



Technology

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INDIGENOUS RADARS-I

R A D A R S Y S T E M T E C H N O L O G I E S

Radar, an acronym for Radio Detection and Ranging, is used for various purposes both military as well as civilians. The military use of radar dates back to World War II. In India, the work on radar for the Armed Forces started during 1967-68 in Electronics and Radar Development Establishment (LRDE), a premier establishment of Defence Research and Development Organisation (DRDO), in Bengaluru. Modifications to Fire Control Radar AA No 3 Mk7, development of S-1000 Mk I radar based on CSF radar ER 370 and FAX Mk I radar for locating mortars and guns for artillery, and Battlefield Surveillance Radar (BFSR) for detecting moving men and vehicles were major innovative achievements during the period.

Late sixties and the early seventies were the formative years for system thinking. Associated with the system, quality assessment and measurement infrastructure, component development, collaborative development, joint working with industry was experimented towards achieving self-reliance. Digital electronics and embedded software became integral part of every equipment and system conceived and developed. Two low level radars, Local Warning Radar and Low Flying Target Detection Radar (later renamed as Indian Doppler Radar-I and II) for the Indian Army and Indian Air Force (IAF), respectively, were the

first indigenous radars mooted for development using contemporary technologies like digital signal processing, digital display and radar data processor.

These radars were followed by Phased Array Radar, Weapon Locating Radar (WLR), BFSR-SR, 3D-Central Acquisition Radar (CAR), 3D Surveillance Radar for Air Force and Navy, 3D-Tactical Control Radar (TCR), Low-level Lightweight Radar (LLLR), 3D LLLR, XtraVision (XV)-2004, manifesting not only in the mastering of ground-based, airborne and ship-borne complex radar systems, but also practice of concurrent system engineering, R&D-industry partnership and professional approach to technology and project management.

In the nineties, beyond the microwave, digital and software technologies changed the world. Radar became sole focused area for LRDE in 2001. Major thrust was given for self-reliance in technologies, components and industrial relationships, and for activities directed towards design and development of complex state-of-the-art electronically scanning T/R module-based active array ground-based and airborne radars.

This issue of *Technology Focus* on Indigenous Radars-I covers Radar System Technologies. The Radar Antenna and Transmitter technologies would be covered in the Indigenous Radars-II (June 2013) issue of *Focus*.



From the Special Editor



Electronic sensors play a vital part in enabling Armed Forces to gather information about the enemy. Radar is an electromagnetic (EM) sensor system used for detection, location tracking, imaging and classification of targets such as man-made objects like aircraft, ships, ground moving vehicles and natural environment including ground features and moving men. It is an important sensor for the commanders' battle space awareness. Modern battle has transformed into network centric with unified battlefields spread across multi theatres of operation. With the advent of microelectronics, radio frequency (RF) management and unprecedented growth in processing power and computation, radar has transformed into a complex, advanced and intelligent sensor. Indian military, aspiring to be a global player, has been integrating emerging technologies to fine tune its strategies and tactics to integrate with global Armed Forces.

The battlefield scenario is continuously changing with sophisticated emerging technologies and therefore the operational environment of modern radar systems is becoming increasingly more complex. Stealthy, long-range, high altitude, high speed, manoeuvring targets, intense jamming environment, large fluctuations of radar cross-section with small change of aspect angle of targets, pose challenges for efficient detection, tracking, measuring, etc. Serious drawbacks of conventional vacuum tube-based transmitters with mechanically rotated antenna, have been the motivating force for the radar scientists to propose and develop new radar technologies to meet the present and future requirements.

The key to successful development of radar systems for many of the applications lies in harnessing the basic technologies involved in the modern radar system design. Component technologies such as microwave tubes, very large scale integration (VLSI)-based application specific integrated circuit (ASIC) chips, electronically controlled phase shifter, dedicated signal processing (DSP) chips, display, and a host of microwave components including antennas form the crucial technologies needed for the sophisticated modern radar system development.

Electronics and Radar Development Establishment has acquired the expertise in designing, testing and evaluation of radar systems using these crux technologies and has translated these into major state-of-the-art radar systems. A number of sub-system level technologies needed for building the most modern state-of-the-art radar systems for military applications has been successfully developed.

Electronics and Radar Development Establishment is committed to provide world-class radars built using state-of-the-art technologies, which are current and contemporary with other radar houses of the world, to provide ground-based, airborne and ship-borne sensors to users. The indigenous radars and the associated technologies developed by DRDO have been covered in two (April and June 2013) issues of the *Technology Focus*. I hope the issues will be useful in generating awareness about the tireless efforts put in by DRDO in developing the cutting-edge defence technologies in the area of radars.

