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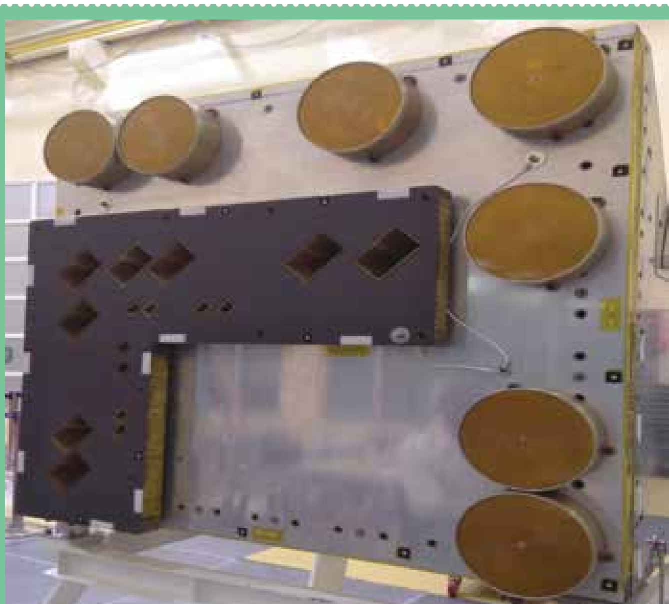

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From the Desk of Guest Editor

Electronic Warfare (EW) is the most vital form of conflict in the present scenario of emerging technological trends. Defence Electronics Research Laboratory (DLRL), Hyderabad is a premier EW laboratory of DRDO meeting the EW system requirements of defence services. Among various state-of-the-art technologies being developed by DLRL, antenna technology continues to take a lead role in achieving indigenisation and self-reliance. Antenna sub-systems play a major role in defining the overall functioning of an EW system in strategic and tactical modes for manipulation and control of the electromagnetic spectrum.

The demanding requirements of modern EW systems call for specially designed custom-made antennas which are not available off the shelf on the international market. EW antennas are distinctly different from radar antennas in their electrical characteristics as well as functioning. EW antennas are tailor-made to meet the specific system as well as platform requirements while ensuring the armed electrical performance. To meet such challenges, the laboratory has established cutting-edge technology in antenna design and development by employing skilled, dedicated manpower, the latest computational electromagnetic simulation tools, and advanced design techniques. DLRL is equipped with the latest infrastructure for characterising antennas in the frequency range of A to K bands.

This issue of *Technology Focus* presents a comprehensive overview of state-of-the-art broadband EW antennas and radomes that have been indigenously developed by DLRL and successfully installed on a various ground-based, airborne, shipborne, submarine, and space-borne platforms.

N Srinivas Rao
OS & Director, DLRL

BROADBAND EW ANTENNAS AND RADOMES

The Electronic Warfare (EW) system can silently observe and capture the enemy's radar and communication signals without revealing its own identity and take appropriate action to disable the enemy's signal operation. EW systems characterise the detected radar and communication systems, find out their location and counter them, if required. All these functions require antennas that are tailor-made to play an extremely important role as the eyes and ears of an EW system.

Defence Electronics Research Laboratory (DLRL), a premier EW laboratory of the Defence Research and Development Organisation (DRDO), has evolved over the past six decades, to achieve self-reliance in EW technologies and systems. Broadband EW antennas and radomes are not available off the shelf from foreign sources meeting specific requirements of the Armed Forces. DLRL has indigenously designed, developed, and productionised wide varieties of HF/VHF/UHF, microwave, and millimeter-wave EW antennas and radomes without importing a single antenna. The dedicated and persistent endeavor of DLRL has resulted in self-sufficiency and self-reliance in the critical field of broadband EW antennas and radomes.

This issue of *Technology Focus* presents an overview of state-of-the-art broadband EW antennas and radomes which have been successfully productionised and incorporated into EW systems and delivered to the users. Electronic warfare is a silent and invisible war that manipulates and controls the electromagnetic spectrum to accurately intercept, identify, locate and counter the enemy radar and communication systems.

