of interest in analogue processing and the exploration of charge-coupled devices combine the advantages of analogue and digital features. Devices still in the experimental stage seem to hold great promise for certain specialized tasks such as transversal filtering and the generation of Fourier transforms.

A recent extension of the work of radar processing lies in the application of Array Processing utilizing advanced real time processing techniques via the attached computer software to enhance the system's Electronic Countermeasures capability.



1GHz fundamental frequency SAW oscillator in a T05 transistor package.



SAW line disperser. The background is the substrate enlarged about 7 times.

SAW devices

An important development in signal processing is the use of SAW devices for delay lines, filters and oscillators. Surface acoustic waves are mechanical waves travelling on the surface of a solid substrate and the speed of travel of those waves is such that a wave train which occupies kilometres of space as a radio wave can be accommodated on a few centimetres of substrate. This allows complex processing functions to be performed such as the correlation of received radar returns with a predetermined function.

For Pulse Compression Radar, SAW dispersive delay lines offer enormous advantages in size, weight, cost and performance over other technologies. The chirp drive pulse required for the transmitter is generated by impulsing a SAW line. A matching line in the receiver will compress the target returns to a pulse length compatible with the bandwidth of the system. SAW dispersive lines for this purpose have been manufactured for chirp pulse lengths up to more than 50μs, for bandwidths up to 100MHz, with pulse compression ratios approaching one thousand.

SAW devices have only one active surface and are fabricated on piezoelectric quartz substrates using conventional, high precision, integrated circuit fabrication techniques.

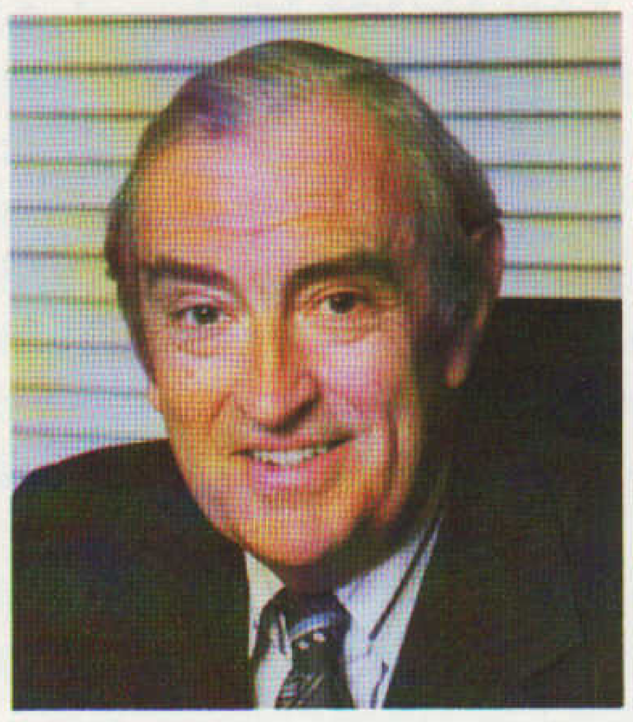
Extensive research into Surface Acoustic Wave Oscillators (SAWO's) has led to the development of a new range of v.h.f./u.h.f./microwave frequency sources. Current designs include local oscillators, VCO's, GW telemetry oscillators, and agile microwave sources.

The unique properties of the SAW oscillator make it possible to combine, for the first time in a single device, the excellent spectral purity and wideband frequency agility that are essential to modern radar systems.

Recent research into SAW fabrication technology enables fundamental frequencies in excess of 1.5GHz to be achieved; thereby eliminating much of the multiplication and filtering that is required in the conventional generation of stable microwave sources.

World Market Trends in Radar for Defence and Air Traffic Control

The following abstract is taken from a paper presented by J. W. Sutherland MA, CEng, FIEE, Managing Director of Marconi Radar Systems Limited, at the opening of the IEE International Conference — Radar '77.



The emphasis of RADAR-77 is primarily technological, but it is the revenue from sales, at least in the private venture sector, which provides the funding for continuing development and therefore a consideration of market trends particularly in export is an appropriate part of the conference. The market for radar-based air defence, air traffic control and naval and military weapon systems appears to be one with continuing growth potential.