S. Varadarajan
Director
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INTRUSION DETECTION RADAR

Battlefield Surveillance Radar–Short Range

The Battlefield Surveillance Radar–Short Range (BFSR-SR) is a lightweight, man portable, user-friendly surveillance electronic sensor developed for the Indian Army. The radar is capable of searching a specified sector and performing track-while-scan (TWS) for multiple ground surface targets to provide all-weather surveillance against intrusion.

BFSR is a fully coherent pulse Doppler radar. The low peak power provides the radar a low probability of intercept (LPI), making it difficult to intercept by enemy sensors. The radar algorithm incorporates Digital Pulse Compression Technology, which improves the LPI characteristics, provides adaptive RF power management based on the depth of surveillance, as well as making the radar capable of resolving closely spaced targets. The radar operates in all-weather conditions and during day and night.



Battlefield surveillance radar–short range

BFSR-SR components include a mounting tripod, an antenna/electronics assembly, two 24 V batteries for power, and an integrated control and display unit (CDU). Targets are classified automatically using Doppler target classification. Output Doppler return is provided to the operator through headphones for the Doppler audio to aid in manual classification.

The radar sensor head consists of a planar antenna, transmit, receive, and processing modules within a single block. The signal processor is a single board field programmable gate array (FPGA)-based implementation, which has been tailored for very low power consumption. The antenna array is made up of micro strip patch array antennas. The transmitter is a solid-state transmit module, while the separate receiver is a super-heterodyne type receiver.

The BFSR processing and display units and control functions are integrated on a single portable CDU. A high resolution, north oriented, coloured radar picture is displayed. The radar display can either be in a Plan Position Indicators (PPI) display, or a B-Scope display. The display also has provision for digital geographic map overlay, which allows the target data to be integrated with tactical data for use by ground forces and commanders.

The interface between the radar and the CDU is based on a two-wire ISDN protocol. The protocol allows the operators to be positioned at a distance from the radar in the safety of trenches/bunkers. This provides them better security and safety, and allows for greater flexibility in deploying the radar at suitable spots to meet technical and tactical requirements.



BFSR-SR has a sophisticated in-built software to detect, track and classify targets like crawling man, single walking man, group of walking men, moving jeep-size vehicle, and moving heavy vehicles at various distances. It comprises an in-built interface for automatic transfer of target data and Doppler audio to remote locations, integrated image sensors to enhance the ability to identify and classify the targets.

The entire system can be carried by three soldiers and is tripod mounted while in operation. An infantry soldier can install the radar and bring it into operation, within 5 min. This radar is a potential ground-based e-sensor for Border Security Force, Coast Guard and Police, for surveillance of designated areas, and can be configured as an effective perimeter sensor for domestic and military airports, large industrial establishments, or other infrastructures.

Low-level Lightweight Radar

The LLLR has been developed to protect valuable assets in the mountainous regions against aerial threats. It is a quadripod mounted fully outdoor shelterless equipment, rugged enough to operate in harsh environment, temperature extremes, and in strong windy conditions. The main constituents of the radar are: composite antenna comprising primary radar antenna and secondary surveillance radar antenna; pedestal to rotate the antenna, a quadripod, and conduction cooled central unit that houses most of the electronics and remote Commander's Display Unit (CDU).

The radar head is connected to the CDU through a two-wire extendable WD field cable. The radar operates on prime-power fed from a rugged generator to a UPS



Low-level lightweight radar system

that provides 28 V DC supply to the system. In case of failure of generator, the UPS automatically switches to a rechargeable lithium-ion battery that can support the system for more than 4 h.

LLLR uses low peak power wide band coded waveforms for transmission and employs sophisticated processing algorithms to suppress ground/weather clutter, and can survive in hostile jamming environment. The basic radio frequency (RF) source and complex modulated waveform is digitally synthesised and suitably up-converted for transmission. The processing on receive comprises of digital pulse compression, Doppler filter bank and adaptive CFAR thresholding followed by binary integration over the dwell. The system has fine resolution in range permitting precise detection of the elements of formation flights. Miniaturisation and low power technologies have been used to a great extent. The entire signal processor of LLLR has been realised in a single multi-layer printed

circuit board using FPGA technology for a highly integrated and low power implementation. The identify friend or foe (IFF) electronics is also highly compact. The communication from radar head to remote CDU is based on ISDN technology.

The system provides excellent detection of low flying aerial threats like aircraft, helicopters and unmanned air vehicles (UAVs) against the background of intense mountain clutter. The radar has an integral IFF Mk XI with Mode-S capability to provide IFF. Hostile targets that are identified by the operator can be designated to weapon sites located in the proximity. Thereafter, target updates are sent continuously over line or radio and presented on a hand-held target data receiver (TDR) at these locations. Shoulder fired missiles can be aimed from these weapon sites against the intruding threats at an appropriate moment.