In a modern war, weapon systems depend heavily on this silent and invisible mode of EW. An EW is broadly classified based on frequency spectrum (radar, communication, EO/IR), functionality (electronic support/attack/protection), and application (strategic, tactical). The three functionalities viz., ES, EA, and EP define the role of EW systems in terms of actions taken to identify and locate threat signals, attack or jam adversary's signal operations, and actions taken to protect its own and friendly forces.

Among other subsystems which form part of an EW system like transmitter, receiver, processor, and display, the antenna is the one that provides the required interface between the RF system and free space. EW antennas are special in class, tailor-made to suit the requirements of the platform, environment, and radiation characteristics.

Unlike conventional antennas which are narrow band antennas, EW antennas are capable of working over multi-octave frequency bands, with desired gain, beamwidth, and polarisation.

ES antennas are receiving antennas with low to moderate gain to intercept, detect, and locate the enemy radar and communication signals. These antennas are categorised into two groups: Frequency Intercept Omni Antennas and Direction Finding Antennas.

ES Antennas

Frequency Intercept Omni Antennas

These omnidirectional antennas act as ears of an EW system and are capable of receiving signals from all directions. They are useful for frequency measurement. Following omnidirectional antennas are developed by the laboratory:

Stacked Biconical Antennas

The laboratory has developed Stacked Biconical Antennas with integral sandwich radome for interception and monitoring applications, over the frequency range of E-K band. It consists of two biconical antennas stacked one over the other, having individual multilayer polariser circuits and enclosed in an integral cylindrical radome. The integral radome has 'A' sandwich configuration for the lower bicone (E-J band) and 'C' sandwich configuration for the upper Bicone (J-K band).

Stacked Biconical Antenna

Blade Antennas

Broadband blade antennas are vertically polarised omnidirectional antennas used on airborne platforms for interception, monitoring, and direction-finding applications. Airborne blade monopole antennas operating in the A-C band and A-D band are designed and developed for use with aircraft. Blade monopole antenna consists of monopole antenna with matching network incorporated to accomplish broadband operation without any tuning mechanism. They utilise the skin of the aircraft as a ground plane.

An airborne blade dipole antenna operating in the A-D band is designed and developed for use on UAVs. These blade dipole antennas are incorporated with a matching network for achieving broadband operation. Both the versions of blade antennas are aerodynamically streamlined and enclosed in an aerodynamically shaped radome to counter the air drag present during aircraft journey.

Blade Antennas

Sleeve Dipole Antenna

A conventional dipole antenna is a narrow band antenna and offers only about 10 per cent bandwidth. Overcoming this limitation, a broadband sleeve dipole antenna operating in the D-E band is developed for interception and monitoring applications.

Sleeve Dipole Antenna

Compact Discone Antennas

Compact broadband discone antennas are designed for operation in A band. The antenna is incorporated with telescopic tubular elements for use in both the disc and conical portion of the antenna. Also, special engineering features were incorporated into the antenna for enabling quick assembly and disassembly operation in the field. The antenna can be folded like an umbrella and carried. The laboratory has also designed another compact discone antenna in A band for ground-based EW system.

Compact Discone Antenna

Shuttle Cock Antennas

A shuttle cock antenna operating over the frequency range of the A-C band is developed. The antenna is designed with canonical shaped elements and has slots for achieving lightweight and low air drag. A further broadband variant of this antenna is designed by incorporating a broadband matching network for operation in the A-C band.

Shuttle Cock Antennas

Conformal Broadband Printed Antennas

Conformal broadband printed antennas operating in the A band, A-C band, and C-E band were developed for interception and monitoring applications of the aerostat platform. The low-frequency band antenna is realised using the flexible conducting sheet. The antennas in higher frequency sub-bands are realised on flexible printed circuit boards. These antennas are enclosed in polyurethane coated nylon fabric radome.

Conformal Broadband Printed Antennas

Multi-bay Monitoring Antenna Sub-systems

Several broadband omnidirectional antennas are stacked one over the other and configured for monitoring applications to meet the platform requirements.

- 2-bay monitoring antenna subsystem comprising of compact broadband discone antenna covering A band and shuttle cock antenna covering A-C band is developed for ground-based applications.
- 2-bay monitoring antenna subsystem comprising of broadband shuttlecock antenna covering A-C band and sleeve dipole antenna covering D-E band is developed for shipborne applications.

- 3-bay monitoring antenna subsystem comprising of conformal broadband printed antennas covering A band, A-C band, and C-E band is developed for deployment on aerostat platform.