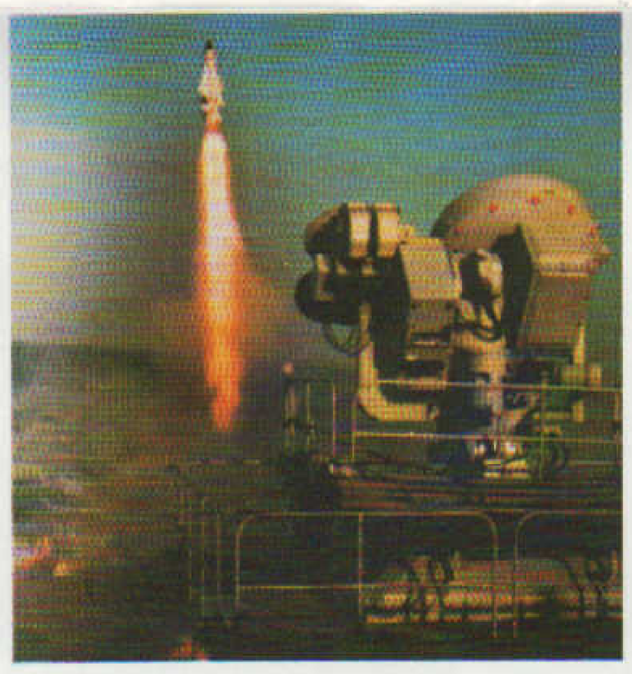
It is primarily the general direction of development world-wide, the availability of new components and techniques, and indeed the element of 'fashion' in radar which help the forward looking commercial organisation to formulate a market and product development policy. The most promising areas of radar technology which are currently leading to positive penetration of the market are associated with cost effective extraction of unambiguous data on all movements in the airspace, and the presentation and utilisation of those data in a way which gives maximum operational flexibility to the end user.

The requirement to produce unambiguous data requires good anti jamming performance and this begins in the aerial; new aerials are now coming in to production with coverage patterns offering exceptionally low off-beam sensitivity to jamming over a very wide band of frequencies, which therefore minimise the menace of all but main beam jamming. If this can be coupled with an appropriate mode of wide band frequency agility, the user is offered a good degree of immunity compared with the vast majority of current systems.

The picking out of wanted data from a welter of extraneous radar returns from meteorological and topographical causes, and in the case of defence systems from deliberate man-made interference of the 'chaff' type, may be tackled in two ways — and it may well be a combination of market and operational aspects which determine which solution is the more appropriate.

High power pulse Doppler radar can give extremely good performance in a highly cluttered environment, and the excellence of detection in this clutter is determined by the noise performance of the Doppler radar transmitter and the resolution and stability of the filtering and gating system. Thus in market and operational terms, pulse-doppler is supreme in circumstances where the requirement puts a premium on a high probability of detection of a very small target in a heavy clutter situation — for example in a high performance close range weapon system.

The other approach to good target visibility at all ranges, in the presence of clutter is through sophisticated radar signal processing. In the latest systems, the overall velocity band is split up into a series of sub-bands; this makes the detection of a target very much easier since it is detecting a moving target against a much smaller background of unwanted signal. As an additional refinement, within each of the bands of velocity covered by individual filters, for every revolution of the aerial a detection threshold can be established for each resolution cell



Antenna S1020, part of the S600 range which has already sold over £80M around the world.

in the radar cover which instantaneously maximises the detection probability of the moving target. As a further benefit of this approach, the composite picture of all the threshold levels at any one time gives a constantly updated 'clutter map' which may be of considerable operational value. The combination of these techniques of ECM, and of modern signal processing with modern designs of extraction equipment give the 'clean' radar response, in a form which can be readily stored or transmitted over narrow band channels and which fulfils current and predicted market requirements.

In recent years developments in integrated circuit design have created great opportunities in the communication, handling and display of radar data. In radar based systems we require data processors to support a variety of operational functions, some carried out with human operators 'in the loop' and others completely automatically. In an air defence system this might be interception control, weapon control, recovery control etc. In an air traffic control environment one may be concerned, for example with individual en-route controller or approach controller functions, with flight plan processing or radar data processing; in a weapon system there are many functions of target selection, firing sequencing, guidance etc., to be performed. Modern components and methods have broadened the market opportunities for companies with a total systems capability.

In the twenty to twenty-five years that computers have been applied in these fields, the technique of a general purpose central machine carrying the total computing load has given way to the 'distributed processing' method in which computers are freely used, and communicate with each other through simplified communications channels. The data-handling facility is now implemented using a network of computers in which each operator has his own local computing facility, and in which security of service is ensured by alternative operating positions and alternative communications channels. Distributed processing offers an elegant and cost-effective solution which has obvious and indeed proven attraction in the market place.

Computing power may be disposed where it is needed; modularity of hardware and software provide flexibility in extending and adapting existing facilities and in trying out new ones. A large system may use several tens of computer complexes, some equipped with displays and operational controls. These are built up from a limited range of standardised parts and can be tested and commissioned individually with very significant economies of time and effort. Nor are software costs increased; many of the computer complexes usually contain identical programs, and software cost is mainly determined by the complexity of the requirement and by the extent to which existing software can be re-used. The requirements of the distributed data processor to achieve maximum exploitation in the market are operational flexbility, a comprehensive range of proven hardware and software elements and, above all in this era of rapidly evolving technology, a design philosophy which allows progressive up-dating and extension of the capability, element by element, as new techniques permit.