LLLR is a portable radar. The speciality of the radar is its mechanical engineering, which permits segmenting the system into easily portable loads that can be carried by men or mules over mountainous terrain. The radar can also be transported as under-slung load by helicopter. The system comprises about 16 sub-assemblies or modules that are carried in roto-mould rugged transit cases and can be rapidly assembled and deployed in just 10 min. The antenna back-up structure, boom, horn and quadripod are all made up of carbon composites. The antenna reflector is made up of horizontal strips placed with sufficient intermediate gap to offer low resistance to wind load.

The radar has gone through extensive user trials and evaluation at EW range and at high altitudes. The system has been recommended for introduction into the Service.

3D Low-level Lightweight Radar

3D LLLR is a multifaceted ground based S band 3D low-level lightweight semi distributed active aperture radar developed indigenously for deployment in diverse terrains like mountains, snow-bound high altitudes, deserts, urban high rise buildings, plains, etc., to meet the operational requirements of the IAF. The radar automatically detects and tracks heterogeneous air targets like helicopters, high-speed and high manoeuvring fighters, slow moving micro-light aircraft, and very small RCS UAVs from a very low altitude (tree top level) to a medium altitude. The radar can scan the valley and provides accurate range, azimuth and height information for multiple targets using an electronically steerable active multi-beam antenna. It sweeps to provide contiguous surveillance based on operational requirements. The radar sensor comprises both primary radar (PR) as well as secondary surveillance radar (SSR) with an integrated IFF Mk XI system with Mode-S.



3D low-level lightweight radar system



The semi-distributed active aperture radar uses indigenously developed advanced VLSI and digital technologies like T/R modules, direct digital synthesiser (DDS), digital receiver, programmable signal processor, and steerable shaped beam in transmit and steerable multiple stacked beams in receive to provide 3D air space awareness with high accuracy, resolution, and reliability.

The radar has been configured into following seven sub-systems: (i) very low side lobe primary triplate dipole planar array integrated with micro-strip IFF and side lobe blanking antennae; (ii) active antenna unit consisting of T/R modules, agile beam formers, beam steering computer; (iii) central unit (CU) housing receivers to extract the target information from multiple channels simultaneously, DDS and clock module, up converter, waveform generator and six channel digital down converter, multi channel, multi rpm signal processing board, health monitoring module and IFF transmitter, receiver and processor modules (along with RF and digital mother board,

GPS and digital magnetic compass); (iv) pedestal; (v) quadripod; (vi) CDU; and (vii) power system consisting of batteries, UPS and generator set. This novel and innovative active aperture architecture, where all the main radar sub-systems are on the rotating platform, helped in avoiding the use of high power RF rotary joint and central transmitter, the two most common single point failures in most of the radars.

The system can be operated either on a battery or on ac power with a power rating of approximately 1 kW. It is configured on a quadripod and can be easily transported by group of men, vehicle, or as under slung carriage by helicopter, across all kind of terrains, remote locations, high rise buildings, high altitude snow-bound mountain peaks, etc. It can be deployed or decamped in less than 15 min by a group of four men. The unique requirements of low level coverage, lightweight and quick deployment as also mechanical ruggedness to operate in extreme climatic conditions, high altitude, high wind load conditions are some of the special features of the radar. Further, operational capabilities like good target detection and consistent tracking in intense clutter background, good level of performance even in hostile EW scenario, robust EMI/ EMC design and good testability/maintainability are some of the other significant features, incorporated in the radar.

The radar has been designed for operation from remote location through CDU which is connected to the main radar system through rugged fibre-optic LAN. Presentation of target plots/tracks, comprehensive health monitoring and diagnosis of each radar module, radar switch on/off is through CDU, which can be located at hundreds of meters to few kilometers away



Heli transportation of 3D low-level lightweight radar

from the radar, to provide safety to the crew during operation. The facility also enables the commander to deploy the radar at a tactically favourable point.

The radar is built to operate in networked or stand-alone mode to support joint or independent operations of the IAF. Target data complies with IACCS/Asterix format, which is suitable for networking and data fusion. Multi electronic counter-counter measure (ECCM) features incorporated in the design, help the radar to deliver intended performance even under intense hostile EM environment.

Besides, 3D LLLR has the additional unique capability of data recording and playback which has been appreciated by the IAF during field trials. The radar, being compact, lightweight and modular, can be used in different innovative roles like air space surveillance in urban areas for VVIPs and large critical installations.

3D LLLR is the first fully indigenously developed and qualified contemporary class of semi distributed 3D low-level active aperture radar which has been accepted by the IAF after rigorous user field trials and

recommended for an immediate induction into the Service. This class of portable 3D active aperture radar is first of its kind in the world.