2-bay Monitoring Antenna Sub-system

2-bay Monitoring Antenna Subsystem

Conformal Printed Antennas on Tail of Aerostat

Direction Finding Antennas

Direction Finding (DF) antennas are antennas with directional beams in free space which act as the eyes of the DF system. The Direction of Arrival (DoA) of the hostile target can be obtained by various techniques of direction finding, viz., Rotary DF (RDF), Amplitude comparison DF (ADF), Phase comparison DF (PDF), or Time Difference of Arrival (TDoA) DF. The antenna subsystems that have been successfully used for various platforms and developed recently for ADF, PDF, and TDoA DF systems are described in the following sections.

ADF Antennas

DoA is obtained by comparing the amplitude of signals received by different antennas distributed over a given platform to achieve 360° field of view. The laboratory has developed a wide variety of Broadband ADF antennas such as log-periodic antennas, cavity-backed spiral antennas, horn antennas, etc. Spiral Antennas are used in most ADF systems because of their excellent features such as ultra broad bandwidth, circular polarisation, flush mounting capability, compact size, and lightweight. Horn antennas are used when the high gain is required to realise high sensitivity DF systems with linear polarisation.

Dielectric Loaded Spiral Antennas

Dielectric Loaded Spiral Antannas

Dielectric loaded spiral antennas are a new class of spiral antennas developed by the laboratory to meet the constraints of size and weight on a given platform covering the B-J band. By introducing inductive and capacitive loadings, the size and weight reduction of antennas are of the order of 40 per cent. The dielectric material is optimised further in terms of thickness with a tapered profile to achieve optimum performance. These antennas are being extensively employed in airborne platforms like UAVs and aircrafts.

Constant Beamwidth Horn Antennas

Constant beamwidth horn antennas working over the frequency band of the E-G band, and H-J band has been successfully designed and developed. The radiation patterns show minimal variation in 3 dB beamwidth over the frequency band of operation. The antenna finds application in amplitude comparison circular array DF systems for providing consistent beam crossover points and hence constant roll-off leading to better system accuracy and sensitivity.

Constant Beamwidth Horn Antennas

PDF Antennas

In phase comparison Base Line Interferometric (BLI) array, DF is obtained by comparison of phase of signals received by different antennas with different inter-element spacings. Moderate gain spiral BLI arrays are used when circular polarisation and broad bandwidth are of primary concern, whereas sectoral horn BLI arrays are used for high sensitivity DF system.

Sectoral Horn BLI Arrays

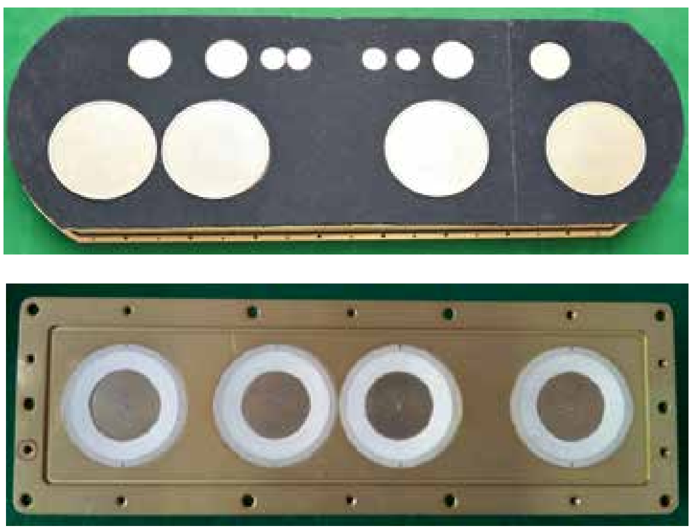
Spectoral horn BLI arrays working over multi-octave microwave frequency bands of E-G band and H-J band, have been developed indigenously to meet the high sensitivity requirement of ongoing projects and programmes which employ phase comparison high accuracy DF technologies for EW systems. End launch coaxial-to-waveguide transition RF input enables placement of antenna elements with the minimum required spacing to provide a wide field of view. Each element of the array has a polariser embedded radome which enables it to receive arbitrarily polarised emitter signals. The four-element array is covered by an absorber-loaded overall thin-wall radome. Sectoral horn BLI arrays are suitable for high accuracy and high sensitivity DF systems on shipborne and airborne platforms.