The use of commercial minicomputers, quite apart from questions of their physical and organisational suitability for many operational roles, may have serious drawbacks in committing the user to a product policy which may be chosen by the mini-computer supplier for reasons quite foreign to the radar need. A highly successful solution pioneered in the UK by Marconi Radar Systems Limited has been based on a 'data-bus' to which one can fit precisely those hardware elements — arithmetic processors, memory, control processors for displays, communications channels and other devices — which are required, selecting them from a relatively compact range

of products. Within this framework modern microprocessors are starting to be exploited in multi-processor organisations capable of operating with hundreds of thousands of words of directly-accessible storage, and supported by increasingly powerful peripheral systems. This modular approach, engineered in a sufficiently rugged form to meet the needs of most military environments, successfully meets the market criteria and shows great promise for the future.

Despite the considerable achievements of hardware developments in creating a more favourable environment for software development, software continues to present major problems for systems suppliers.

Software remains in commercial terms a high-risk activity in which the implications of particular aspects of requirement are not easy to evaluate, and in which the progressive clarification and evolution of requirement can considerably complicate the implementation process. Clearly the availability of a substantial body of proven software is a major factor in the market place, and can go far to resolve the uncertainties. A need surely remains, however, for purchasers and suppliers alike to review their methods in relation to software, to arrive at better and more certain working arrangements. In conclusion, one has attempted to assess which of the many developments currently evolving in the broad field of radar are likely to have market significance in the next few years.

Overseas orders for Computer Imagery Trainers

The Royal Malaysian Navy is the world's first overseas armed service to train its gun aimers with a system employing TEPIGEN, the new system, designed by Marconi Radar, which generates realistic images from a computer. The weapon trainer, valued at over £1½ million, employs the TEPIGEN (Television Picture Generator) simulator system to train personnel in the operation of anti-aircraft and anti-ship weapons.

The Locus 16 computer produces life-like scenes with realistic action and sound.

TEPIGEN is a radically new training aid which produces life-like, three dimensional television pictures to simulate the actual visual conditions obtaining in a variety of human tasks ranging from gunnery aiming to ship handling and flying training. These television pictures are entirely synthesized from computer generated video signals. The size, location, orientation, visibility and colour of objects in the pictures are a product of both the particular TEPIGEN programme and the operator's response to the displayed scene. Thus the principal advantages of a TEPIGEN system over conventional simulators using film or televised models are its realism, its extreme flexibility and its simplicity of operation.

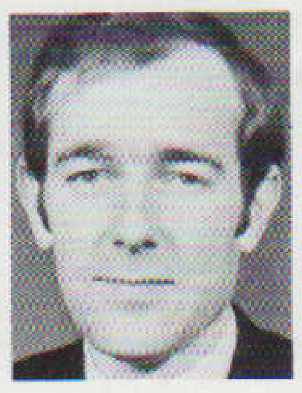
The TEPIGEN gunnery aiming trainer for the Royal Malaysian Navy will provide practical aiming and tracking instruction in the use of gunsights and gun laying apparatus for crews of anti-aircraft and anti-ship weapons. The trainer comprises a rolling platform to simulate the deck motion of a ship, a Bofors 40mm L70 naval gun, two visual displays for the gun layers and an Exercise Controller's console. Two Marconi Locus 16 computers are used, one in the TEPIGEN picture generator and a second as the exercise control computer.

The gun layers will be trained in their normal position on the Bofors gun on which the view seen through the gunsights is produced on television displays. The visual presentation of the graticule, the targets, the scenery and atmospheric effects on this display is generated entirely by computer, composed instantly from mathematical models held in the Locus 16 computer. This scene changes with the observer's view and the effects of poor visibility sun, cloud and different light levels corresponding to the time of day. For training gun layers, a repertoire of attack sequences involving up to four fully manoeuvrable targets is prepared. As these sequences are easily changed and the types of target, such as aircraft, helicopters or ships, can be varied, there is no question of a trainee becoming familiar with one particular exercise.

The Marconi system will also include computer generated sound. This is of considerable importance since operators rely on changes in electronic and gearbox sounds to confirm the response of the weapon to their control.

Control of an exercise is achieved by means of a comprehensive control console which enables the instructor to monitor and assess the performance of the student. The console is fitted with a display terminal and keyboard for monitoring and control of exercise parameters, a television display for monitoring the student's picture, and a control panel for overall command of the simulator. When an exercise is not being run the instructor's console can be used for the preparation of models for future exercises.

INTRODUCING



Richard Worby

Frank Cottrell

Richard Worby has been appointed Sales Manager 'C' with territorial responsibility for N. America, together with application and product responsibility for naval sales worldwide.

Frank R. Cottrell has been appointed Sales Manager, Control and Simulation Division, based at the New Parks Works, Leicester. He served eight years in the forces in air traffic control before retiring with the rank of Flight Lieutenant.

Subsequently, he was involved with the marketing and sales of civil and military radars and travelled extensively in Latin America.

Radar Systems International

the journal of
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