Pulse compression radar system

Production of the radar has commenced against the firm order by the IAF.

SURVEILLANCE AND AIR DEFENCE RADARS

Pulse Compression Doppler Radar

Pulse compression Doppler radar (PCDR) is a fully coherent, 2D, transportable surveillance radar developed to meet the air defence role of the IAF for ground-controlled interception of targets. The radar is capable of detecting air targets with low and medium altitude coverage. A mechanically rotating, doubly curved parabolic antenna with pencil beam in azimuth and cosecant squared radiation beam in elevation illuminates the space and covers 360° in azimuth. The high gain corrugated horn antenna with fairly low side lobe levels supports horizontal polarisation. The role of IFF is achieved through an integral vertically polarised radiating elements.

Coded wave forms for digital pulse compression (DPC) have been employed to exploit the benefits of the energy of a long pulse and the resolution of a short pulse, manifesting in high range resolution, to detect the low flying aircraft against heavy ground clutter and tracking multiple targets flying in formation. The high range resolution enables the separation of the desired target echo from the undesired echoes, by providing inter clutter visibility.

The matched filter hardware facility can be dynamically re-configured to instantaneously adapt to a variety of coded transmitted wave forms.



Integrated radar data processor (RDP) for track-while-scan (TWS) is capable of handling multiple tracks. The radar has facility to automatically communicate selected target information, through high speed digital modems in a networked mode of operation, to the higher echelons.

The radar, as a transportable system, is a three-vehicle configuration. Antenna and power sources are mounted on one vehicle. The electronics mounted in shelters are distributed on other vehicles.

3D Surveillance Radar for Air Force

The 3D surveillance radar (3DSR) is a medium range surveillance system for the IAF to meet the operational requirements of a base radar. The radar is capable of TWS of airborne targets up to 150 km subject to line-of-sight (LoS) clearance and radar horizon. It employs multi-beam coverage in the receive mode to provide necessary discrimination in elevation. It employs seven beams to achieve elevation coverage of 30°. The antenna is mechanically rotated in azimuth to provide 360° coverage. To obtain an optimum detection performance against various classes of targets, two operator selectable antenna rotation rates (ARR) have been provided. The IFF antenna is placed atop the primary planar array antenna (PPAA). A side lobe blanking (SLB) antenna is placed on top of the IFF antenna unit, which helps to blank unwanted detections caused from echoes received through the side lobes of PPAA.

The flexible architecture of the radar is a reliable and adaptable technology for multiple applications, i.e., early warning for air defence weapon system and air defence sensor at air bases. The radar has advanced



3D surveillance radar for air force

technologies like multi-beam antenna, DPC with code agility, digital receiver, fully programmable signal processor using SHARC DSP, map channel processing, coherent high power transmitter with automated and remote operation capability, unlimited sector planning facility, advanced ECCM, video and user-friendly human machine interface (HMI). The software controlled high-speed digital technologies offer real-time configuration to operational crew. The advanced software algorithms, multiple high-speed processors, and state-of-the-art digital technologies have made the radar an effective and user-friendly sensor for 24 x 7 airspace awareness during peace and war time.

The radar is packaged on two high mobility TATRA vehicles to meet operational and battlefield mobility requirements. The antenna, including hoisting and rotating mechanism along with the transmitter, receiver and digital signal processing electronics, are

housed on radar sensor vehicle (RSV). Operator console and control post provisions are housed in a shelter put on data centre vehicle (DCV) on a second TATRA vehicle. RSV has a flexibility to function as a radar in stand-alone mode if the battle situation demands so. Two 125 kVA generators are housed on a third TATRA vehicle. The radar, which is easy to operate, mobile, transportable by air, rail and road, can be deployed and decamped in less than 30 min. After extensive user evaluation trials, 3DSR has been inducted into the IAF.

3D Surveillance Radar for Navy

This 3D surveillance radar is a stand-alone medium range, all-weather radar for the operational requirements of the Indian Navy (IN). The radar is the first indigenously developed ship-borne medium range radar. It is capable of TWS for airborne and surface targets up to a range of 200 km. It uses current technologies like multiple beam formation on reception, digital receivers with DDS of waveform and DPC.



3D surveillance radar system on stabilisation platform



3D surveillance radar onboard INS Dunagiri

The radar employs multi-beam coverage in the receive mode to achieve necessary discrimination and granularity in elevation data. It employs eight beams to achieve elevation coverage of 50°. The antenna is mechanically rotated in azimuth to provide 360° coverage. For optimum detection performance against various classes of targets, operator selectable ARRs have been provided.