Sectoral Horn BLI Arrays

Broadband BLI Antenna Panel

Broadband BLI antenna panel, C-J band, is designed, developed, and successfully qualified for all environmental tests including full qualification. Each broadband BLI antenna panel, C-J band consists of three Spiral BLI arrays in the C-D band, E-G band, and H-J bands. Each BLI array further consists of 4 cavity-backed spiral antennas which are mounted on a common ground plane covered with an overall A sandwich radome. The spacing among the antennas is thoroughly studied and optimised for overcoming the electromagnetic interference among them to achieve a smooth radiation pattern in the C-J band. By using a novel hybrid loading technique a gain improvement of more than 3 dB was achieved in the C-D band. A total of 9 such panels are developed and successfully qualified for environmental tests for integration on large aircraft.

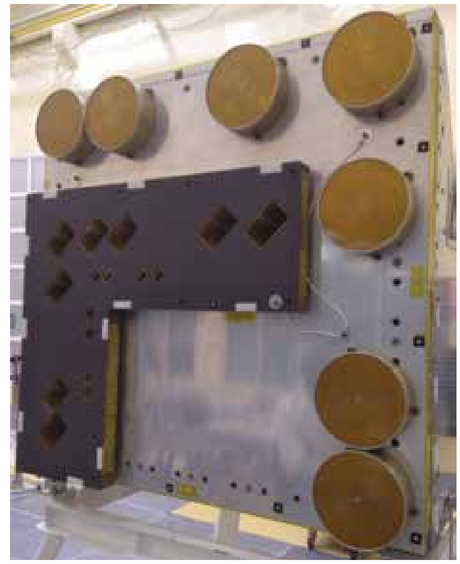
For small aircraft and also for UAV platforms a compact size and lightweight broadband BLI antenna panel, the C-J band is successfully designed and developed. Each BLI panel consists of two BLI arrays in the C-D band and E-J band. In this lightweight panel, the cavity-backed spiral antenna in the C-D band is designed with a size reduction of 40 per cent is achieved. The broadband BLI antenna panel, C-J band is thus realised with a compact form factor and lightweight. A total of 8 such panels are developed and successfully qualified for environmental tests for integration on aircraft and UAV platform.



Broadband BLI Antenna Panel

Two dimensional BLI Array

Two-dimensional BLI array consisting of spiral and pyramidal horn antennas as radiating elements has been realised for space-borne ELINT system. The spiral BLI array working in the C-D band, has 7 elements mounted in orthogonal axes, one being common for vertical and horizontal BLI arrays for DF in two orthogonal directions, i.e., elevation and azimuth. The horn BLI array consists of four antennas mounted in slant 45^0 with different inter-element spacing. The slant 45^0 mounting enables the array to receive signals of both vertical and horizontal polarisation. Two such arrays, one vertically and another horizontally mounted, complete the 2–D BLI array subsystem. The vertical and the horizontal arrays give the angle of arrival in elevation and azimuth planes, respectively. Two sets of pyramidal horn arrays are employed to cover the E-G band and H-J band. The surface of the horn antenna mounting bracket is covered with a magnetically loaded silicon rubber sheet to suppress surface currents and ensure smooth radiation patterns. All the material, components, and processes used in realising this 2-D array are space-qualified and have been subjected to stringent quality tests as per ISRO standards.