A high power RF signal from the transmitter is delivered to antenna cabin through a rectangular waveguide. Low power transmission mode to transmit lower power using solid-state power amplifier (SSPA) has been provided in case of failure of the liquid-to-liquid cooling system or TWT-based transmitter. The radar also has sector blanking facility for inhibiting/blanking radiation from primary/secondary radar.

The primary antenna uses planar array technology for transmitting and receiving signals. The SLB antenna and the IFF antenna are also mounted on top of the primary antenna structure. The IFF system information is used in conjunction with the primary data for marking friendly/enemy ships and aircraft on the radar display. The SLB antenna provides good ECCM feature. The stabilisation system uses half Gimbal



concept to correct/compensate the Ship's pitch and roll movements during sailing.

Advanced DSP techniques employed include: Moving target indication (MTI); and adaptive MTI, constant false alarm rate (CFAR) schemes and detection threshold on range and azimuth on sectoral basis; least jammed frequency (LJF) selection; staggered PRF to eliminate blind speeds and detection of tangential targets based on clutter map.

The radar has unique features, wherein its operations are fully automated and controlled from a radar console with appropriate menus, keys and hot keys. It has a dedicated and exhaustive online FDFL facility, capable of testing the total system from the RF receiver to data processor to display, together with routine monitoring of sub-systems. Data communication between various radar modules is over LAN/Ethernet. Further, data can also be transferred to the CAAIO system onboard ship, over an ATM switch-based backbone.

The radar has been evaluated by users for the detection of surface tracks, manoeuvring targets, cruise missiles and in intense ECM environment. During the missile trials, the radar was able to achieve clear detection and tracking performance, in various modes of operation. The software could handle the sea clutter, moving platform compensation and multipath effects. The radar has also been identified for mid life upgrade of R class ships.

3D Tactical Control Radar

The 3D tactical control radar (TCR) is a medium range surveillance radar system for the Indian Army for meeting the operational requirements of a tactical

control radar for detection and identification of aerial targets, transmission of the target data and exercising tactical control over air defence weapon system. The radar is designed as a directly usable unit in the field, which is configured on two TATRA vehicles. The first vehicle, known as the radar sensor vehicle (RSV), houses the electronic sub-systems along with antenna hoisting mechanism and hydraulic jacking arrangement. A twin power source of 100 kVA along with UPS, is mounted on the second vehicle known as, power source vehicle (PSV).

The radar is capable of TWS of targets up to 90 km subject to LoS clearance and radar horizon. The radar employs multi-beam coverage in the receive mode, to provide for necessary discrimination in elevation data. It employs eight beams to achieve elevation coverage of 50°. The antenna is mechanically rotated in azimuth to provide 360° coverage. To obtain an optimum detection performance against various classes of targets, operator selectable ARRs have been provided. The IFF antenna is placed atop the PPAA. A side lobe blanking (SLB) antenna is placed on top of the IFF antenna unit. The SLB antenna helps to cancel targets being detected from echoes received through the side lobes of PPAA.

A provision to automatically transmit data through field lines and through radio in a broadcast mode has been incorporated. The transmitted data is received by target data receivers (TDR), which are located at a distance from the radar. Target data processing at TDR includes parallax correction with respect to weapon location and threat prioritisation of targets. The radar uses a 20" LCD display with PPI, TOTE and man-machine



Radar sensor vehicle



Power source vehicle

3D tactical control radar configuration

aperture radar (ISAR) have also been incorporated in the radar to provide high-resolution representation and classification of sea-borne targets. The secondary roles of the XV-2004 are: navigation, weather avoidance and detection of search and rescue transponder (SART) beacon.

interface (MMI) windows/displays. The TOTE display gives the target parameters. The unique feature of the radar is its fully automated and controlled operation from the radar consoles with sufficient menus, keys, and hot keys. It is also supported by a tracker ball, which acts as the mouse for the system. The radar has a dedicated and exhaustive fault diagnostic facility capable of testing the total system from the RF receiver to data processor to display, in addition to routine monitoring by individual subsystems.

The 3D TCR has undergone five phases of user trials including summer and high altitude winter trials and is being inducted into the Indian Army.

PATROL/IMAGING RADAR

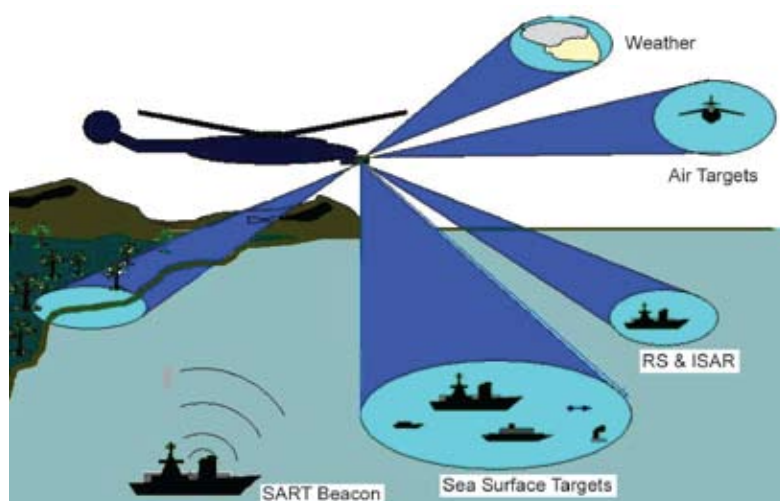
Maritime Patrol Airborne Radar

DRDO has successfully designed and developed a maritime patrol airborne radar, XtraVision 2004 (XV-2004). The primary roles of the radar are: anti-ship and anti-submarine surveillance, and air-to-air detection. The map modes comprising 2D imaging through range signature (RS) and inverse synthetic

The radar incorporates advance techniques and features and multiple modes such as frequency agility and scan-to-scan integration, for de-correlating the sea clutter. The radar system is based on open architecture, which is optimised for very low RCS targets, such as submarine periscope against rough weather and sea clutter. It can detect surface targets over 360° in azimuth from optimised flight altitudes up to 110 NM for a large ship and proportionate ranges for small ships, small boats and submarine periscope. It has capability to track multiple targets and prioritise them.



XtraVision 2004 radar on airborne platforms



Schematic of XtraVision radar: Multiple modes of operation

The XV-2004 is a low-volume, lightweight system for detecting and tracking boats, ships, and submarine periscopes in adverse sea clutter environment. It is designed to operate in dense electromagnetic environments under all weather conditions and high sea states. It relies on highly integrated microwave sub-systems, efficient thermal management, COTS digital technologies and mission critical operational software, where all signal and data processing functions are fully programmable. The full radar realisation, qualification, integration and evaluation have been successfully completed by DRDO. Sub-systems were developed with participation from Indian industry. The radar has successfully completed user associated technical trials.

PHASED ARRAY RADARS

Multifunction Radar

The multifunction radar is based on electronically steerable phased array antenna. It can simultaneously perform surveillance, target designation, multiple targets and missile tracking, and guidance. The radar

is developed as the primary sensor element at the firing unit level for the surface- to-air missile weapon system. It is packaged in two vehicles, namely, Flight Level Radar (FLR) and Flight Command Centre (FCC). FLR houses all the essential sub-systems of the radar, where as FCC houses the display consoles, computers, and communication equipment. System operates in multiple frequencies for target surveillance and tracking operation, command uplink for guidance and for IFF.

The radar performs the total weapon control functions at the firing unit. The integrated ground support role demands sensor surveillance of the assigned volume of space for targets to support the missile coverage, acquisition of aircraft targets handed over from Squadron Control Centre, tracking of targets preparatory to engagement, tracking of targets and missiles during engagement, command guidance of missiles, and integrated IFF function. These functions are performed concurrently by the computers using



Multifunction flight level radar

the agile radar beam. System derives its multi-target and multifunction capability from the inherent beam agility of the phased array antenna.

The radar can slew to any angle within 360° at a rate of $20^\circ/\text{s}$. It is supported by 3D central acquisition radar (3D CAR), and surveillance radar at squadron and firing unit level. In general, multifunction is operated on surveillance off mode. In the autonomous mode, the radar gets the target information through 3D surveillance radar. Slew command to the system can also be issued depending on the target position to bring it within the FLR coverage.

North alignment and position of both FLR and 3D CAR are important parameters taken care with the usage of land navigation system and GPS instruments. Time synchronisation messages and data transfer from 3D CAR to FCC at specified rate are done through integrated radio and line modem (IRLM). IRLM work on VHF radio link, failing which it automatically shifts to line link. In the event of tracking the same target by 3D CAR and FLR, a multisensor data fusion software at FCC, fused single track is displayed at operator console.

When the system is in squadron mode of operation, Surveillance Coordination Centre (SCC) controls the entire weapon system. The link between firing unit squadron is established through UHF LoS communication radio link. SCC sends 3D cue to firing unit, based on which FLR acquires the target and passes on the track data back to SCC. Depending on the threat algorithm at SCC, decision is made to allot the target to the battery for its engagement. SCC has the capability of controlling multiple firing units.