Two dimensional BLI Array

Circular BLI Array DF Head

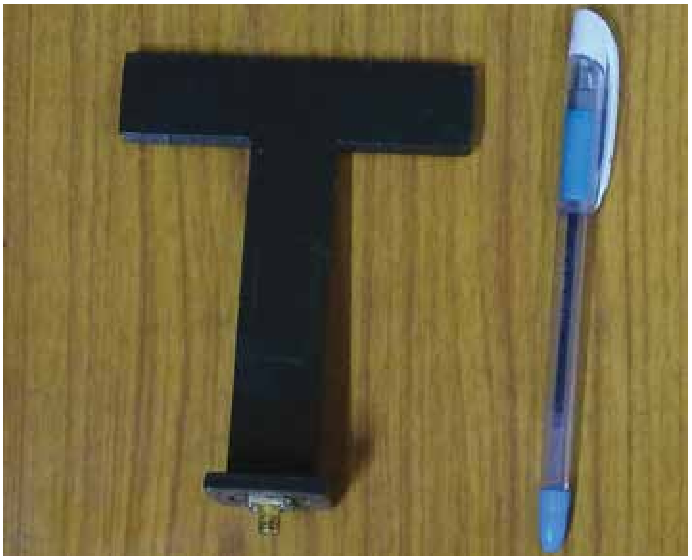
Spiral antenna-based circular BLI arrays have been realised for the passive homing head of anti-radiation missiles to meet the requirement of phase comparison direction-finding. The dielectric-loaded spiral antennas have been developed in two sub-bands, 5 no. each in the D-G band and H-J band for phase comparison direction finding and 4 no. of dielectric-loaded spiral antennas covering the D-J band for amplitude comparison DF. All these antennas are arranged in a circular

Circular BLI Array DF Head

configuration to meet the form factor of the missile head.

Broadband Phase-Matched DF Antennas

The laboratory has designed and developed broadband phase-matched dipole antennas covering A band, A-C band, and D-E bands for a state-of-the-art shipborne intelligence system. The antennas are incorporated with broadband balun and impedance matching networks.



Broadband Dipole Antennas

3 Bay DF Antenna subsystem

Communication Intelligence (COMINT) system using phase correlation DF techniques rely on phase-matching characteristics of broadband omnidirectional antennas. Broadband phase-matched dipole antennas/monopole antennas are generally used depending on the platform's requirements. A 3-bay DF antenna subsystem covering the A-E band is designed and developed for the shipborne COMINT system. Each bay consists of five phase matched dipole antennas. The antenna subsystem is incorporated with push on assemblies for antenna to bay arm, bay arm to the bay mast, and bay mast to bay mast assemblies for quick and reliable assembly and performance.

DF Antenna sub system for COMINT

TDoA DF Antennas

The DF is obtained by comparing the Time Difference of Arrival (TDoA) of signals received by different antennas distributed over a given platform. The accuracy of the DF system depends on the spatial separation between different antennas. DLRL has developed four antennae TDoA systems using mm-wave bi-conical antennas and dual linear polarised antennas for Electronic Intelligence (ELINT) systems.

MMW Biconical Antenna

MMW biconical antenna has been developed with integral 4 layer Polariser and 'C' sandwich radome meeting the requirement of standalone functionality for frequency interception in the mm-wave frequency band. The antenna has a customised connector with extended center pin length to enable Bicone connectivity. This antenna has also been used for TDoA and DF subsystem on the airborne platform.

MMW Biconical Antenna

Dual Polarised Antennas

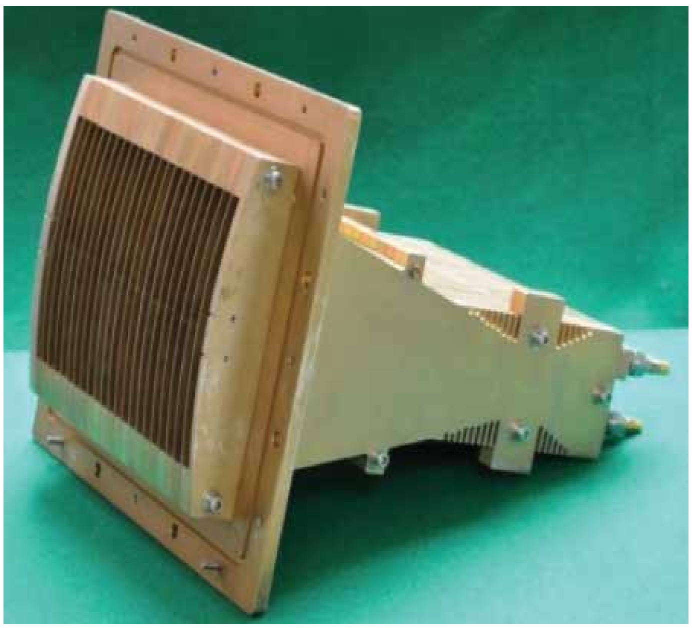
To counter the stealth technology, there is renewed interest in the operation of radars in the VHF/UHF band. Dual polarised omnidirectional antennas capable of intercepting both horizontal and polarised signals are required for DF systems. DLRL has designed and developed dipole loop antennas in the A-D band for the ground-based system. These antennas have separate ports for horizontal and vertical polarisations. DLRL has also developed a novel dual-polarised dipoloop antenna consisting of dipole and loop antennas realised as a single module and enclosed in an integral radome. The antenna has a single port for the reception of both horizontal and vertical polarised signals. Dipoloop antenna operating in 70-500 MHz is designed for airborne TDoA DF system.