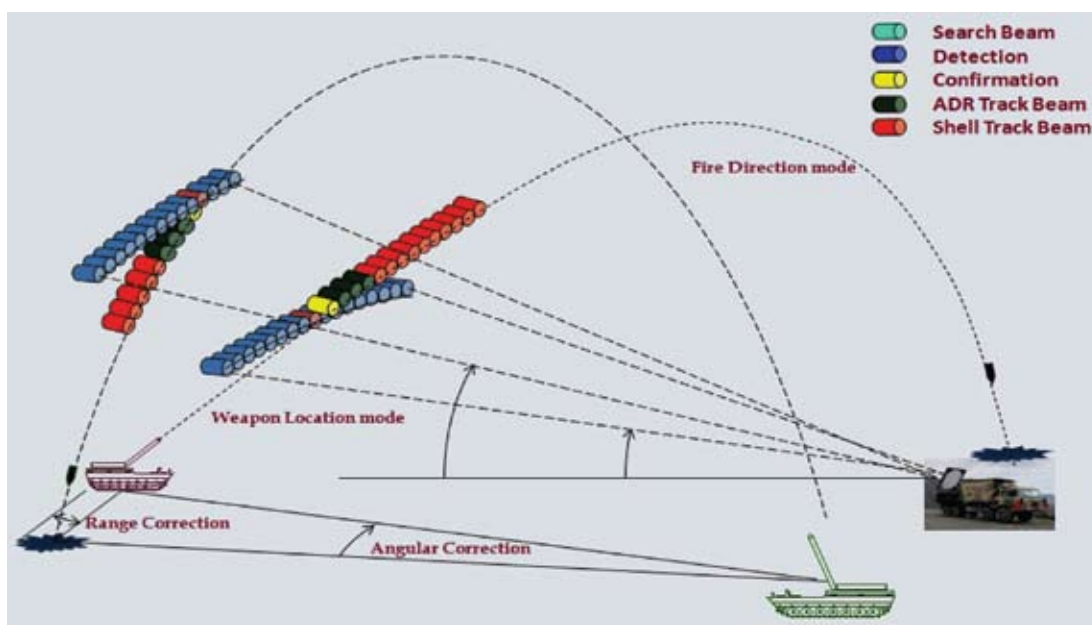
Weapon Locating Radar

The weapon locating radar (WLR) is a coherent, electronically scanned, C band, pulse Doppler, passive phased array radar designed to detect and track automatically incoming artillery rounds, mortar and rockets, and locate the hostile launchers. It can also track and observe the fall of short from friendly rounds, to provide fire corrections to counter the enemy fire. The radar can detect mortars, artillery guns and unguided rockets at various distance. Complex design of the radar array and algorithms permits the WLR to operate effectively even under severe clutter and high density fire environment. It can track several targets simultaneously.

The technological challenge in the design of WLR lied in achieving high probability of location for all calibers of projectiles having very low radar cross-section (RCS) both for high and low angle fire. Energy-time management has been optimised to address the challenges to meet the stringent location accuracies in absolute grid coordinates. An adaptive radar resource scheduling feature has enhanced the efficiency and reliability of the radar.

The radar can scan hostile targets in one quadrant. The array can electronically scan from its referenced mean bearing. The whole array can be rotated on either side by 135° to achieve 360° coverage from a given position within 30 s, to quickly change the scanning sector in response to potential threats.

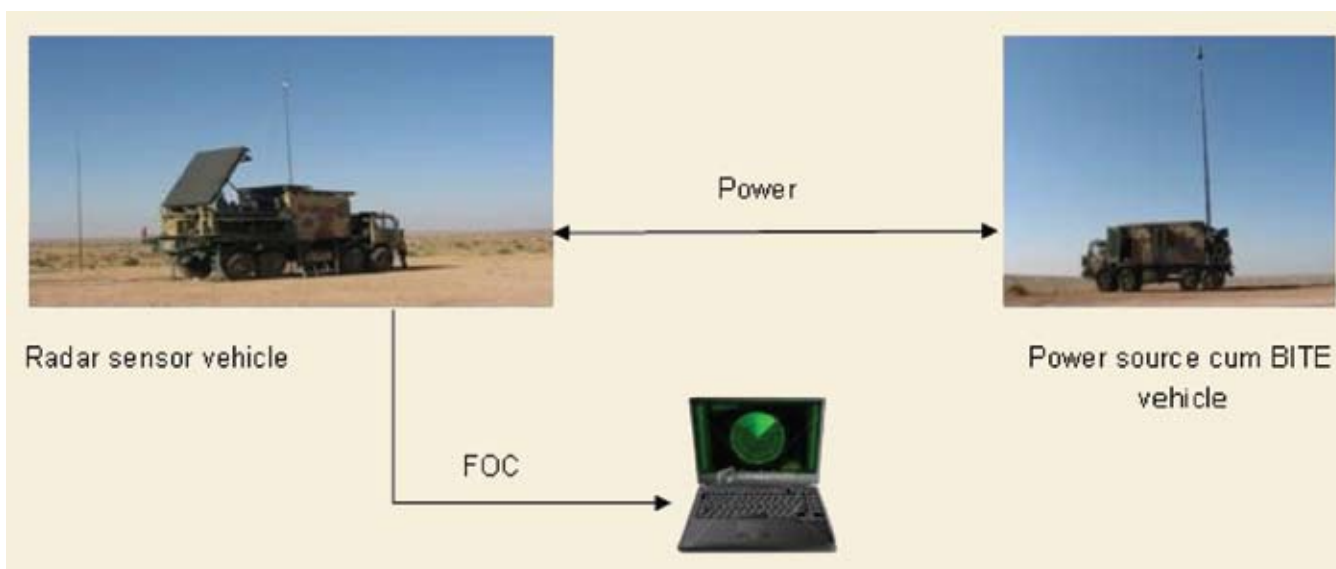
On detecting an incoming hostile round, the radar automatically acquires and classifies the threat and initiates a track sequence while it continues to search