Dipole Loop Antenna

Electronic Attack Antennas

The purpose of Electronic Attack (EA) antennas is to transmit very high power in the direction of the hostile target so that the enemy receiver system gets jammed electronically and can't extract any useful information regarding the source platform. For jamming single targets, the laboratory has developed high gain, high power handling capable horn antennas and reflector antennas. DLRL has also developed Omni and directional jammer antennas and antenna subsystems for EW and homeland security systems with applications for ground-based, shipborne, and UAVs. Wide varieties of dipole antennas, monopole antennas, helical antennas, log-periodic antennas, and horn antennas in various frequency bands are developed for EA roles in EW systems and homeland security systems for anti-drone applications. Moreover, in a modern threat scenario, the protection of highly valued and strategic targets is vital. They may be attacked by hostile targets from different directions simultaneously. In this situation, conventional servo-based jammer systems cannot meet the requirements. DLRL has developed a state-of-the-art Rotman Lens fed multiple-beam jammer antenna to protect vital targets from multi-threat attacks. This antenna simultaneously generates high gain multiple beams to electronically attack multiple threats.

Rotman Lens fed multibeam jammer antenna consists of inline fed sectoral horn linear array with high power TNC connector for efficient power handling of 100 W RF input, with minimum dissipation and optimum thermal management. Rotman Lens beamforming network generates 15 high power fixed multiple beams providing effective jamming coverage of 90° in the H-J band. The antenna has been installed on naval ships to provide the functioning of a standoff jammer.


High Power Linear Array Antenna


Rotman Lens Beamforming Network

COM Jammer Antennas

Various types of jammer antennas are designed for use in communication EW systems and homeland security systems.


Compact Log Periodic Dipole Antenna

DLRL has also designed jammer antenna subsystem consisting of helical antennas, biconical antennas, and horn antennas for anti-drone system.


Jammer Antenna Subsystem for Anti-drone System

Helical Antennas

Biconical Antennas

Shared Aperture Antennas

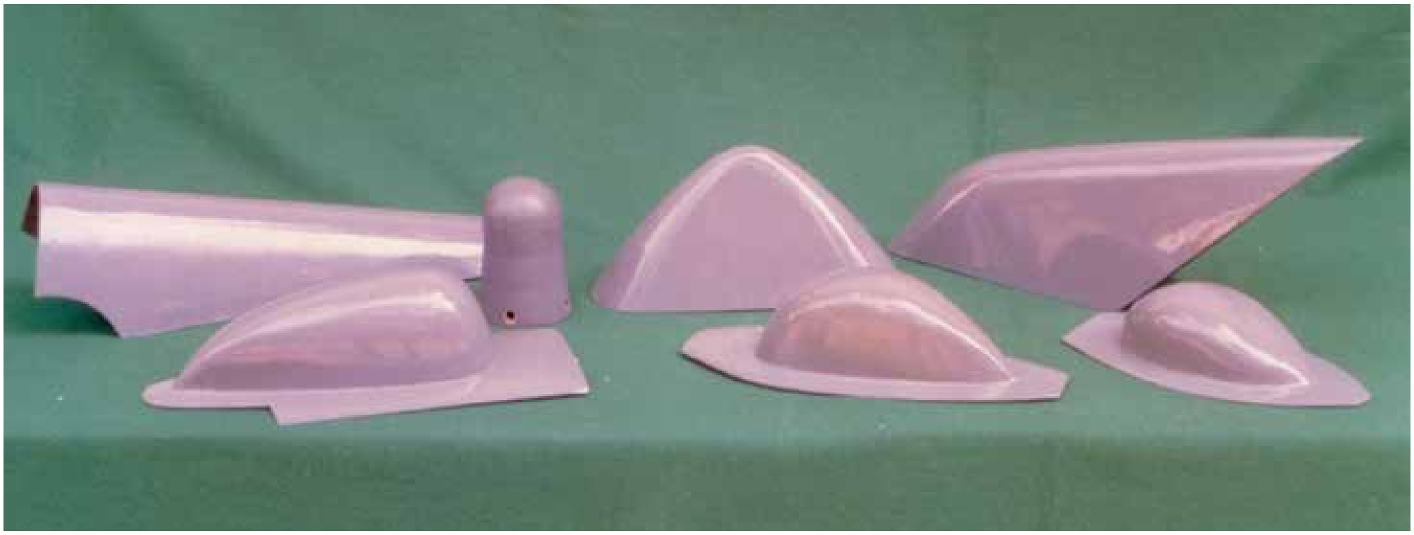
A shared aperture antenna is broadband phased array antenna that provides multiple functions using a common aperture instead of using separate multiple antennas for multiple functions. This can be done on a time-sharing basis or by aperture segmentation basis on a common aperture. These antennas reduce the Radar Cross Section (RCS) of the platform drastically, thereby enhancing platform survivability.

A planar array antenna in combination with solid-state MMIC-based Transmit/Receive (T/R) modules is an attractive choice for a shared aperture antenna. DLRL has developed an innovative 16x16 Body of Revolution (BoR) Vivaldi planar array antenna suitable for T/R module-based active aperture phased array EW Systems working in the G-J band. This system is capable of using a planar array as a shared aperture for multiple (both ES and EA) functions to counter modern threat radars. BoR antenna is a 3-D Vivaldi antenna having rotational symmetry in both planes and does not require any additional matching circuit. It is the most favourable array element because of ease of assembly and disassembly of the connector with elements in the planar configuration.

BoR Antenna

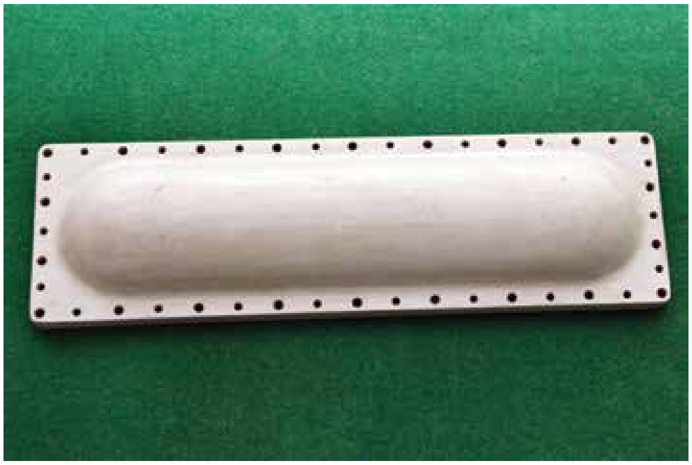
Radomes

Radomes are electromagnetic windows that protect the antennas from environmental extremities with minimum degradation in electrical performance. DLRL has designed and developed a wide variety of radomes to meet operational requirements of antennas and antenna subsystems for deployment on different types of platforms. These include monolithic and multi-layer sandwich configurations with conformal and streamlined construction. DLRL has developed state-of-the-art 5 layer C sandwich radomes for the underwater platform and 3 layers A sandwich radomes for airborne platforms, meeting the contradictory requirements of high strength and low loss.



Streamlined Radomes

Submarine Radomes



Submarine Radomes for PDF

Infrastructure Facilities

As part of its infrastructure, the laboratory has established a wide range of antenna measurement facilities and a Computational Electromagnetic (CEM) Centre.

Rectangular Anechoic Chamber

The PNA-based antenna measurement system procured from M/s NSI, USA was installed in a refurbished Anechoic Chamber having the dimensions of 30(L) x 15(W) x 15(H) feet. In addition to using the PNA as a receiver in the measurement system, it can also be used for S- parameter measurement of antennas and microwave components being developed/used in antenna subsystems. The antenna measurement facility is being exhaustively used for radiation pattern measurement of various types of antennas being designed in the C-K band. Due to swept-frequency capability, the measurement time is drastically reduced especially for testing antennas with a multi-octave frequency bandwidth.