Operational modes of weapon locating radar

for new targets. Algorithms for trajectory computations use environmental factors, along with trajectory and track data, for estimating both launch and impact points to the desired accuracy. The fence concept of beam positioning, and grazing the radar air space, makes it

impregnable for hostile projectiles without detection. The computed launch point can be reported by the radar operator to the friendly artillery to direct counter-battery fire towards enemy artillery. Tracking of the target is achieved with mono-pulse signals and the in-



Weapon locating radar: System configuration

built pulse compression features improve the radar's low probability of interception (LPI). Its processors perform real-time signal processing on the acquired data. An adaptive algorithm based on modified version of the Runge-Kutta method and incorporation of constant false alarm rate (CFAR) techniques aid in the accuracy of target detection. An operator can select the suitable CFAR technique for maximizing accuracy of track/information. The data is processed on the state-of-the-art programmable digital signal processor using modified extended Kalman filters (one with size six states and another with seven states). Moving target indication (MTI) aids to improve the clutter rejection performance of the radar.

Target information is presented as a high resolution multi-mode colour display on the ruggedised power PCs in real time and can be overlaid on a digital map. The WLR can store a large size digital map for display purposes. Other artillery modes of displays include plan position indicator (PPI), RHI, etc.

Up to 99 weapon locations can be tracked and stored at any time. The data can be automatically transmitted to a command centre and can be communicated with higher echelons. The radar data can also be displayed at a convenient remote screen to protect operators from any targeted attacks on the radar. Many radars can be networked together to operate in tandem to provide more information with enhanced accuracy.

WLR is configured into two vehicles named as, radar vehicle and power source-cum-BITE vehicle. The radar vehicle contains electronic and antenna shelter. The power source-cum-BITE vehicle contains two diesel generator sets and radar target simulator.

Long-Range Solid-state Active Phased Array Radar

With unprecedented reliability, superior performance, computer-controlled beam direction and shape in microseconds, active electronically scanned phased array technology has transformed the way battle space is scanned, target information is acquired and it is engaged. The long-range solid-state active phased array radar (LSTAR) system, developed under the technology demonstration programme, is aimed for meeting the requirements of the primary radar for airborne early warning and control (AEW&C) system currently under development and consequently, is a leading programme demonstrable on a ground-based platform.

LSTAR is mainly for surveillance, detection and tracking of airborne targets in ranges of 200-300 km. It carries out target detection and provides measurements of range, azimuth, elevation and target speed. The active array antenna consisting of a common bank of transmit receive modules and radiating elements mounted on either side of the dorsal unit provides a coverage of 120° on either side. New technologies for 200 W transmit receive modules, active array antennas, distributed beam steering network and digital receiver/Exciter have been developed and demonstrated. The electronically scanned active phased array technology has been developed for the first time in the country.

The central unit of the LSTAR has state-of-the-art DDS-based exciter, programmable waveform generator and the digital receiver technology. The radar data processor (RDP) built into the system provides target identity, target state vector and maintenance of multiple target tracks based on updates. The radar operate with low as well as medium PRF waveforms



using PDP. The computer-controlled inertia-less beam positioning provides the radar performance features of variable dwell times, adaptive revisits, programmable sector, and pseudo-random scan patterns. The radar system utilises a fully coherent detection system with features like automatic burst-to-burst frequency agility, wide RF bandwidth, low side lobe levels and side lobe blanking facility to fully meet the ECCM features.



Long-range Solid-state Active Phased Array Radar

June 2013 issue of
Technology Focus

will cover

INDIGENOUS RADARS-I
Radar Antenna and Transmitter Technologies

Technology Focus focuses on the technological developments in the Organisation, covering the products, processes and technologies.

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अध्यक्ष

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डी आर डी ओ भवन, नई दिल्ली

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डीआरडीओ की ओर से निदेशक, डेसीडॉक द्वारा मुद्रित एवं प्रकाशित

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