Low Frequency Antenna Test Range

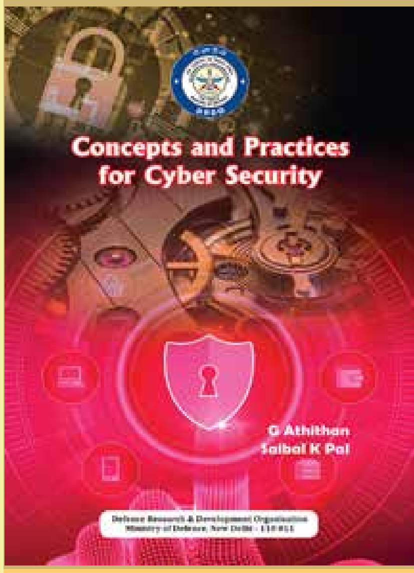
DLRL has established a ground reflection antenna test range for the evaluation of antennas. The frequency range of operation is from A band to G band. The test range is equipped with a vector network analyser-based antenna pattern recording system. The distance between transmitting and receiving antennas is about 20 m.

Computational Electromagnetic Centre

DLRL has established a state-of-the-art CEM Centre with 72 core processor having 2 TB RAM and with simulation tools such as Ansoft HFSS with High-Performance Capability (HPC), CST MW studio, and FEKO for carrying out antenna design and simulation studies to achieve optimum performance. This is accomplished by carrying out detailed simulation studies concerning antenna pattern distortion studies onboard platforms. This design approach has reduced the development cycle of antenna subsystems drastically.

Latest DRDO Monographs For Sale

Concepts and Practices for Cyber Security



Price:

INR ₹ 1500, US $ 35, UK £ 30

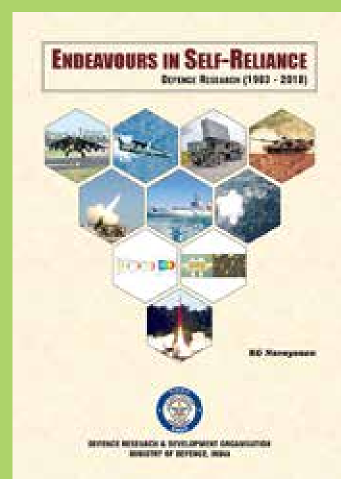
Dr G Athithan and Dr Saibal K Pal

While the objective of the monograph is to address the compelling need for cyber security awareness in the age of information systems, the focus is on both theory and practice. Keeping this in view, the book starts with the basic concepts behind the development and operation of information systems. As is necessary for a book on security, it highlights threats to information systems next. Guidelines for formulation of cyber security policies and the means for their implementation and operation constitute the middle core of the book. Incorporating cyber security during the many stages of a system development cycle is given due coverage next, followed by a discussion on applicable standards. The penultimate chapter gives an overview of the emerging domain of quantum information technology and its impact on cyber security. The treatment of the subject is at a level accessible to the middle-level managers in public and private organisations. At the same time, experts in the domain too would find something to reflect upon and to evolve new solutions to the persisting problems of cyber security.

ENDEAVOURS IN SELF-RELIANCE
DEFENCE RESEARCH (1983 - 2018)

Dr KG Narayanan

This book is a historical account of Defence Research and Development in India, covering the period 1983 – 2018, which were decades of explosive growth and achievements, expectations and challenges. Annual budget grew from Rs. 300 crores to Rs. 17,000 crores. Output of the defence R&D efforts measured by financial value of indigenous production achieved went up steeply to Rs. 300,000 crores. Hundreds of development projects were completed covering every aspect of defence requirement. Through the efforts of a single generation of scientists, soldiers, managers and policy makers, the indigenous capabilities in nuclear weapons, guided missiles, fighter aircraft, aerial early warning system, UAVs, battle tanks, artillery guns, rocket launchers, strategic submarines, underwater sensors, torpedoes, radars, communications, electronic warfare and other domains including life support measures for the warfighters were inducted in service use. This chronicle describes the huge efforts made by the establishments under the aegis of the Department of Defence Research and Development, as succinctly and spontaneously as possible, based on the reports and descriptions rendered by the laboratories and by major contributors who participated in the vast national endeavour.



Price:

INR ₹ 2100, US $ 75, UK £ 65

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